LECTURE NOTES

Degree and Diploma Programs
For Environmental Health Science Students

Vector and Rodent Control

Ethiopia Public Health
Training Initiative

Aymere Awoke, Laikemariam Kassa

Haramaya University

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PREFACE

Certain species of arthropods and fresh water snails are responsible for the transmission of some important diseases. In tropical countries the largest groups of illnesses are probably vector borne. Similarly, rodents and snails are also potential reservoirs for a number of diseases besides their contribution economic to losses.

These vector borne diseases, however, could have through the application of environmental modification methods.

This lecture note contains 13 chapters where the general feature, life cycle, medical importance and appropriate prevention and control strategies are touched with some practical examples and review questions. In been prevented or controlled through the application of vector control methods, particularly other words, it will guide the reader to the subject matter of vector and rodent control by presenting general information first and then specific diseases transmitted by the vector and its control methods.

A lecture note on vector and rodents control was prepared in 2002 by Ato Solomon Tassew for Diploma environmental health students by collecting the necessary information relevant to the course from existing books, journals, and lecture materials. Now by putting similar effort that material is reorganized and updated with the aim of making it a sufficient reference material for degree Environmental health science students. Comments of different instructors from department of Environmental health, Faculty of health sciences, Haramaya University were also incorporated which brought the material to its present status.

Finally, it is hoped that this material will be important not only for professionals who are engaged in public health work but also it would be of a paramount importance to others who are interested in public health work. Generally, Environmental health professionals have the responsibility to plan and apply appropriate vector control programs at community level to prevent diseases transmitted by arthropods, rodents and snails through organized community participation. To accomplish this responsibility this material is worth helping.

ACKNOWLEDGEMENT

This material was first prepared in 2002 by Ato Solomon Tassew for Diploma environmental health students. It is based on the previous lecture note that this material with wider content is made. Therefore we express our warm gratitude to Ato Solomon Tassew.

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ABBREVATIONS

Ae:	Aedes
An:	Anopheles
APOC:	African Program for Onchocerciasis Control
BHC:	Benzene Hexa chloride
CHF:	Common Housefly
CU:	Culex
DDT:	Dichloro-Diphenyl-Trichloroethane
DNOC:	Dinitro-ortho-Cresol
Glos:	Glossina
IPM :	Integrated Pest Management
Ma :	Mansonia
M.L.C:	Minimum Lower Concentration
OCP	Oncoserciasis Control Program
Ph:	Phelebotomus
Pla:	plasmodium
Sim:	Simulium
Spp.	Species
Try:	Trypanosoma
ULV:	Ultra Low Volume
W.W:	Water Wettable

CHAPTER ONE
INTRODUCTION

Learning Objective

At the end of this chapter, the student (the reader) will be able to: -

- List the different ways of vector borne disease transmission.
- Define relevant words like vector, arbo-virus, technical grade insecticide, etc.
- Describe the roles of insects in the ecosystem.
- Describe the general features, medical importance and methods of control of insects of public health importance under class insecta.
- Describe the transmission cycle of onchocerciasis, filariasis, yellow fever and malaria.
- Draw applicable control strategy for the diseases caused by body louse and fleas.

1.1. Existing Problems of vectors

The relation ships of early humans to insects were similar to those between insects and other primates and mammals. Insect parasites, fed on humans, annoyed them and transmitted diseases among them. In common with other mammals, humans have acquired host-specific parasites, for instance, the head and body louse. Insects also destroyed stored foods, shelters and articles made of wood, plant fibers and animal hides. In turn, primitive peoples, sometimes as a regular part of their diet ate insects. Honey was widely sought in both the old and new worlds. Honeybees are native to the old world and stingless bees produce honey in the tropics of the new world.

With development of agriculture and cities, humans came in to cooperation and conflict with insects. Despite the devastating effects of some insects as destroyers of crops and wooden structures, and as carriers of diseases, it is generally agreed that the majority of insects are directly or indirectly beneficial to human society.

Since effective vaccines or drugs were not always available for the prevention or treatments of these diseases, control of transmission of the disease often rely on control of the vector. The discovery of the insecticide Dichlorodiphenyl trichloroethane (DDT) was a major breakthrough in the control of vector borne diseases. In the 1950s and early 1960s, programs were organized in many countries which attempted to control or eradicate the most important vector-borne diseases by the large scale application of DDT. The objective was to eradicate the diseases or to reduce transmission to such a low level that control could be maintained through the general health care facilities with out the need for additional control measures.

Initially these programs were largely successful and in some countries it proved possible to reduce the vector control activities. However, in most countries, success was short lived; often the vectors developed the so called resistance to the pesticides in use, creating a need for new and more expensive chemicals. This situation, eventually led to a return to significant levels of disease transmission. Permanent successes were mostly obtained where environmental modification was carried out in order to prevent the disease vectors from having breeding or resting place. Due to this fact, many scholars are now advocating the importance of environmental change as an effective and first line control strategy for vector and rodent control.

Vector borne diseases are prevalent in the tropics and subtropics and are relatively rare in temperate zones, although climate change could create conditions suitable for outbreaks of diseases such as Lyme disease, Rocky Mountain spotted fever, malaria, dengue fever, and viral encephalitis in temperate regions. There are different patterns of vector-borne disease occurrence. Parasitic and bacterial diseases, such as malaria and Lyme disease, tend to produce a high disease incidence but do not cause major epidemics. An exception to this rule is plague, a bacterial disease that does cause outbreaks. In contrast, many vector viral diseases, such as Yellow fever, dengue, and Japanese encephalitis, commonly cause major epidemics. There has been a world wide resurgence of vector-borne diseases since the 1970s including malaria, dengue, Yellow fever, louse-borne typhus, plague, leishmaniasis, sleeping sickness, Lyme disease, Japanese encephalitis, Rift Valley fever. Reasons for the emergence or resurgence of vector-borne diseases include the development of insecticide and drug resistance; decreased resources for surveillance, prevention and control of vector borne diseases; deterioration of the public health infrastructure required to deal with these diseases; unprecedented population growth; uncontrolled urbanization; changes in agricultural practices;

deforestation; and increased travel.

Therefore, control methods generally focus on targeting the arthropod vector. These include undertaking personal protective measures by establishing physical barriers such as house screens and bed nets; wearing appropriate clothing (boots, apparel that overlap the upper garments, head nets, etc.); and using insect repellents. Environmental modification to eliminate specific breeding areas or chemical and biological control measures to kill arthropod larvae or adults may also b e undertaken. Areas such as ports and airports should be rigidly monitored, with control measures utilized to prevent important arthropod disease vectors from entering the country. Some efforts to control vector borne diseases focus on the pathogen. It is clear that people will always have to live with vector-borne diseases, but maintenance of a strong public health infrastructure and undertaking research activities directed at improved means of control—possibly utilizing biological and genetic-based strategies, combined with the development of new or improved vaccines for diseases such as malaria, dengue and Lyme disease—should lessen the threat to human health.

The field of medical entomology continues tomass more information and to encompass more innovations, particularly regarding procedures for control. Perhaps most important among recent trends is the amalgamation of arthropod life history and behavior information as well as awareness of problems with environmental disruptions into the development of more holistic control schemes.

The control of insects and other pests has long been an important aspect of public health in temperate and tropical parts of the world.

Many insects and other arthropods are of medical and veterinary importance in that they either cause pathological conditions or transmit pathogenic organisms to man or animals. The arthropods involved may be causal agents themselves, developmental transfer hosts, or vectors of pathogens. The study of these conditions includes broad aspects of the biology and control of the offending arthropods and recognition of the damage they do and the way that they do it. The bearing of public and individual health and on the health of domestic and wild animals is obvious. Both mental and physical health, plus general comfort and well-being are concerned. Insects are extremely successful animals and they affect many aspects of our lives despite their small size. All kinds of natural and modified ecosystems both terrestrial and aquatic support communities of insects that present a bewildering variety of life styles, forms and functions.

We should study insects for many reasons. Their ecologies are highly diverse and often they dominate food chains and food webs in biomass and species richness. Insect life cycles are adapted to a variety of a biotic condition, including seasonal extremes of heat and cold, wet and dry, and notably to unpredictable climate. In the tropical countries the largest group of illnesses is probably insect-borne, and it is important to know the habits of the insect vectors. Similarly rodents contribute as potential reservoirs of a number of important diseases besides their attribute to economic losses. Therefore, knowledge of these vectors is of significant public health importance.

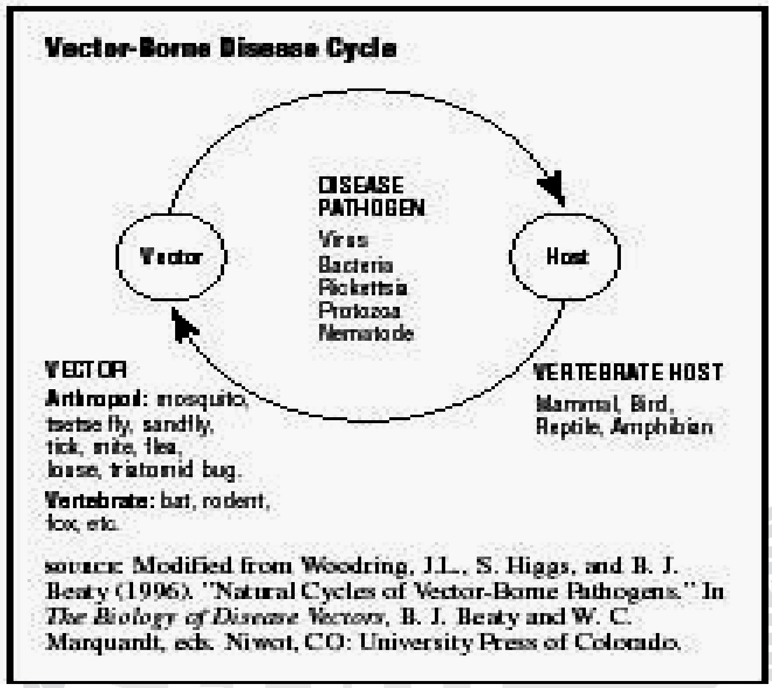

Fig.1.1 Vector born diseases transmission

Vector borne diseases are a heavy burden on human populations, a major cause of work loss, and a serious impediment to economic development and productivity. They require an intermediate living agent for their transmission. Their epidemiology is influenced by attributes of their vectors, which in turn are closely linked to environmental conditions. Over the past decades, the increased demands on the landscape for food and shelter and an increased number of by-products of man's living environment have led to unparalleled changes. Some of these changes have led to an increase in the distribution of several vector borne diseases, including malaria.

The key to the success of arthropod-borne disease transmission lies in the competence of vector efficiency. Whereas one vector species may be extremely efficient in the transmission of a particular pathogen, a closely related species may be totally incompetent as a vector. Even within a single vector species, individuals and populations vary dramatically in their competence to transmit a particular pathogenic agent. The expression of vector competence appears to be controlled, in part, by genetic factors involving multiple genes. Environmental factors and behavioral patterns of vector and human populations combine to provide favorable conditions for malaria transmission. While much is known about vector biology, behavior, and malaria parasites, the importance of human behavior in malaria transmission has been largely overlooked. This failure to consider community attitude and beliefs about malaria has contributed to the inability of programs to achieve sustainable control. An intimate knowledge of community attitudes, knowledge and behavior can form the basis for appropriate planning of control measures.

1.2 Definition of Terms

1. Arbo viruses: are viruses' that are transmitted from one vertebrate to the other by the help of mosquitoes and other arthropods.
2. Biological vectors- are vectors that transmit disease pathogens after the multiplication or development of the pathogen in the

insect gut or muscle. E.g. malarial mosquito

3. Insecticides: are substances or an agent that kill insects or other arthropods.
4. Insecticide formulation:- is the addition of substances (solvent or diluents) which enable a given chemical insecticide to be used to greatest advantage.
5. Mechanical vectors- are vectors that transmit pathogenic Microorganisms without undertaking any developmental change. E.g. common house fly
6. Medical Entomology:-This is a special phase of entomology and parasitology which deals with arthropods which affect the health and well-being of man and vertebrate animals. In other words medical entomology is a medical science directly concerned with vectors that affect human and animal health.
7. New World:-refers to Countries or regions in the Western hemisphere.
8. Old World:- refers to the Eastern hemispher; the world of Europe, Asia and Africa.
9. Rodents:- comprise a great number of mammals, ranging in size from the rats and mice to as large as the Porcupines and which belong to the order rodentia. In this course we are concerned with the domestic rats and mice, which is one of the serious health hazards in the community.
10. Technical grade insecticides: are an insecticides that exist in its purest commercial form.
11. Vector(s):-In communicable disease terminology, vectors are arthropods or other invertebrates which transmit infection by inoculation into or through the skin or mucous membrane by

biting or by deposit of infective materials on the skin or on food or other objects.

1.3 Ways of Vector Borne Disease Transmission:

Generally there are three types of vector borne disease transmission. Namely, Mechanical disease transmission, Biological disease transmission, and hereditary disease transmission.

1. **Mechanical disease transmission:-** is a type of disease transmission in which the vector is no more than a carrier that transmit pathogens without any change either on the number or form of disease pathogens. Example-Trachoma.

2. **Biological disease transmission:**
   In this type of disease transmission certain developmental pattern exists either in the vector or host or in both cases. It is sub-divided in to

2.1. Propagative:

In propagative type of disease transmission only the number of pathogens increases and the developmental stage remain constant. The disease plague and typhus are a good examples of propagative type of disease transmission.

2.2. Cyclo-developmental:

In this type of disease transmission only the developmental stage (form) of the disease pathogen changed (small to big, immature to matured stage, etc.) while the number of the pathogenic organism remain constant.

2.3. Cyclo-propagative:

This type of disease transmission is a combination of both propagative and cyclo-developmental where by the disease pathogen under take a change both in number and developmental form (stage). E.g. Malaria.

3. **Transovarian(Hereditary)disease transmission:-** is a type of disease transmission where by the causative agent is transmitted to the immature stage (usually to egg) from the adult insects and / or other arthropods who carry disease pathogens and when the infected egg complete its developmental stage, it become infective or can transmit the disease to man and other animals. Ticks are very good examples of arthropods that exhibit hereditary disease transmission.

1.4. Insects of Public Health Importance Introduction

Arthropod is the great phylum of invertebrate animals. They were the first animal phylum to overcome the problems of locomotion, respiration, and water conservation in a terrestrial environment. The phylum comprises at least 85 per cent of all known species of animals. All species under phylum arthropoda have the following characteristics in common

- Bilaterally symmetrical body sub-divided into segments.
- Body covered with exoskeleton, which is made up of cuticle that

contain chitin. (Nitrogenous polysaccharide). Chitin is a tough and rigid substance made up of poly (N-acetyl)-D-glucosamine ($C_{15}H_{20}N_2O_{10}$). It is water proof, parasite proof, shock proof and do not dissolve with acids.

- Jointed appendages are present on some body segments. (Wings, legs, antennae)
- Body cavity between the alimentary canal and the body wall.
- Open circulatory system that works by diffusion.
- Central ladder type of nervous system that work with ganglia.

The phylum arthropoda from public health point of view can be sub-divided in to five important classes namely Insecta, Arachnida, Diplopoda, Chilopoda and Crustacea.

Insects are the earth's most varied organisms. Almost half (50.8 per cent) of the species of living things and 72 per cent of all animals are insects.

Of all the animal phyla, only the arthropods and the chordates have succeeded extensively in adapting to life in dry air. Insects now inhabit virtually all land surfaces of the globe except the extreme polar regions and the highest mountain peaks.

Insects that feed on green plants are termed phytophagous. All parts of green plants are attacked: roots, trunks, stems, twigs, leaves, flowers, seeds, fruits, and sap in the vascular system. Insects that kill other insects are termed entomophagous. Of these, the predators kill their prey more or less immediately, while parasitoids feed externally or internally in their host for some period before finally killing it.

A typical adult insect has a segmented body with an external skeleton, or exoskeleton, composed of chitin and protein. The exoskeleton provides not only strong support and protection for the body but also a large internal area for muscle attachments. Their body is divided in to three main regions, head, thorax, and abdomen. The head bears a pair of large compound eyes and as many as three simple eyes, or ocelli, a pair of sensory antennae, and the feeding appendages or mouth parts. The thorax is composed of three segments, each bearing a pair of legs. The last two segments may also bear a pair of wings. The abdomen is composed of no more than 10 or 11 visible segments and lacks appendages except for a pair of cerci and the reproductive external genitalia that may be present near the tip of the anal opening.

Entomologist express as the orders of class insecta could reaches to about 30. But the most common orders of insects are diptera, anoplura, coleoptera, hemiptera, hymenoptera, lepidoptera, orthoptera, siphonaptera, mallophaga, isoptera, homoptera and odonata.

1.5 Order Diptera

All species under order diptera are fliers. Adult insects belonging to the diptera have one pair of functional wings and undergo holometabolous life cycle. The larva is different from adult in structure, habitat, and food source. Generally there are more than 50,000 species of both biting and non-biting diptera and the majority of which have no medical importance, but few of them are the most important disease vectors. They are divided in to three sub families based on their antennal structured. These are Nematocera, Brachicera and Cyclorapha. Most of the families (including Culcidae, Simulidae, Psycodidae, Glosinidae and Muscidae) which are discuced in the concicative chapters are included under this order.

Review Questions

1. Write the three types of disease transmission and give a short description for each.
2. Define the following terms or phrases.
    A. Vector
    B. Biological vector.
    C. Arbo-virus.
    D. Technical grade Insecticides.
3. Describe the burden of vector borne diseases on human population.

CHAPTER TWO
CULICIDAE (MOSQUITOES)

Learning objective

At the end of this chapter the reader will be able to

- Describe the general characteristics, medical importance, lifecycle and control methods of mosquitoes.
- Discuss the mode of transmission of diseases that are transmitted by Anopheles mosquitoes.
- Identify the different species of mosquitoes which are the vectors of different diseases.
- Mention the control methods of Anopheles and other mosquitoes
- Identify the genera under culicinae mosquitoe
- Describe the medical importance of culex mosquitoe.
- Describe the general prevention and control methods.
- Discuss the techniques and steps of mosquitoe management

2.1 Introduction to the family Culicidae (mosquitoes)

2.1.1 Occurrence

Mosquitoes -have a world wide distribution. Mosquitoes are notorious as proven vectors of some of the most devastating human diseases. There is little need to document the impact on human public health of malaria, yellow fever, filariasis, and several mosquito-borne diseases of arboviral etiology. Rift Valley fever and the equine encephalitis are important livestock diseases transmitted by mosquitoes. Although over 2,500 species of mosquitoes have been described worldwide in 18 genera and subgenera, those species of greatest importance as vectors of pathogenic agents are found in the genera *Aedes, Culex, Anopheles*, and *Mansonia.* They belong to the class insecta, order diptera family Culicidae, which is divided in to three subfamilies toxorhychitnae, anophilinae, culicinae and 37 generas,and about 3454 species of mosquitoes, of which about 100 are vectors of human diseases. The *Anophelinae* and the culicinae are blood feeders but the third subfamily, the *toxorhynictinae*, do not feed on blood and so do not concern in here. The most important man biting belongs to the genera Anopheles, *Culex, Aedes, Mansonia, Hemagogus* and *Sabethes.*

2.1.2 External morphology

Mosquitoes are one of the most important groups of biting dipterans, which have:

- long slender body
- Long needle shaped piercing mouth parts.
- Scales on the thorax, legs, abdomen, and wings.
- Three pairs of long thin legs.
- one pair of functional wing

Mosquitoes are very small (3-6mm) with easily fragile physical appearance, and they can be sexed by examining their antennae (male-feathery, female-short, invisible).

They can be easily identified from other insects by

-Mouth parts –possession of a mouth part which is conspicuous and forwardly projected proboscis

-The presence of scales on their abdomen, legs and thorax

- The presence of fringe of scales at the posterior margin of wings.

2.1.3 Blood feeding and Gonotrophic Cycle

Female mosquitoes are the one that bite and take a blood meal After emerging from pupa they mate shortly and spermatozoa passes from the male to the spermatica of the female.This sperm is enough to fertilize all the eggs that can be laid by the female through out her life time thus only one mating and insemination per female is required. After mating it is a must for a mosquito to have a blood meal for the eggs to be matured. This is the normal procedure and is referred to as anautogenous development. A few species, however; can develop the first batch of eggs without a blood-meal. This process is called autogenous development. After taking a blood meal they have to take a rest for digestion and egg maturation. The speed of digestion of the blood-meal depends on temperature and in most tropical species takes only 2-3 days, but in colder, temperate countries blood digestion may take as long as 7-14 days. Then the matured eggs are oviposited at the appropriate place. Such a repeated process of blood feeding then egg maturation followed by oviposition through out the females life time is called Gonotrophic cycle.

2.1.4 Life cycle

The mosquito has four distinct stages in its life cycle: egg, larva, pupa, and adult. The adult is an active flying insect, while the larvae and pupae are aquatic and occur only in water. Depending on the species eggs are laid either on the surface of water or are deposited on moist soil or other objects that will often be flooded. One method of classifying mosquitoes, which is important in the control of the larval stage, is by the type of habitat in which the eggs are laid. Those species that lay eggs singly on the moist soil usually near the edge of temporary pools of water are known as flood water mosquitoes. These eggs only hatch after they have been flooded by water. *Psorophora*, *Aedes*, and *Ochlerotatus* mosquitoes are floodwater mosquitoes which are most abundant shortly after spring rainfall. Those species that lay eggs on the surface of the water, either clumped in rafts or as single floating eggs, are known as permanent water mosquitoes. *Anopheles*, *Culiseta*, and *Culex* are permanent water mosquitoes found. Floodwater mosquitoes are usually pests in April and May, with permanent water mosquitoes being problems later in the summer.

The females usually mate only once but produce eggs at intervals through out their life. In order to be able to do so most female mosquitoes require a blood meal. Male do not suck blood but feed on plant juice.

The Eggs - Many species lay their eggs directly on the surface of water either singly having a boat shape (*Anopheles*) or stuck together in rafts (*culex*) which allow the eggs to float on the water surface. Aedes lay their eggs just above the water line or on wet mud: these eggs hatch only when flooded with water. The eggs of all mosquitos' species are not aquatic; hatching is affected by many environmental factors especially by temperature.

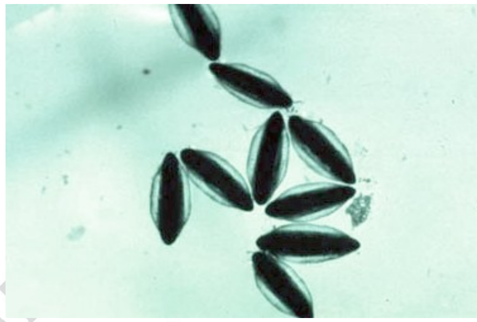

Fig 2.1 Eggs of anopheles spp

In harsh environmental conditions eggs of *Aedes* spp can stay weeks or months in the quiescent state before hatching by arresting its embryonic development such state of quiescence is called Diapause. There are environmental factors which stimulate the diapause to be broken out; such factors include temperature, decreased dissolved oxygen of the water body, and shortened day length.

- **The Larvae** of mosquitoes are active in feeding and in moving. They feed on yeast, bacteria, and small aquatic organisms. They have a siphon located at the tip of the abdomen through which air is taken in and come to the surface of water to breathe. They dive to the bottom for short periods in order to feed or escape danger. *Anopheles* larvae, which feed and breathe horizontally at the surface, have a rudimentary siphon. Larvae of *mansona*i do not need to come to the surface to breath since they can obtain air by inserting the siphon in to a water plant. In warm climate larval period lasts about 4-7 days.

Fig 2.2 Larvae of culex

- **Pupae:** the fully grown larva changes in to a comma shaped pupa which does not feed but spends most of its time at the water surface. Unlike most insect pupae it is able to move.

Fig.2.3 pupae of mosquito

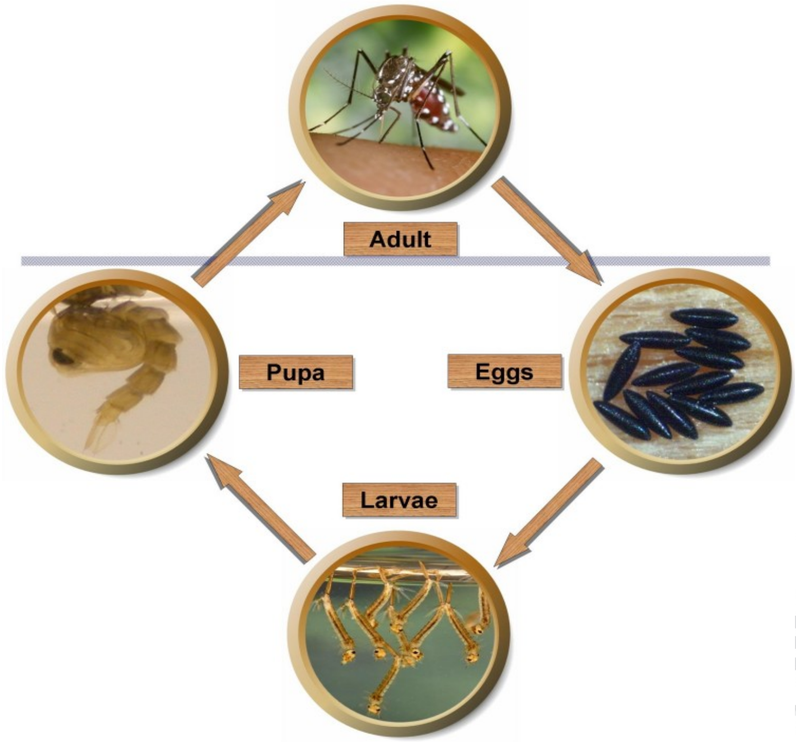

Fig. 2.4 The life cycle of mosquitoe

- **Adult behavior**

The Knowledge of behaviour of mosquitoes governs the selection of control methods.

Anopheles are active between sunset and sunrise, usually they become active at twi-light.

The resting position of adult anopheles is angled or perpendicular where as *culex* and *aedes* rest horizontally with the resting surface.

2.1.5 Feeding Habits

- Female mosquitoes feed on animals and humans.
- Most spp. Show a preference for certain animals or for humans.
- Mosquitoes are attracted by the body odors, carbon dioxide and heat emitted from the animal or person

Mosquitoes that bite person to obtain blood meal are called Anthropophagic and those that prefer feeding on non human are called Zoophagic.

-The anthropophagic mosquito can be divided in to:

-endophagic- feed indoor

-exophagic-feed outdoor

-endophilic- rest in indoor

-exophilic- rest in outdoor

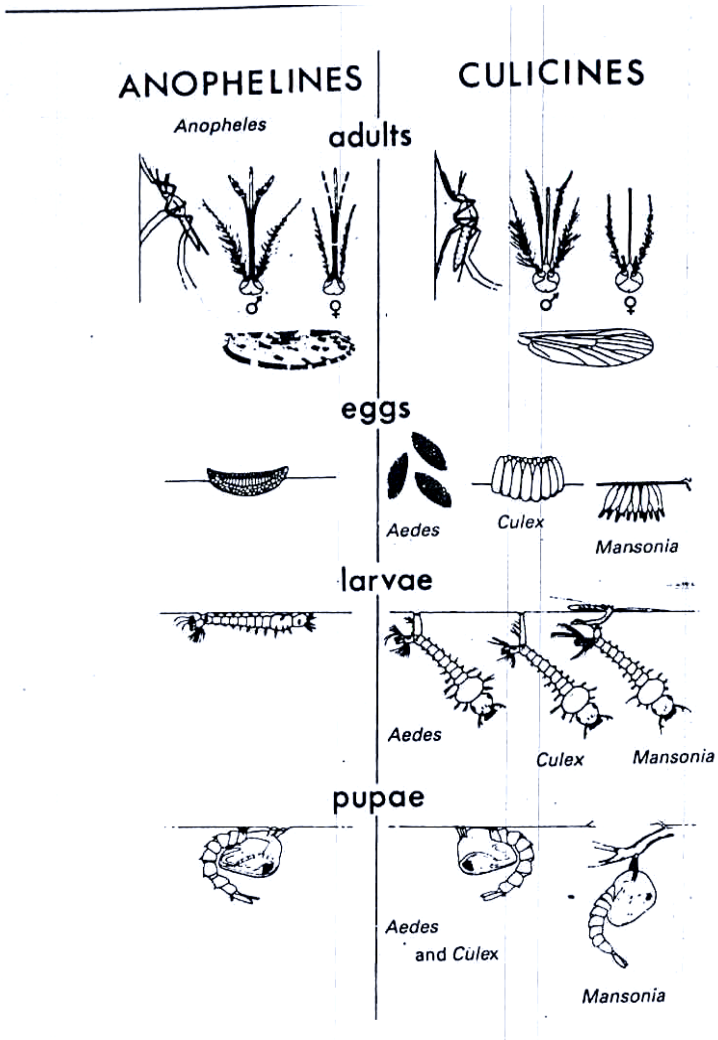

Fig.2.5 Diagrammatic representation of the principal characters separating the various stages in the life cycle of *anopheline* and *culicine* mosquitoes.

Table 2.1.The following characters can determine the sex of a mosquito.

S.No	Character.	Female	Male
1.	Proboscis	Sharp	Blunt
2.	Bite	Yes	NO
3.	Antennae	Slender, thin and sparsely haired.	Thick, bushy and heavily haired.

Table 2.2 Differentiation of Anopheles larvae from Cullex Larvae

Sen.	Character	Anoph., larva	Culex larva.
1.	Siphon	Short	Longer
2.	Body at rest.	Parallel	Vertical or an angle to the watersurface.
3.	Head	Rotates 180^0 when feeding.	Do not rotate
4.	Float hairs	Bushy	Simple.

Table 2.3 Differentiation of Adult Culex from Adult Anopheles.

S.No.	Character.	Adult Culex.	Adult Anopheles.
1.	Palp	Shorter than proboscis and not clubbed at the tip	As long as proboscis and clubbed at the tip.

2.	Resting position	Parallel	Angled or perpendicular.
3.	Wing	Not spotted (clear)	Highly spotted (marked)
4.	Scutellum	Tri-lobed	One lobe.

2.2 Anophelinae (Anopheles Mosquitoes)

2.2.1 External Morphology of Anopheles

The main features distinguishing adults of the Anophelinae, and in particular the genus *Anopheles*, from other mosquitoes have been given previously, but a brief summary is presented here.

Most, but not all, Anopheles have spotted wings, that is the dark and pale scales are arranged in small blocks or areas on the veins. The number, length and arrangement of these dark and pale areas differ considerably in different species and provide useful characters for species identification. Unlike c*ulicinae* the dorsal and ventral surfaces of the abdomen are about as long as the proboscis and in males, but not females, they are enlarged (that is clubbed) apically.

2.2.2 Life Cycle of Anopheles

After mating and blood-feeding Anopheles lay some 50-200 small brown or blackish boat-shaped eggs singly on the water surface. In most *anopheleses* there is a pair of conspicuous lateral air-filled chambers called the egg shaft. These floats help to keep the eggs floating on the water surface. *Anopheles* eggs cannot withstand desiccation and in tropical countries they hatch within 2-3 days, but in colder temperate climates hatching may not occur until after about 2-3 weeks, the duration depending on temperature.

Anopheles larvae have a dark brown or blackish sclerotized head, a roundish thorax with numerous simple and branched hairs and a single pair of thoracic palmate hairs dorsally, which help to maintain the larvae in a horizontal position at the water surface. On each side just below and lateral to the spiracles is a sclerotized structure bearing teeth some what resembling a comb and called the pecten. At the end of the last abdominal segment are four sausage-shaped transparent anal papillae, which have an osmoregulatory function.

As in all mosquitoes there are four larval instars in Anopheles larvae. Anopheles larvae are filter-feeders and unless disturbed remain at the water surface feeding on bacteria, yeasts, protozoa and other micro-organisms and also breathing in air through their spiracles. When feeding, larvae rotate their heads 180^0 so that the ventrally positioned mouth brushes can sweep the underside of the water surface. Larvae are easily disturbed by shadows or vibrations and respond by swimming quickly to the bottom of the water, they resurface some seconds or minutes afterwards.

Anopheles's larvae occur in many different types of large and more or less permanent habitats raging from fresh and salt-water marshes, mangrove swamps, grassy ditches, rice field's, edges of streams and rivers to pounds and borrow pits. They are also found in small and often temporary breeding places like puddles, hoof prints, wells, discarded tins and some-times in water-storage pots. A few species occur in water-filled tree-holes. A few Anopheles breed in water that collects in the leaf axils of epiphytic plants growing on tree branches such as bromeliads, which somewhat resemble pineapple plants. Some Anopheles prefer habitats with aquatic vegetation, others favour habitats without vegetation. Some species like exposed sunlight waters whereas others prefer more shaded breeding places. In general, Anopheles prefers clean and unpolluted waters and are usually absent from habitats that contain rotting plants or are contaminated with faeces.

In tropical countries the larval period frequently lasts only about 7 days but in cooler climates the larval period may be about 2-4 weeks. In temperate areas some Anopheles overwinters as larvae and consequently may live many months.

In the comma-shaped pupa the head and thorax are combined to form the cephalothorax which has a pair of short trumpet-shaped breathing tubes situated dorsally with broad openings. The abdominal segments have numerous short setae and segments 2-7 or 3-7 have in addition distinct short peg-like spines. The last segment terminates in a pair of oval paddles. Pupae normally remain floating at the water surface with the aid of the pair of palmate hairs on the cephalothorax but when disturbed they swim vigorously down to the bottom with characteristic jerky movements. The pupal period lasts 2-3 days in tropical countries but sometimes as long as 1-2 weeks in cooler climates.

2.2.3 Adult Behaviour

Most *Anopheleses* are crepuscular or nocturnal in their activities. Thus blood feeding and oviposition normally occur in the evenings, at night or in the early mornings around sunrise. Some species such as *An. albmanus* malaria vector in centeral and south America bite people mainly outdoors (exophagic) from about sunset to 21.00 hours. In contrast in Africa species of the *An. gambiae complex* which contains probably the world most efficient malaria vectors bite mainly after 23.00 hours and mostly indoors (endophilic). As already discussed previously the times of biting and whether adult mosquitoes are exophagic or endophagic may be important in the epidemiology of disease.

Both before and after blood-feeding some species will rest in houses (endophilic) whereas others will rest outdoors (exophilic) in a variety of natural shelters such as amongst vegetation, in rodent burrows, in cracks and cervices in trees, under bridges, in termite mounds, in caves and among rock fissures and cracks in the ground. Most *Anopeles* species are not exclusively exophagic or endophagic, exophilic or endophilic but exhibit mixture of these extremes of behaviour. Similarly few anopheles feed exclusively on either humans or non-humans most feed on both people and animals but the degree of anthropophagism an important Indian malaria vector commonly feeds on cattle as well as humans whereas in Africa *An.gambiae sensustricto*(of the *gambiae complex*) feeds more rarely on cattle and thus maintains as stronger mosquito-man contact . This is one of the reasons why *An. gambiae* is a more efficient malaria vector than An*. Culicifacies.*

2.2.4 Public Health Importance of Anopheles mosquitoes

1. Biting Nuisance

Although Anopheles mosquitoes may not be disease vectors in an area they may constitute a biting nuisance. Usually, however, it is the *culicine* mosquitoes, especially *Aedes* and *psorohora* species that cause biting problems.

2. Malaria

Introduction

Malaria is a serious vector-borne disease affecting a greater proportion of the world's population than any other vector-transmitted diseases. Over 200 million cases of malaria occur every year, and the number is increasing. Large areas of regions where malaria had been controlled are now suffering again from this significant public health problem.

In Ethiopia too, it is one of the leading causes of disease burden, with 350 days lost per year per 1000 population. There are about 4-5 million clinical cases every year. Since 1994, malaria epidemic continues to be reported from most regions of Ethiopia. The increasing trend of epidemic has burdened the already inefficient health services. Malaria accounts for nearly a quarter of all out patient visit in health facilities. It is the second highest causes of hospital admission accounting for 9.7%of all admissions and 3.1% of hospital deaths in 1994/95. Over 70% of the Ethiopian land is malarious and 60% of the population is living in this area.

The country has also experienced the worst malaria epidemic in 1958 with three million malaria cases and 150,000 deaths. Most malarious areas were under inhabited, even though they had water and potentially rich soil. Thus, it is understandable that malaria was considered as the number one public health problem. In farmers, malaria has contributed to economic failure.

This is because it diminishes the working capacity of those who are not killed by the disease. Additionally, High transportation costs render treatment very expensive. The increase in malaria prevalence is determined by several factors such as mosquito resistance to insecticides, parasite resistance to drugs, changes in land-use patterns and reductions in funding and manpower dedicated to control activities.

Distribution

Malaria exists in 100 countries but is mainly confined to poorer tropical areas of Africa, Asia and Latin America. More than 90% of malaria cases and the great majority of malaria deaths occur in tropical Africa.

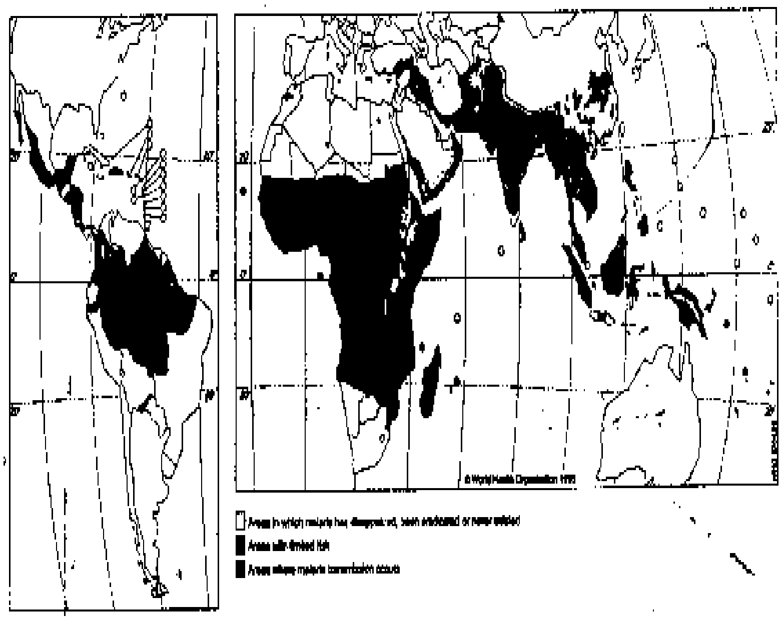

Fig. 2.13
Approximate distribution of malarious regions, 1996 (© WHO).

Causative agent

Single-celled protozoan parasites of the genus *Plasmodium*. Four species infect humans by entering the bloodstream.

- P. falciparum: found throughout tropical Africa, Asia and Latin America
- P. vivax: worldwide in tropical and some temperate zones
- P. ovale: mainly in tropical west Africa
- P. malariae: worldwide but very patchy distribution.

Plasmodium falciparum is the main cause of severe clinical malaria and death.

Transmission of Malaria

Transmission of malaria is byInoculation via the bite of infected bloodfeeding female mosquitoes of the genus *Anophele*s, which transfer parasites from human to human.

Only mosquitoes of the genus *Anopheles* transmit the four parasites that cause human malaria. Because the sexual cycle of the malaria parasite occurs in the vector, it is conventional to call the mosquito the definitive host, and humans where the Asexual cycle occurs are the intermediate hosts.

Male and female malaria gametocytes are ingested by female mosquitoes during blood feeding and pass to the mosquito's stomach where they undergo cyclical development that includes a sexual cycle termed sporogony. Only gametocytes survive in the mosquito's stomach, all other blood forms of the malaria parasites (The asexual forms) are destroyed. Male gametocytes (microgametocytes) extrude flagella that are the male gametes (microgametes) and the process is called exflagellation. The microgametes break free and fertilize the female gamets (macrogametes), which have formed from the macrogametocytes. As a result of fertilization a zygote is formed which elongates to become an ookinete. This penetrates the wall of the mosquito's stomach and reaches its outer membrane where it becomes spherical and develops in to an oocyst. The nucleus of the oocyst divides repeatedly to produce numerous spindle-shaped sporozoites then the oocyst is fully grown (about 60-80-µm) it ruptures and thousands of sporozoites are released in to the haemocoel of the mosquito. The sporozoites are carried in the insect's haemolymph to all parts of the body but most penetrate the salivary glands. The mosquito is now infective and sporozoites are inoculated into people the next time the mosquito bites. It has been estimated that there may be as many as 60, 000-70, 000 sporozoites in the salivary glands of a vector although the number may be much less and very few are injected into a person.

Oocysts can be seen on the stomach walls of vectors about four days after an infective blood-meal, after about eight days they are fully grown and rupture. Sporozoites are usually found in the salivary glands after 9-12 days, by the time required for this cyclical development (exogenous or extrinsic cycle) depends on both temperature and plasmodium species. For example, at 24^{o}c sporogony in *p.vivax* takes only nine days in *p.falciparum,* 11 days in *p. malariae*, 21 days at 26^{o}c sporogony of P*. ovale* is completed in 15 days.

The sporozoite rate is the percentage of female vectors with sporozoites in the salivary glands varies considerably not only from species to species of mosquitoes but also according to locality and season. Sporozoite rates are often about 1-5% in species such as *An. gambiae* and *An.arabiensis* of the *An. gambiae* complex but less than 1% in many other species such as *An albimanus* and *An* *culicifacies* .For practical purposes it can be said that once a vector becomes infective it remains so throughout its life.

In humans, parasites multiply exponentially in the liver and then in infected red blood cells. Mosquitoes ingest parasites with a blood meal, the parasites undergoing another reproductive phase inside the mosquito before being passed on to another human.

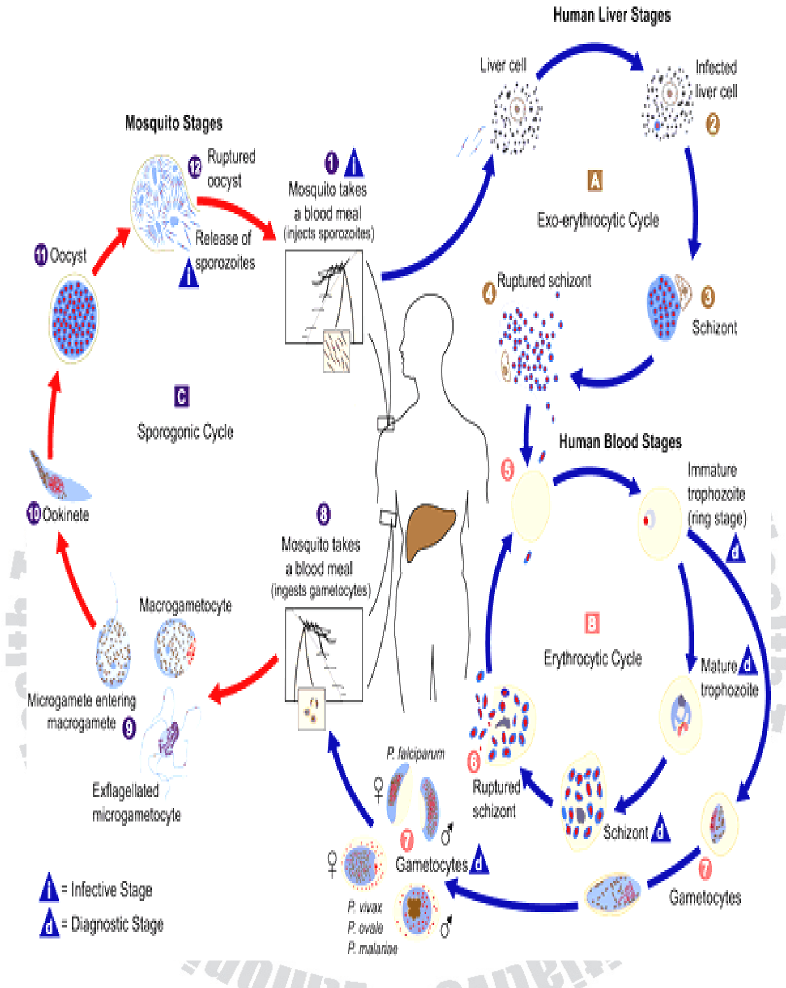

Fig. 2.6 Life-cycle of *Plasmodium*

Symptoms

Malaria begins as a flu-like illness 8-30 days after infection. Symptoms include fever (with or without other indications such as headache, muscular aches and weakness, vomiting, diarrhoea, cough). Typical cycles of fever, shaking chills and drenching sweats may then develop. The periodicity of these cycles depends on the species of parasite, coinciding with parasite multiplication and destruction of Red Blood Cells (RBC), which also leads to anemia. Falciparum malaria may not show this cyclic pattern and can be fatal if untreated or treated with insufficiently effective drugs. Death may be due to infected RBC blocking blood vessels supplying the brain (cerebral malaria), or damage to other vital organs. In areas where the disease is highly endemic, people are infected so frequently that they develop a degree of acquired immunity and may become asymptomatic carriers of infection. Epidemics are often associated with non-immune people moving to highly endemic areas, where they quickly succumb to infection. Epidemics and atypical increases in malaria incidence have been increasing.

Common malaria vector species

***An. Gambiae* complex**

The An. Gambiae complex contains six morphologically very similar specie (An. gambiae, An. arabiensis, An. melas, An. merus, An. quadriannulatus, An. bwanbae), that can be separated by banding patterns of the polyten chromosomes found in half-gravid females and fourth instar larvae. The species differ in certain aspects of their biology, behaviour and distribution.

An. funestus

It breeds on more or less in permanent waters, especially with vegetation such as marshes, edges of streams, rivers and ditches, and rice fields with mature plants providing shade It prefers shaded habitats. Bites humans predominantly, but also domestic animals: feeds indoors and also outdoors: after feeding rests mainly indoors.

An. arabiensis

One of six species of the An. gambiae complex. It breeds on ricefields, borrow pits and also temporary waters such as pools, puddles hoofprints, only in sunlit habitats. Adults bite humans indoors and out doors but also cattle, after feeding rests either indoors or outdoors. Tends to occur in drier areas than does *An. gambiae,* and is more likely to bite cattle and rest outdoors than *An. gambiae.*

An. anthropophagus

Shaded pools and ponds, only rarely in rice fields are its common breeding places. It bites humans indoors and mainly it rests indoors after feeding.

An aquasalis

The common breeding sites are tidal salt-water marshes, lagoons, salt-water regions of rivers, estuaries, rarely fresh water, sunlit or shaded habitats. It bites humans and domestic animals indoors or outdoors, rests mainly outdoors.

An albitarsis

Larvae breeds nearly always in sunlit ponds, large pools and marshes with filamentous algae. The adult bites humans and domestic animals almost indiscriminately, feeds outdoors and also indoors, usually rests outdoors after feeding.

An. campestris

It breeds deep and usually shaded or partially shaded waters such as ditches, well and shaded parts of ricefields, larvae also sometimes in brackish waters. It bites humans and animals indoors and out doors, substantial numbers rest indoors after feeding.

An. donaldi

Shaded habitats such as tree-covered swamps, forest pools, often with vegetation, ricefields are the preferable breeding sites. They bite domestic livestock but also feeds on humans inside or outsides houses, rests mainly outdoors.

An. farauti

There are several morphologically similar species, known as An. Farauti no 1. An. farauti no.2. and An. farauti no .3 etc and all are species of the An. punctuates complex. Larvae of An. farauti usually occur in semi permanent waters such as swamps, ponds, lagoons, edges of slow-flowing streams, put also in puddles, hoof prints, pools and man made containers, water may be fresh, slightly brakish or even polluted and in sunlight or shade. Adults bite animals but also humans indoors or outdoors and rest afterwards mainly outdoors, but also indoors.

An.freeborni

It has become apparent that this species consists of at least two separate buy morphologically similar species, namely *An. freeborni and An. hermsi. It seems that in* the past malaria in california was transmitted by An.herms occurs in north-western Mexico and it, not An freeborni, is the local malaria vector.

Larvae occur in ditches, irrigation ditches, polls seepages, mostly with filamentous algae or floating or emergent vegetation, ricefields, prefers sunlight. Bites animals and humans mainly outdoors but also indoors rests indoors.Over winters as hibernating adults.

An. minimus

Water such as foothill streams, irrigation ditches, borropits and ricefields are suitable breeding sites. It prefers shaded areas. Feeds mainly on humans, but will bite domestics animals, feeds and rests mainly in doors.

An. pharoensis

It breeds on marshes, ponds especially those with abundant grassy or floating vegetation , also rice fields. Bites human and animals indoors or outdoors, rests outdoors after feeding.

An sergentii

Borrow pits, rice fields, ditches, seepage waters, Slow-flowing streams, sunlit or partially shaded habitats are suitable breeding sites. Bites humans or animal indoors or outdoors, rests in houses and caves after feeding.

An. Superpictus

They breed on flowing waters such as torrents of shallow water over rocky streams, pools in rivers, muddy hill streams, vegetation may be present, it prefers sunlight. It bites humans and animals indoors and outdoors, after feeding rests mainly in houses and animals shelters, but also in caves.

Prevention and control of Malaria

• Avoidance of mosquito bites and use of vector control measures to reduce mosquito transmission, such as insecticide-impregnated bed nets, spraying houses with residual insecticides.

• Environmental management to minimize potential mosquito breeding sites or to make aquatic sites unsuitable for the development of mosquito larvae.

When exposure is likely, use appropriate prophylactics drugs such as chloroquine, chloroquine + proguanil, or mefloquine, doxycycline, or sulphadoxine-pyrimethamine in areas where chloroquine-resistant parasites are found. No prophylactic drug can guarantee full protection. In endemic areas, malaria control relies on diagnosis and prompt treatment of infected individuals based on clinical symptoms and microscopic diagnosis, if possible. Suspected or confirmed infections should be swiftly treated as life-threatening disease can develop within hours of infection. Drugs effective against local parasite populations must be used; the drug of choice will be determined by the resistance pattern in the area where the infection was contracted. Severe or cerebral malaria is fatal if untreated and requires immediate hospital treatment, usually with injectable quinine. Regular assessment of a country's malaria situation is necessary, allowing early detection, containment or prevention of epidemics.

3. FILARIASIS

Filarial development in mosquitoes

Filarial development of *Wucheriera .bancrofti* and *Burgia .malayi* within the mosquito vector, and the basic mode of transmission from mosquito to humans is the same for all vectors. Basically, the life cycle in the mosquito is as follows. Microfilariae ingested with the blood-meal pass into the stomach of the mosquito (in some vectors such as Anopheles many may be destroyed during their passage through the oesophagus). Within a few minutes they exsheath, penetrate the stomach wall and pass into the haemocoel, from where they migrate to the thoracic muscles of the mosquito. In the thorax the small larvae become more or less inactive, grow shorter but considerably fatter and develop, after 2 days, into' sausage-shaped forms. They undergo two molts and the third stage larvae become active, leave the muscles and migrate, through the head and down the fleshy labium of the proboscis. This is the infective stage and is formed some 10 days or more after the microfilaria has been ingested with a blood-meal.

When the mosquito takes further blood-meals, infective (third-stage) larvae 1.2-1.6 mm long rupture the skin of the labella of the labium and crawl onto the surface of the host's skin. Several infective larvae may be liberated onto the skin when a vector is biting. However, many of these small worms die. Only a few manage to find a skin abrasion, sometimes the small lesion caused by the mosquito's bite, and thus enter the skin and pass to the lymphatic system. It should be noted that the salivary glands are not involved in the transmission of filariasis, and also that there is no multiplication or sexual cycle of the parasites in the mosquito.

Infection rates of infective larvae in anopheline vectors vary according to the mosquito species and local conditions, but they are often about 0.1-5% for W.bancrofti and about 0.1-3% for B.malayi.

There are no animal reservoirs of W.bancrofti, but the nocturnal subperiodic form of B. malayi, transmitted by Mansonia mosquitoes, is a zoonosis.

The presence of filarial worms in the thoracic muscles of mosquitoes, or infective worms in the proboscis, does not necessarily implicate mosquitoes as vectors of bancroftian or brugian filariasis. This is because there are several other mosquito-transmitted filariae. For example, various setaria species infecting cattle, *Dirofilaria, repens* and *Dirofilaria immitis* infecting dogs, and various other species of *Brugia*, such as *B. patei* in Africa and *B. pahangi* in Asia infect animals but not people. Careful examination is therefore essential to identify the filarial parasites found in mosquitoes as those of *W.bancrofti* or *B.malayi*.

Summery of the Control of Anopheles Mosquitoe (see also on mosquito abatement)

-Alteration of natural breeding sites

-filling

-draining

-Burnt oil application on the breeding areas

-Abate (Temphose)

-Bacterial larvicide – B. *sphaericus* and B. *thurgensies*

Biological control -Fishes-Gambusia

Adult

-personal protection measures

-repellents

-treated bed nets (pyrethroids)

-Application of insecticides

-DDT- 2gm. /m^2

-Malathion

2.3 Culicinae Mosquittoes

2.3.1 Introduction

The subfamily culicinae contains 34 genera of mosquitoes, of which the medically most important ones are *Culex, Aedes, Psorophora, Mansonia, Haemagogus* and *Sabethes*. The genera *Culex, Aedes* and *Mansonia.* are found in both temperate and tropical regions, whereas *psorophora* species are found only in North, Central and South America. *Haemagogus* and *Sabethes* mosquitoes are restricted to Central and South America.

Certain *Aedes* mosquitoes are vectors of yellow fever in Africa, and *Aedes, Haemagogus* and *Sabethes* are yellow fever vectors in

Central and South America. *Aedes* species are also vectors of the classical and haemorrhagic forms of dengue. All six genera of *culicine* mosquitoes mentioned here, as well as some others, can transmit a variety of other arboviruses. Some *Culex*, *Aedes* and *Mansoni*a species are important vectors of filariasis (*Wuchereria bancrofti* or *Brugia malayi*). *Psorophora* species are mainly pest mosquitoes. It is not easy to give a reliable and non- technical guide to the identification of the six most important *culicine* genera. Nevertheless, characters that will usually separate these genera are given below, together with notes on their biology.

2.3.2 Culex Mosquitoes

Distribution

They are found more or less world-wide, but they are absent from the extreme northern parts of the temperate zones.

Eggs

The eggs are usually brown, long and cylindrical, laid upright on the water surface and placed together to form an egg raft which can comprise up to about 300 eggs. No glue or cement-like substance binds the eggs to each other; adhesion is due to surface forces holding the eggs together. Eggs of a few other mosquitoes, including those of the genus *Coquillettidia*, are also deposited their eggs in rafts.

Larvae

The siphon is often long and narrow but it may be short and fat. There is always more than one pair of sub ventral tufts of hairs on the siphon, none of which is near its base. These hair tufts may consist of very few short and simple hairs which may be missed unless larvae are carefully examined under a microscope.

Adults

Frequently, but not always, the thorax, legs and wing veins are covered with somber-coloured, often brown, scales. The abdomen is often covered with brown or blackish scales but some whitish scales may occur on most segments. Adults are recognized more by their lack of ornamentation than any striking diagnostic characters. The tip of the abdomen of females is blunt. The claws of all tarsi are simple and those of the hind tarsi are very small. Examination under a microscope shows that all tarsi have a pair of small fleshy pluvial.

Biology

Eggs are laid in a great variety of aquatic habitats. Most *culex* species breed in ground collections of water such as pools, puddles, ditches, borrow pits and rice fields. Some lay eggs in man made container-habitats such as tin cans, water receptacles, bottles and storage tanks. Only a few species breed in tree-holes and even fewer in leaf axils. The most important species, *culex quinquefasciatus* which is a filariasis vector, breeds in waters polluted with organic debris such as rotting vegetation, household refuse and excreta.

Larvae of this vector species are commonly found in partially blocked drains and ditches, soak-away pits, septic tanks and in village pots, especially the abandoned ones in which water is polluted and unfit for drinking. It is a mosquito that is associated with urbanization, and towns with poor and inadequate drainage and sanitation. Under these conditions its population increases rapidly. *Culex tritaeniorhynchus* is an important vector of Japanese encephalitis and breeds prolifically in rice fields and also in grassy pools. In southern Asia larvae are common in fish ponds which have had manure added to them.

Culex quinquefasciatus, and many other culex species, bite humans and other hosts at night. Some species, such as, *culex quinquefasciatus* commonly rests indoors both before and after feeding, but they also shelter in outdoor resting places.

Public Health importance of Culex

1. Biting Nuisance

In several areas of the world a lot of money is spent on mosquito control, not so much because mosquitoes are vectors of disease but because they are such truoublesome bitters.

2. Lymphatic Filariasis

Lymphatic filariasis is rarely life-threatening. It causes widespread and chronic suffering, disability, and social stigma. It can lead to grotesquely swollen limbs - a condition known as elephantiasis.

Distribution

It is endemic in over 80 countries in Africa, Asia, South and Central America and the Pacific Islands. More than 40% of all infected people live in India and one-third live in Africa.

Causative agent

It is caused by parasitic nematode worms of the family filariidae.

Three species are of significance, *Wuchereria bancrofti, Brugia malayi* and *Brugia timori.*

Transmission

It is transmitted via the bite of blood-feeding female mosquitoes, which transmit immature, larval forms of the parasitic worms from human to human.

Culex quinquefasciatus mosquitoes and some species of *Anopheles* mainly transmit *Bancrofti parasites*. *Mansonia* mosquitoes mainly transmit *Brugia* parasites. In humans, adult worms can live for many years, producing large numbers of larval forms (known as microfilariae), which circulate in the lymphatics and blood where they can be ingested by blood-feeding mosquitoes, so completing the transmission cycle.

Forms

Both *bancroftian* and *brugian* filariasis occur in two distinct forms. The nocturnal periodic forms in which the microfilariae are in the peripheral blood only at night. it is transmitted by night –biting mosquitoes such as *Anopheles, Mansonia* and *Cl. quinquefasciatus*. During the day the microfilariae are in the blood vessels supplying the lungs and are not available to be taken up by mosquitoes .In subperiodic forms of *W. bancrofti* and *B.malayi* the microfilariae exhibit a reduced periodicity and are present in the peripheral blood during the day as well as at night, but there nevertheless remains a degree of periodicity . For example subperiodic *W. bancrofti*, such as found in Polynesia has a small peak in microfilarial density during the day time and can therefore be called diurnal subperodic, whereas subperiodic *B.malayi* in West Malaysia, Sumatra, Sabah, Thailand, etc has a slight peak of microfilariae at night, and so can be called nocturnal sub eriodic.

Bancroftian filariasis

Wuchereia bancrofti occurs throughout much of the tropics (central and south America, Africa, Asia, Pacific areas) and also in subtropical countries in the Middle East. It is the most widely distributed filarial infection of humans. *Bancroftian* filariasis is essentially an urban disease, there are no animal reservoirs and the parasites develop in only mosquito and humans.

The nocturnal periodic form is transmitted by various anopheles species and throughout much of its distribution also by *culex quinquefasciatus*. This mosquito is wide poured in the tropics and breeds mainly in waters polluted with human or animal feaces or rotting vegetation and other filth; larvae are found in septic tanks, cesspools, pit latrines, drain and ditches, and in water-storage jars if they contain organically polluted water. It is mosquito that has increased in number in many town due to rapid and increasing urbanization and the resultant proliferation of in sanitary collections of water. Adults bite at night and after feeding they often rest in houses. Although *Cx. quinqufasciatus* is a good vector in most areas of Africa, it is a poor vector in West Africa where most transmission of *bancroftian* filarasis is by *anopheline* mosquitoes.

In New Guinea, *mansonia* uniformis and night- biting culex species are also vectors.In China, and formally Japan, *Aedes togoi*, which breeds in rock-pools containing fresh or brackish water and in rain-filled receptacles such as pots and cisterns, is also a vector of nocturnal periodic bancroftian filariasis, although it is more usually known as a vector of brugian Filariasis. Adults bite early in the evening around sunset.

In the Philippines Ae. Poicilius is the most important vector. Adults bite in the early part of the night, mainly in doors but also sometimes outdoors. After feeding adults rest outdoors. Larvae occur in leaf axils of banana, plantain and colocasia plants.

The diurnal subperiodic form occurs in the Polynesian region from where the nocturnal periodic form is absent. The most important vector is Ae. Polynesiensis, a day-biting mosquito which feeds mostly outdoors but may enter houses to feed; adults rest almost exclusively out of doors. Larvae occur in natural containers such as split coconut shells, leaf bracts and crab-holes, and also in man made containers such as discarded tins, pots, vehicle tyres and canoes. Aedes Pseudoscutellaris is another out of doors day-biting mosquito that is a vector of diurnal subperiodic W.bancrofti in Fiji. It breeds maninly in tree- holes and bamboo stumps but larvae are also found in crab-holes. In New Caledonia Ae. Polynesiensis is absent and the most important vector is *Ae. Vigilax*, adults of which feed outdoors mainly during the day. Larvae are found in brackish or freshwater in rock-pools and ground pools.

The **nocturnal subperiodic** form is found inThailand and is transmitted by the Ae.niveurs group of mosquitoes. Adults bite and rest outdoors, larvae are found mainly in bamboo.It should be noted that although several Aedes mosquitoes are vectors of filariasis, especially the bancroftian form, Ae. Aegypti, is not a vector of lymphatic filariasis. Natural infection rates of mosquitoes with infective larvae of W.bancrofti range from about 0.5%, depending greatly on vector species and local conditions.

There are three basic disease stages:

1. Asymptomatic: patients have hidden damage to the lymphatic system and kidneys.
2. Acute: attacks of ‘filarial fever’ (pain and inflammation of lymph nodes and ducts, often accompanied by fever, nausea and vomiting) increase with severity of chronic disease.
3. Chronic: may cause elephantiasis and hydrocoele (swelling of the scrotum) in males or enlarged breasts in females.

Prevention and control

Transmission can be reduced by avoiding mosquito bites in endemic areas (e.g. through use of repellents, bed nets, insecticides). Mosquito vectors often breed in polluted urban waters (such as blocked drains and sewers) so good sanitation and environmental management to minimize mosquito breeding places can play a major role in reducing the risk of the disease.

The global elimination strategy has two major components:

• Mass administration of drugs to 'at-risk' populations with once-a-year, one-day treatment (to interrupt transmission).

• Promotion of rigorous, simple hygiene techniques for lymphoedema (to alleviate and prevent suffering of affected individuals).

Lymphatic filariasis is used to be treated with a 12-day treatment regimen using the drug diethylcarbamazine (DEC), but recent work has shown that a single dose of DEC is equally effective. Ivermectin has also been registered for treatment of filariasis, and albendazole was shown to have additional antifilarial effects.

The treatment strategy is now based on annual, single-dose, 2-drug regimens of ivermectin+albendazole in countries that are co-endemic for onchocerciasis, and of DEC+albendazole in all other countries.

3. Encephalitis

This is an arthropod-borne viral infection that attacks the central nervous system and causes inflammation of the brain. In the U.S. there are three major kinds: Eastern, Western and St. Louis encephalitis. These diseases are normally transmitted between animal populations and occasionally to people. *Culex tarsalis* and *Cx. pipiens* are two common encephalitis vectors. In Asia, a more deadly disease called Japanese encephalitis is common and can have a major impact on military operations if troops are not properly protected.

2.3.3 Aedes Mosquitoes

Distributions

It has world-wide distribution; their range extends well into Northern and Arctic areas where they can be vicious biters and serious pests to people and livestock.

Biology

Although some *Aedes* species breed in marshes and ground pools, including snow-melt pools in Arctic and sub arctic areas, many especially tropical species, are found in natural or man made container-habitats such as tree-holes bamboo stumps, leaf axils, rock-pools, village pots, tin cans and tyres. For example *Ae. aegypti* breeds in village pots and water – storage jars placed either inside or outside houses. Larvae occur mainly in those with clean water intended for drinking. In some areas *Ae.Aegypti* also breeds in rock-pools and tree-holes. *Aedes africanus* an African species involved in the sylvatic transmission of yellow fever, breeds mainly in tree-holes and bamboo stumps, whereas *Ae. bromeliae,* another African yellow-fever vector, breeds almost exclusively in leaf axils, especially those of banana plants, pineapples and coco-yams (Colocasia).

Aedes albopectus which is a vector of dengue in South-east Asia, breeds in natural and man made container-habitats such as tree-holes water pots and vehicle tires. This species was introduced into the USA in 1985 as dry, but viable eggs which had been oviposited in tyres in Asia and then exported. .

Larvae of *Ae. Polynesiensis* occur in man made and natural containers, especially split coconut shells, whereas larvae of *Ae. Pseudoscutellaris* are found in tree-holes and bamboo stumps. Both of these species are important vectors of diurnal subbperioldic bancroftian filariasis. *Aedes togoi*, a vector of nocturnal periodic *bancroftian* and *burgian* filariasis, breeds principally in rock-pools containing fresh or brackish water.

The life cycle of *Aed*s Mosquitoes from eggs to adults can be rapid, taking as little as about 7 days, but it more usually takes 10-12 days; in temperate species the life cycle may last several weeks to many months, and some species over winter as eggs or larvae.

Adults of most *Aedes* species bite mainly during the day or early evening. Most biting occurs out of doors and adults usually rest out of doors before and after feeding.

Eggs

Eggs are usually black, more or less ovoid in shape and are always laid singly. Careful examination shows that the eggshell has a distinctive mosaic pattern. Eggs are laid on damp substrates just beyond the water line, such as on damp mud and leaf litter of pools, on the damp walls of clay pots, rock-pools and tree-holes.

Aedes eggs can withstand desiccation, the intensity and duration of which varies, but in many species they can remain dry, but viable, for many months. When flooded, some eggs may hatch within a few minutes, others of the same batch may require prolonged immersion in water, thus hatching may be spread over several days or weeks.

Even when eggs are soaked for long periods some may fail to hatch because they require several soakings followed by short periods of desiccation before hatching can be induced. Even if environmental conditions are favorable, eggs may be in a state of diapauses and will not hatch until this resting period is terminated. Various stimuli including reduction in the oxygen content of water, changes in day length, and temperature may be required to break diapauses in *Aedes* eggs.

Many *Aedes* species breed in small container- habitats (tree-holes, plant axils, etc) which are susceptible to drying out, thus the ability of eggs to withstand desiccation is clearly advantageous. Desiccation and the ability of *Aede*s eggs to hatch in installments can create problems with controlling the immature stages

Larvae

Aedes species usually have a short barrel-shaped siphon, and there is only one pair of sub ventral tufts which never arise from less than one-quarter of the distance from the base of the siphon. Additional characters are at least three pairs of setae in the ventral brush, the antennae are not greatly flattened and there are no enormous setae on the thorax. These characters should separate *Aedes* larvae from most of the *culicine* genera, but not unfortunately from larvae of South American *Haemagogus*. In central and South America, *Aedes* larvae can usually be distinguished from those of *Haemagogus,* by possessing either larger or more strongly speculate antennae; also the comb is not on a sclerotized plate as in some *Haemagogus*.

Adults

Many, but not all, *Aedes* adults have conspicuous patterns on the thorax formed by black, white or silvery scales in some species yellow. Scales are present. The legs often have black and white rings. *Aedes aegypti*, often called the yellow fever mosquito, is readily recognized by the lyre shaped silver markings on the lateral edges of the scutum. Scales on the wing veins of *Aedes* mosquitoes are narrow, and are usually more or less all black, except may be at the base of the wing. In *Aedes* the abdomen is often covered with black and white scales forming distinctive patterns, and in the female it is pointed at the tip.

Fig 2.4.1 adult *Aedes albopectus*

Public Health importance of Aedes Mosquitoes

1. Yellow fever

Yellow fever is a zonoosis, essentially a disease of forest monkeys, which occasionally transmitted to humans. It is an acute disease of short duration which often causes death. The yellow fever virus mainly occurs in population of monkeys in dense forests and the disease is transmitted from monkey to monkey by forest dwelling mosquitoes called *Aedes africanus* in Africa, *heamagogus* and *sabeths* in south and central America

Yellow fever. is usually an acute and highly fatal viral disease although it's occasionally only a mild infection. It probably originated in Africa and was brought to the New World on slave ships. There are two epidemiological types of the disease, urban and jungle yellow fever. The same virus causes both types, but the mosquito vectors and vertebrate hosts are quite different.

Aedes aegypti is the most common urban vector, but *Ae. albopictus* is a potential vector in areas where it has become established. Yellow fever is still common in South America.

Transmission

In Africa the yellow fever virus occurs in certain cercopithecid monkeys inhabiting the forest and is transmitted amongst them mainly by *Aedes africanus*. This is a forest-dewlling

mosquito that breeds in tree-holes and bites mainly in the forest canopy soon after sunset –just in the right place at the right time to bite monkeys going to sleep in the tree-tops. This sylvatic, forest or monkey cycle, as it is sometimes called, maintains a reservoir in the monkey population (Figure 2.4.2). In Africa, monkeys are little affected by yellow fever, dying only occasionally. Some species of monkeys involved in the forest cycle, such as the red-tailed guenon, descend from the trees to steal bananas from farms at the edge of the forest in this habitat, the monkeys get bitten by different mosquito including *Aedes bormeliae* (formerly called *Ae. Simpsoni*). This species bites during the day at the edges of forest and breeds in leaf axils of bananas, plantains and other plants such as coco-yams (Colocasia) and pineapples. If the monkeys have viraemia, that is yellow fever virus circulating in their peripheral blood, *Ae. Bromeliae* becomes infected, and if the mosquito lives long enough it can transmit yellow fever to other monkeys or more importantly to people. This transmission cycle, occurring in clearings at the edge of the forest involving monkeys, Ae. Bromeliae, and humans, is sometimes referred to as the rural cycle (Figure 2.4.2). When people return to their villages they get bitten by different mosquitoes, including *Ae. Aegypti*, a domestic species breeding mainly in man made containers such as water-storage pots, abandoned tin cans and vehicle tyres. If people have viraemia then *Ae. aegypti* becomes infected and yellow fever is transmitted among human population by this species. This is the urban cycle of yellow fever transmission (Fig 2.4.2)

It is possible for people to become infected in the forest by bites of *Ae. africanus*, but the likelihood of humans acquiring yellow fever by a canopy-feeding mosquito is not very high. There is increasing evidence in West Africa that in rural areas other *Aedes* species spread the virus from monkeys to people. The epidemiology of yellow fever is complicated and variable. In some areas for example, yellow fever may be circulating among the monkey population yet rarely gets transmitted to humans because local vector mosquitoes are predominantly zoophagic. Other primates in Africa such as bush-

babies (Galago species) may also be reservoirs of yellow fever.
There is some evidence from West Africa that yellow fever virus may be trans-ovarially transmitted in *Aedes* species, as males have been found infected with the virus.

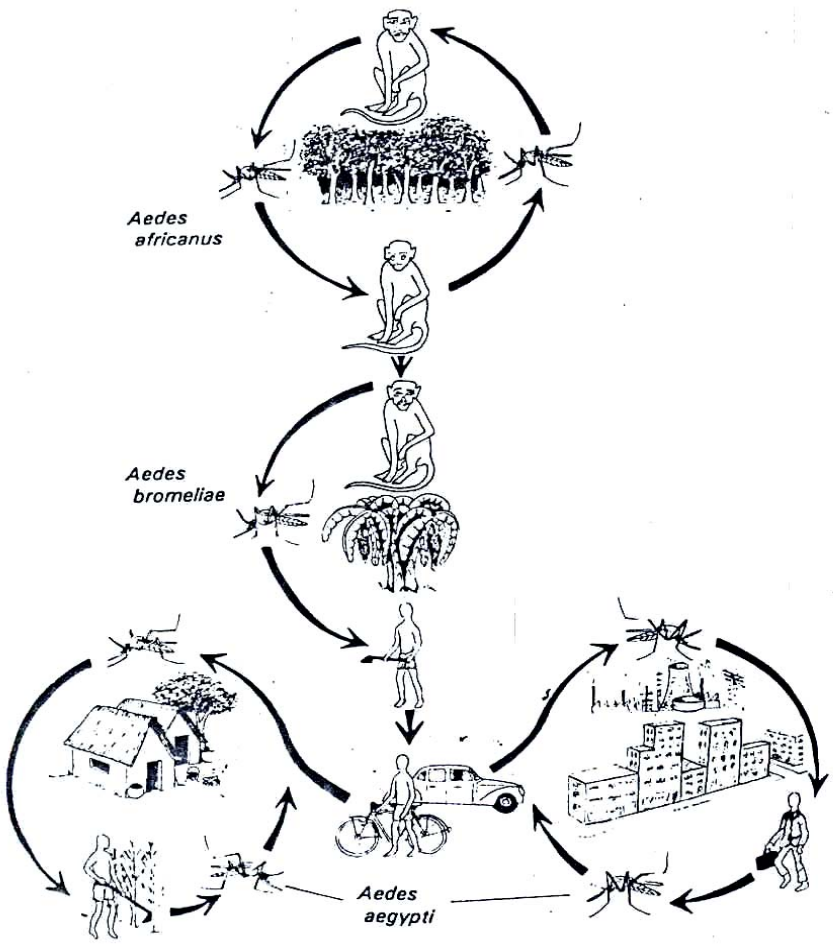

Fig 2.4.2 Diagrammatic representation of the sylvatic, Rural and urban transmission cycles of yellow fever in Africa.

Viraemia

The intrinsic incubation period of yellow fever in humans is about 4-5 days, usually a little less in monkeys. Thus, after 4 or 5 days the virus appears in the peripheral blood, that is viraemia is produced, and this occurs irrespectively of whether monkeys or humans are showing overt symptoms of the disease. Viraemia lasts only 2-3 days, after which the virus disappears from the peripheral blood never to return and the individual is immune. Monkeys and people are therefore infective to mosquitoes for only about 2-3 days in their entire lives. A relatively high titre of yellow fever (and also any other arbovirus) is needed before it can pass across the gut cells of the mosquito into the haemolymph, from where it invades many tissues and organs, including the salivary glands, where virus multiplication occurs.

This is the extrinsic cycle of development and can take 5-30 days, depending on temperature, the type of virus and the mosquito species, but in yellow fever, and most other mosquito-borne viral infections, the incubation period is typically 12-15 days. A mosquito must therefore live a sufficiently long time before it becomes infective and capable of transmitting an arbovirus-or malaria or filariasis.

2. Dengue fever

This viral disease is commonly called break bone fever. It is characterized by a sudden high fever, severe headache, backache and pain in the joints. Dengue is transmitted from person to person by Aedes aegypti and Ae. albopictus. There are four strains or types and at least one or all four are found throughout much of the world. Recovering victims are generally immune to future infections, but only from the strain they were infected with. Therefore, a person can potentially experience all four different strains of dengue.

Important Species of Aedes

Aedes aegypti is a small dark species easily identified by the lyre-shaped, silvery-white lines on the thorax and the white bands on the tarsal segments. It is a vector of urban yellow fever and dengue, and it is a pest when present in large numbers. *Aedes aegypti* is essentially a tropical species, probably introduced into the Western World from Africa. This is a thoroughly domesticated mosquito and breeds almost exclusively in artificial containers in and around human habitations. The females lay their eggs singly on the water just at the margin, or on the sides of the container above the water line. They prefer human blood to that of other animals and readily enter homes to find suitable hosts. *Aedes aegypti* bites mainly in the morning and late afternoon. It attacks quietly, preferring to bite around the ankles, under shirt sleeves, or on the back of the neck.

Aedes sollicitans. This is the most important of the salt-marsh mosquitoes since it transmits eastern equine encephalitis (EEE), and is also one of the most severe pest mosquitoes known. Adults can have a golden-brown color on top of the thorax and a longitudinal stripe of white or yellowish-white scales on the abdomen.

The proboscis and tarsi also have wide pale bands. Females lay their eggs singly on the mud of salt marshes where they remain until flooded by high tides or rains. Oviposition generally occurs in marsh areas that are not covered by daily tides. They usually use pot holes and depressions of various sizes, but they may also lay eggs over rather extensive level areas. Eggs must stay dry at least 24 hours before they can hatch. After having been dry for a week or two, they will hatch in a few minutes when water covers them. *Aedes sollicitans* adults are strong fliers and often migrate in large swarms from marshes to cities and towns many miles away. They very commonly fly 5-10 miles and may travel up to 40 miles or more. Migratory flights begin just before dark and may include tremendous numbers of mosquitoes. They rest among the grasses during the day but will readily attack anyone who disturbs them.

Aedes nigromaculis. This is medium-sized dark mosquito with a longitudinal line of yellowish-white scales on the upper surface of the abdomen. It is an important pest mosquito throughout the western plains. In recent years, it has attained prominence as a pest in the irrigated pastures. The adult is a severe biter and attacks readily. It will bite during the daytime, but is most active in the evening. It is a strong flier and may migrate several miles from its breeding ground.

Aedes vexans (flood-water mosquito). *Aedes vexans* is a medium-sized, brown mosquito with narrow rings of white scales on the hind tarsi and a V-shaped notch on the middle of each band of scales on top of the abdomen. It may be found in every state, and it's a major pest in most of the northern U.S. *Aedes vexans* breeds in rain pools, flood waters, roadside puddles, and practically all temporary bodies of fresh water. Adults migrate long distances (5-10 miles) from their breeding ground. They are vicious biters and are especially annoying at dusk and after dark.

Aedes taeniorhynchus (black salt-marsh mosquito). The black salt-marsh mosquito has cross bands of white scales on top of the abdomen and white rings on the proboscis and tarsi. This is the most abundant and troublesome salt-marsh species.

Aedes albopictus. (Tiger mosquito or Asian tiger mosquito). This species was recently introduced into the continental U.S. from Southeast Asia via used tires. As of 1991, it was established in 160 counties in 18 states. *Aedes albopictus* resembles *Ae. aegypti* except that the lyre-shaped markings on the thorax are replaced by a stripe of silvery-white scales. It's a forest-dwelling species and has adapted itself to urban environments. it is found mainly in artificial containers, especially tyres.

*2.*3.4 Haemagogus Mosquitoes

Distribution

Haemagogus is found only in Central and South America

Eggs

The eggs are usually black and ovoid and laid singly in tree-holes and other natural container-habitats, occasionally in human-made ones. There is no simple method of distainguishing eggs of *Haemagogus* from those of *Aedes* or *psorophora* mosquitoes.

Larvae

Larvae have a single subventral tuft arising, as in *Aedes* larvae, not less than a quarter of the distance from the base of the siphon. They resemble *Aedes* larvae but can usually be separated by the following combination of characters: antennae short and either without, or with only very few, spicules, a ventral brush arising from a sclerotized boss. In some species the comb teeth are at the edge of a sclerotized plate, in *Aedes* this plate is absent.

Adults

Adults are very colourful and they can easily be recognized by the presence of broad, flat and bright metallic blue, red, green or golden coloured scales, covering the dorsal part of the thorax. Like *Sabethes* mosquitoes they have exceptionally large anterior pronotal thoracic lobes behind the head. *Haemagogus* adults are rather similar to *Sabethes* in other respects, and it may be difficult for the novice to separate these two genera. However, no *Haemoagogus* mosquito has paddles on the legs, which is a conspicuous feature of many, but not all, species of *Sabethe*s.

Biology

Eggs can withstand desiccation. Larvae occur mostly in tree-holes and bamboo stumps, but also in rock-pools, split coconut shells and sometimes in assorted domestic containers. They are basically forest mosquitoes. Adults bite during the day, but mostly in the tree tops where they feed on monkeys. Under certain environmental conditions, however, such as experienced at edges of forests, during tree felling operations or during the dry season, they may descend to the forest floor to bite humans and other hosts. *Haemagogus spegazzinii*, *Hg. Equines, Hg. Leucocelaenus* (this species was previously placed in the genus *Aedes)*, *Hg. Janthinomys* and *Hg. Capricornii* are all involved in yellow fever transmission in forest areas.

2.3.5 Sabethes Mosquitoes

Distribution

Sabethes mosquitoes are found only in central and South America.

Eggs

Little is known about the eggs of *Sabethes* species, but it appears that they are laid singly, have no prominent surface features such as bosses or sculpturing and are incapable of withstanding desiccation. The eggs of *sabethes chloropterus*, a species sometimes involved in the sylvatic cycle of yellow fever, are rhomboid in shape and can thus be readily identified from most other culicine eggs.

Larvae

The siphon has many hairs placed ventrally, laterally or dorsally, and is relatively slender and moderately long. *Sabethes* larvae can usually be distinguished from other mosquito larvae by having only one Pair of setae in the ventral brush, the comb teeth arranged in a single row, or at most with 3-4 detached teeth, and by the absence of a pectin.

Adults

The dorsal surface of the thorax is covered with approessed iridescent blue, green and red scales. The anterior pronotal lobes are very large. Adults of many species have one or more pairs of tarsi with conspicuous paddles composed of narrow scales. Their presence immediately distinguishes sabethes from all other mosquitoes. Species, which lack these paddles, resemble those of Haemagogus and a specialist is required to identify them.

Biology

Larvae occur in tree-holes and bamboo stumps; a few species are found in leaf axils of bromeliads and other plants. They are forest mosquitoes. They bite during the day, mainly in the tree canopy, but like *Haemagogus* adults, may descend to ground level at certain times to bite humans and other hosts. *Sabethes chloropterus* has been incriminated as a sylvan vector of yellow fever.

2.3.6 Mansonia Mosquitoes

Distribution

This is principally a genus of wet tropical areas, but a few species occur in temperate regions.

Eggs

Eggs are dark brown-black and cylindrical, but have a tube-like extension apically which is usually darker than the rest or the egg. Eggs are laid in sticky compact masses, often arranged as a rosette, which are glued to the undersurfaces of floating vegetation.

Larvae

Mansonia larvae are very easily recognized because they have specialized siphons adapted for piercing aquatic plants to obtain air The siphon tends to be conical with the apical part darker and heavily sclerotized; the siphon has teeth and curved hairs which enable the larva to attach to plants and insert its siphon. Pupae also breathe through plants, by inserting their modified respiratory trumpets into plants.

Adults

Typically adults have the legs, palps, wings and body covered with a mixture of dark (usually brown) and pale (usually white or creamy) scales giving the mosquito a rather dusty appearance. The speckled pattern of dark and palescales on the wing veins gives the wings the appearance of having been sprinkled with salt and pepper, and provides a useful character for identification. Closer examination shows that the scales on the wings are very broad and often asymmetrical. In other mosquitoes these scales are longer and narrower.

Biology

Eggs are glued to the undersurfaces of plants and hatch within a few days; they are unable to withstand desiccation. All larval habitats have aquatic vegetation, either rooted, such as grasses, rushes and reeds or floating, such pistia stratiotes, Saluinia or Eichhornia. Larvae consequently occur in armament collections or waters, such as swamps, marshes, ponds, borrows grassy ditches, irrigation canals and even in the middle of rivers if they we floating plants.

Larvae and pupae only detach themselves from plants and rise to the surface of the water if they are disturbed. Because they are more or less permanently attached to plants the immature stages, are frequently missed in larval surveys. It is therefore not easy to identify breeding places with certainty unless special collecting procedures are undertaken, such as the collection of plants to which the immature stages are thought to be attached. It is often difficult to control breeding of *Mansonia* species by conventional insecticidal applications, because of the problems of getting the insecticides to the larvae, which may be some distance below the water surface.

Adults usually bite during the night, but a few species are day-biters. After feeding most *Mansonia* rest out of doors, but a few species rest indoors. The main medical importance of *Mansonia* mosquitoes is as vectors of filariasis, such as nocturnal periodic and nocturnal sub periodic forms of *Brugia malayi* in Asia. In Africa filariasis (*W.bancrofiti*) is not transmitted by *Mansonia* species, although they can be vectors of a few, but not very important, arboviruses.

2.3.7 Psorophora Mosquitoes

The species under the genera *psorophora* are of minor medical importance and are therefore only briefly described. *Psorophora* mosquitoes are found only in the Americas, from Canada to South America. They are similar in many respects to *Aedes* species. For example, their eggs look like those of *Aedes* and they can withstand desiccation, and a specialist is required to distinguish the larvae and adults of the two genera. Breeding places are mainly flooded pastures and sometimes rice fields; larvae of several species are predators. Although they can be vectors of a few arboviruses, such as Venezuelan equine encephalomyelitis, their main importance is as vicious biters; some pest species can be very large.

2.4 Control Strategies for Mosquitoes

2.4.1. Mosquito Survey Techniques.

The need for surveys: Whether pest managers are aligned with a medical or engineering organization, it's essential to conduct mosquito surveys to determine the species present, their abundance, their potential as disease vectors, and to collect enough information to base a pest management program on. Surveys should be a continuing part of the pest management program to evaluate the effectiveness of pest management actions. They will also help determine the effectiveness of pest management actions and anticipate increases or decreases in operations relative to changing mosquito populations. To adequately conduct mosquito surveys, the first thing needed is an adequate map Use it to become familiar with the area, locate breeding places for all developmental stages of mosquitoes and establish good sites for sampling stations.

A. Larval surveys. Larval surveys show the exact areas where mosquitoes are breeding, so they have special value in guiding mosquito management operations. Identify and mark the map for regular larval dipping stations, then inspect them periodically throughout the breeding season. Also, conduct random larval samplings in the control area to check the effectiveness of larviciding operations. Larval stations may be barrels, small pools, ditches, drains, ponds or almost any type of water collection. If possible, use a white enamel dipper to collect survey samples, then record findings as the number of larvae per dip. Use large-mouth pipettes or siphons to collect samples from small areas such as tree holes. Return sample specimens to a laboratory for identification.

B. Adult surveys. Several methods are available to conduct adult mosquito surveys, including traps and resting stations as well as biting and/or landing rates. The methods used in a particular situation will depend upon the habits of the species concerned. Use a combination of methods whenever possible, particularly when there are several species with different behavioral characteristics present. In addition to the adult survey methods discussed below, there are a number of special procedures occasionally used in research or special disease survey programs.

(**1) Light traps**. The "New Jersey" light trap is a large, durable trap that military forces have used for many years for adult mosquito surveys. More recently, the CDC or Army light trap has replaced the New Jersey design as the mosquito trap used on many military installations, and it is a commonly used in field operations The Army light trap functions very similarly to the New Jersey light trap, but is collapsible. Both of these traps provide a relative index of abundance for most species. Addition of carbon dioxide (as dry ice) will greatly increase the efficiency of traps. Note that some *Anopheles* and *Aedes* are poorly (or not at all) attracted to light, so don't use light traps to collect them. Also, consistently use the same type and size bulb to obtain a standard index for seasonal or locality comparisons. Whenever possible, place light traps 6 feet above ground where they are sheltered from wind as much as possible and far away from other artificial light sources. Ideal locations are between the installation and breeding areas. Operate traps 3-4 nights a week unless the main purpose is to detect uncommon species. In this case, operate them every night. In either situation, operate traps from dusk to dawn. Remove the contents as soon as possible each morning following collections to avoid excessive damage to specimens. Sort collections according to species and sex, and record the numbers taken at each station. Average the weekly index for several stations to give a composite index for a particular area or installation. A commonly-used index is the number of female mosquitoes caught per trap night; that is, the total number of females of a species divided by the number of traps divided by the number of nights operated. The weekly trap index is also useful to plot a graph to show mosquito population changes resulting from control measures on seasonal and annual variations. Rainfall and temperature figures are useful to determine when to start or stop control operations when such figures are plotted along with the trap index for past years.

(2) Biting or landing rates. Collecting mosquitoes as they bite or land on a person or animal is a simple way to determine the important pest species and estimate their relative abundance. Standardize the method used as to timing, the person or animal used, and locations in order to make comparisons between the biting rates which occur at different locations. Sample regular stations at intervals of 1-2 weeks and collect mosquitoes with an aspirator for a designated period of time (usually 10-15 minutes) from a standard area such as the back or from both legs of the subject. Then convert the number of each species collected to bites per hour to obtain a standard index. When populations are very high, this method is useful for a rapid check of mosquito abundance before and after treatment but don't use it in areas where disease transmission is known to exist unless the subject is adequately protected from the potential of becoming infected

(3) Resting stations. Adults of many species are inactive during the day; they're easily found resting quietly in cool, dark, and damp places. Use a vial aspirator to make collections in houses, stables, sheds, culverts, and similar shelters to get a good indication of mosquitoes species in the area. To prepare a population density index, conduct counts in a standard way for equal time periods so records of one inspection will be comparable with those made at the same station on other days.

(4) Animal bait stations. Animal bait stations are excellent devices for collecting mosquitoes during disease outbreaks or for more long-term research. These stations may be made large enough for a horse or small enough for small caged animals such as raccoons. Such devices can be made of cloth, but normally are best constructed of wood. They should be constructed so mosquitoes can enter through an opening on each side. Make these openings somewhat funnel shaped with a much smaller opening on the interior of the trap; this makes it easy for mosquitoes to enter, but difficult to escape. The trap must have an opening large enough for an individual to enter, close the door, and then collect resting adult mosquitoes.

2.4.2. Mosquito Abatement (Management).

Introduction

Mosquito abatement methods may be either long term or temporary programs directed against larvae or adults. Larvae management includes using larvicides and eliminating breeding sources by improving water drainage or using other methods of water management. Managing adults may involve applying insecticidal aerosols and sprays over infested areas, using residual sprays, chemical barriers, and/or personal protection methods such as screens, nets, and repellents.

A. Long-term methods. Long-term abatement methods focus on controlling water where mosquitoes breed. Ditching, pumping, filling and similar measures can take much time, labor and equipment to give long-term results. Their high initial cost, both to implement and to maintain equipment, must be weighed against the cost of temporary measures, such as insecticide application, on a scheduled and continuing basis, but results are much more effective and permanent when conducted properly. Installations should not begin such long-term measures without first obtaining assistance from experienced entomologists.

(**1) Stream and pond management:**

(a) Improving natural draining. Shallow sluggish streams and ponds containing plant growth provide excellent conditions for mosquito breeding. Increase the water flow rate and reduce its surface area to decrease mosquito breeding; this is often less expensive than other methods. Obtain instruction from maintenance engineers to plan and carry out this operation.

(b) Stream flushing. Where existing drainage control includes small dams, it may be possible to use these systems for mosquito abatement. To do this, periodically release collected water, either manually or by automatic siphon, to flush the stream below the dam. The stream must have sufficient capacity (with high banks) to prevent the stream from flooding over its banks. This can be a very effective means of abatement if it is possible to flush a stream more often than it takes for the specific mosquito species breeding in it to complete its aquatic development.

(**c) Impounded water**. Mosquito abatement in impounded water depends on reservoir preparation, water level fluctuation and proper shoreline maintenance. Clear reservoirs to provide clean water surface after impoundment between maximum and minimum water levels. Fill or alter depressions between minimum and maximum water levels to drain during water level fluctuations of the lake or pond. Accomplish winter impounding after the normal breeding season ends. Lower the water level at intervals not to exceed 10 days to strand eggs, larvae and pupae at the margin, strand protective debris, and expose larvae to predators. Changes to water levels may involve a cyclical fluctuation, a seasonal recession, or a combination of these methods. Shoreline drainage, removing and burning driftwood, and controlling growth of shoreline vegetation should all be a part of this action so water level fluctuation will not cause an increased breeding area for another pest species.

(2) Managing aquatic vegetation. Aquatic vegetation protects mosquito larvae and pupae protection from wave action and natural enemies and, in some cases, may seriously interfere with larvicidal applications on the water surface. If such vegetation is a serious problem, its elimination becomes an essential part of mosquito abatement. Either chemical or mechanical removal may be the proper procedure, depending on the type of vegetation, size of area, and how the water is used. Give consideration to soil erosion and effects of any vegetation management techniques on fish and wildlife.

(3) Coastal marshes. To manage mosquitoes in these areas, alter the salt content of water in the marsh, or use dikes and tide gates designed to control flooding. Planners need a thorough knowledge of the species and habits of the mosquitoes present to effectively conduct this type of management. Salt content in the water may seriously affect or limit the breeding of some species. Opening channels to let sea water enter breeding areas, or excluding sea water to reduce salt content may measurably reduce mosquito breeding.

Use tide gates to prevent salt water from leaking in natural water courses or ditches. Two or more gates are sometimes used side by side. Install break waters and spearheads to prevent sand from blocking outfalls.

(4) Fish. Surface feeding fish are sometimes used as a supplementary control measure against mosquito larvae. The most useful are killifishes (*Fundulus spp.*) in salt water and top minnows (*Gambusia, Labistes and Panchax spp*.) in fresh water. Of these, *Gambusia species* are usually used. Remove marginal aquatic plants to help fish catch mosquito larvae more easily.

(5) Pumping. Use pumps to drain water when the area to be drained is at or below the water level of an adjacent body of water. Several standing pools may be drained into one, and the water pumped from this pool to the selected outfall.

(6) Filling and grading. Fill and grade shallow pools to prevent mosquitoes from breeding in such places as beneath buildings, on improved grounds, or beside roadways. Filling may reclaim valuable land areas, as well as eliminate mosquito breeding. If hydraulic filling is recommended, take care not to block natural drainage. Cracks and low areas are likely to form as the fill settles, and will afford breeding places when flooded; pest managers can effectively treat these areas with mosquito larvicides.

(7) Ditching. Adequate ditching should remove water so ground surfaces become dry and ditch levels return to normal within 4-7 days (depending on climate and species) after the ditch is filled by heavy rainfall or irrigation. Soil texture, topography, vegetation, rainfall, and water movement during tides in salt marshes are important factors. In designing drainage systems, care is needed to prevent creating mosquito breeding areas in new locations.

B. Temporary methods. Larvicides and adulticides are the most important temporary mosquito abatement methods. Pest managers should use such temporary measures to give immediate relief from mosquitoes and when more permanent measures are lacking or in planning. Temporary methods are often much less costly than permanent measures and, in some instances, may be used at less expense than permanent systems, provided they do not adversely effect people or the environment. Also, it is often vital to take such temporary methods to rapidly reduce disease vectors during an arthropod-borne disease epidemic or during short-term operations an endemic disease area.

(1) Larval management. To temporarily manage mosquito breeding, treat water surfaces with insecticides, or eliminate small water accumulations in temporary containers. Breeding areas include most types of ground water accumulations, as well as containers such as tin cans, cisterns, wells, reservoirs, fire barrels, roof gutters, tires, catch basins, etc. All such water-holding containers must be treated for effective management to be achieved.

(a) Larviciding is done with many forms of pesticides. Solutions, emulsions, suspensions, dusts or granules may be applied with ground-operated equipment. Use granular formulations where a heavy plant cover must be penetrated.

(b) Containers such as empty tin cans and old tires, in which mosquitoes may breed, should be eliminated as much as possible. Treat those that can not be eliminated with larvicide to prevent breeding. Solicit the help of all people in the area to eliminate temporary water containers.

(2) Adult control Adult mosquitoes are effectively controlled with residual chemicals and space sprays. Adequately screening occupied structures is also essential where mosquitoes occur.

(a) Indoors. Use space sprays to manage mosquitoes indoors where immediate reduction is needed. These sprays have little or no residual effect and must be reapplied whenever new mosquitoes enter the area. Where frequent reentry is a problem, or where disease-bearing species are present, apply residuals to all surfaces where mosquitoes are likely to rest (unless otherwise prohibited, such as in a food service area or hospital). Treat surfaces such as door and window screens, walls, corners, chest interiors, etc. Screens with apertures equivalent to 18 x 16 mesh are essential to keep disease-bearing and pest mosquitoes, flies, and other insects from entering buildings.

(b) Outdoors. Use Ultra Low Volume (ULV) space treatments to manage adult mosquitoes outdoors. These treatments can't completely eradicate mortality of mosquitoes in the target area, but their repellent effects commonly give adequate protection for a day or more. In areas where breeding is continuous or the population is dominated by migratory species, ULV space sprays alone are seldom satisfactory unless done on a repetitive basis. Such repetitive treatments are usually very expensive and pose some risk to people or the environment; avoid them except in the most unusual conditions. When properly applied on a non-repetitive schedule, ULV space treatments will leave a small residual deposit which is not dangerous or unsightly. Exterior residual sprays have a limited value in protecting single residences or small camps. For larger areas where ULV treatments are not possible, apply a residual spray to vegetation surfaces within a radius of 100 feet or more around the site to protect people and kill mosquitoes resting in the vegetation.

C. Contingency considerations. Mosquitoes are generally the most important arthropods managed in contingency operations because of the number, types and distribution of diseases they transmit. A historical review of all the conflicts fought in Asia, Africa, Central America and South America clearly demonstrates the adverse impact of these insects on peoples' ability to carry out their battlefield or policing missions. These actions are essential to effectively combat such mosquito-borne diseases:

(1) Individual protective measures. These are those measures all people must take to protect themselves. People should use skin-applied repellents, insect repellent mesh jackets, bed nets, limited amounts of aerosol space sprays, and head nets in extreme cases. For additional protection, they should wear the uniform properly with sleeves down and buttoned and pants tucked into the boots. In areas where malaria is endemic, preventive drug treatments (chemoprophylaxis) should be started before deployment and rigidly enforced as long as people are in the area and for a prescribed period of time after leaving the area as directed by the command surgeon or preventive medicine officer.

(2) Unit protective measures. In addition to the above individual actions, a unit can carry out additional measures when it's operational overseas or during contingency operations to reduce the potential for arthropod-borne disease transmission. The main unit effort should focus on training people in protective measures and then strictly enforcing them, especially the regular use of malaria chemoprophylaxis as directed by the command surgeon or preventive medicine officer. Since Air Force and Navy units normally operate from established bases, their units normally receive direct unit support from the preventive medicine or pest management engineering units described in Army and Marine Corps units operate more diversely and as a result must have an increased pest management capability in each unit. Unit field sanitation teams give this support before deployment, using 2-gallon pesticide sprayers and selected premixed pesticides, such as those normally included in self-help programs on fixed installations.

Pest management support beyond this level is given by preventive medicine or engineering units.

3)Area protective measures. Area protective measures are those carried out by preventive medicine or engineering units with specially trained technicians using special equipment and controlled or restricted-use pesticides. These are the only military units with the equipment and training needed to conduct a large scale pest management operation.

Steps for effective mosquito control

- **Education**

One of the most effective tools available is awareness of mosquito biology so that you can eliminate future mosquito breeding sites from your yard. You should be aware of the life cycle of mosquitoes so you can take steps to avoid rearing mosquito larvae in water containers on your property. You should eliminate larval breeding sites such as discarded tires, beverage cups/litter, and unused children's wading pools. Residents should clean and replenish pet water and bird bathes every 3 days, clean roof gutters to allow proper drainage, prevent standing water in flower pots, ensure good property drainage, and plug hollow tree stumps. Water gardens or small fountains should be treated with larvicides or contain mosquito eating fish to prevent emerging adult mosquitoes. Maintenance of screen doors and windows will prevent adult mosquitoes from entering homes. Remember, any container that will hold water for 5 to 7 days is a potential breeding site for mosquito larvae.

Fig.2.4.3 (a) some of the breeding sites of mosquitoe

- **Source Reduction of Larval Habitats**

One of the simplest ways to reduce larval mosquito populations is to drain any unnecessary containers/pools of water which allow mosquito larval development. If it is not possible to drain areas, then treating them with larvicides if they are supporting larvae is an alternative.

Many mosquito larvicides on the market are very host specific and only disrupt the larval stage of mosquitoes and do not harm non target species.

Fig.4.3 (b) some of the breeding sites of mosquitoe

- **Personal Protection**

People can reduce their exposure to biting mosquitoes by wearing insect repellent when they are outdoors. They can also avoid being outside at dawn, early evening, and dusk when the majority of biting female mosquitoes are active. Wearing long sleeved clothing with long pants also provides protection. Repellants which contain from 10 to 30% DEET (N, N diethyl-*m*-toluamide) are most effective, but always read and follow label directions for proper application. Special care should be taken when applying repellants to children.

- **Chemical Control for Adult Mosquitoes**

Homeowner chemical control for adult mosquitoes is not practical and decisions regarding control should be left up to municipal regulation. Area wide chemical control for adult mosquitoes in Oklahoma is typically applied by thermal fogging or Ultra Low Volume (ULV) spraying.

This type of control is not usually effective in Oklahoma because it is very rare for conditions to be conducive for fogging adult mosquitoes. Adult mosquitoes must come into contact with the pesticide, so timing of application is critical. Since different mosquito species are active during different periods throughout a 24hr day it is critical to fog at exactly the proper time to get effective control of the target species. Extensive behavioral knowledge of the species to be controlled must be utilized and the spray applied only when adults are active. Weather conditions must be considered, as windy conditions usually present in the spring in Oklahoma may cause pesticides to drift out of an area so that they never reach their intended target. If ULV spraying is utilized the air temperature should be at least 60^{o}F, with wind velocities between 3-5 mph. Spraying in the heat of the day is not recommended as ULV droplets volatilize and go upward out of target areas. ULV spray equipment must be properly calibrated and operated by experienced personnel to ensure proper pesticide application rates. Pesticide label rates and recommendations must be followed according to the manufacturers instructions for all pesticides applied. Mosquito control products available for consumer use are typically sold through local home and garden supply stores. Product availability may vary according to location and state regulation

Review Questions

1. Write at least three distinguishing features of mosquito from other biting dipteras.
2. Describe the medical importance, and control methods for *anopheles*, *culex*, and *aedes*
3. Justify the reasons why malaria is still the most prevalent disease in the tropics .
4. Which host of malaria is referred as definitive host?
5. What are the steps in mosquitoe management.

CHAPTER THREE

SIMULIDAE /BLACK FLY/

Learning objectives

At the end of this chapter the reader will be able to

- Describe the specific features of black flies
- Discuss how onchocerciasis is transmitted by black flies
- Discuss the life cycle, medical importance and control methods of black flies.

3.1 Occurrences

Class: Insecta;

Order: Diptera;

Family: Simulidae;

Genus: Simulium;

Species: -damnosum, neavei.

There are more than 1300 known species of black flies (or "buffalo gnats," as they are sometimes called) in the family Simulidae. Their range extends throughout the temperate and tropical regions of the world.

Fig.3.1 Adult black fly

3.2 Identification:

Adult black flies are quite small, about 1.5-4 mm long, relatively stout bodied and, when viewed from the side, have a rather humped thorax. As their vernacular name indicates they are usually black in colour but many have contrasting patterns of white, silvery or yellowish hairs on their bodies and legs, and others may be predominantly or largely orange or bright yellow.

Black flies have a pair of large compound eyes, which in females are separated on the top of the head (a condition known as dichoptic); in the males the eyes occupy almost all of the head and touch on top of it and in front, above the bases of the antennae (a condition known as holoptic). In the males, but not females, the small lenses are larger on the upper than lower half of the eyes (Figure 3.2) The antennae are short, stout, cylindrical and distinctly segmented (usually 11 segments) but without long hairs. The mouth parts are short and relatively inconspicuous but the five-segmented maxillary palps, which arise at their base, hang downwards and are easily seen. Only females bite. The arrangement and morphology of the mouth parts in similar to those of the biting midges (Ceratopogonidae) the mouthparts, being stout and broad, do not penetrate very deeply into the host's tissues. Teeth on the labrum stretch the skin and the rasp-like action of the maxillae and mandibles cuts through it and rupture the fine blood capillaries. The small pool of blood produced is then sucked up by the flies. This method of feeding is ideally suited for picking up the microfilariae of Onchocerca volvulus which occur in human skin not blood.

The thorax is covered dorsally with very fine and appressed hairs, which can be black, white, silvery, yellow or orange and may be arranged in various patterns. The relatively short legs are also covered with very fine and closely appressed hairs and may be uni-colorous or have contrasting bands of pale and dark colour. The wings are characteristically short and broad and (lack scales or prominent hairs. Only the veins near the anterior margin are well developed, the rest of the wing is membranous and has an indistinct venation. The wings are colourless or almost so.

When at rest the wings are closed flat over the body like the blades of a closed pair of scissors.

The abdomen is short and squat, and covered with inconspicuous closely appressed fine hairs. In neither sex are the genitalia very conspicuous. Blackflies are most easily sexed by looking at the eyes.

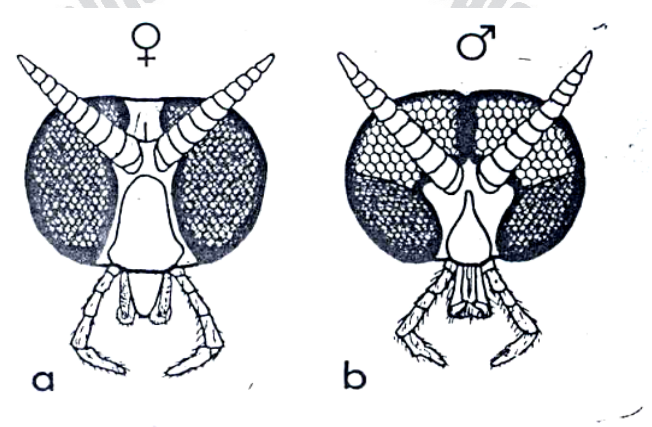

Figure 4.1 Front view of simuliid heads. (a) Adult female with dichoptic eyes; (b) adult male with holoptic eyes.

3.3 Life Cycle

When first laid the eggs are pale and often whitish but darken to a brown or blank colour. They are about 0.1-0.4 mm long, more or less triangular in shape but with rounded corners and have smooth shells which are covered with a sticky substance. They are always laid in flowing water but the type of breeding place differs greatly according to species. Habitats can vary from small trickles of water, slow flowing streams, lake outlets and water flowing from dams to fast-flowing rivers and rapids. Some species prefer lowland streams and rivers whereas others are found in Mountain Rivers. In species such as S. ochraceum, one of the South American vectors of onchocerciasis, eggs are scattered over the surface of flowing water while females are in flight in most species, however, ovipositing females alight on partially immersed objects such as Rocks, stones and vegetation, to lay their eggs. Usually some 150-800 eggs are laid in sticky masses or strings on a level with, or just below, the water line on submerged objects. Femalses may crawl underneath the water and become completely submerged during ovipositing. There may be a few favoured oviposition sites in a stream or river, resulting in thousands of eggs from many females being found together. Simulium damnosum, for example, frequently has such communal oviposition sites.

Eggs of S.damnosum hatch within about 1-2 days but in many other tropical species the egg stage lasts 2-4 days. Eggs of species inhabiting temperate and cold northern areas may not hatch for many weeks and some species pass the wither as diapausing eggs.

There are 6-9 (usually7) larval instars and the mature larva is about 4-12 mm long depending on the species, and is easily distinguished from all other aquatic larvae. The head is usually black, or almost so, and has a prominent pair of feding brushes (cephalic fans), while the weakly segmented, cylindrical body is usually whitish, but may be darker or sometimes even greenish. The body is slightly swollen beyond the head and in most, but not all, species distinctly swollen towards the end. The rectum has finger-like rectal organs which on larval preservation may be extruded and visible as a protuberance from the dorsal surface towards the end of the abdomen. Ventrally, just below the head, is a small pseudopod called the proleg which is armed with small circles of hooklets.

Larvae do not swim but remain sedentary for long periods on submerged vegetation, rocks, stones and other debris. Attachment is achieved by the posterior hook-circlet (anal sucker of many previous authors) tightly gripping a small silken pad. This has been produced by the larva's very large salivary glands and is firmly glued to the substrate. Larvae can nevertheless move about and change their position. This is achieved by alternatively attaching themselves to the substrate by the proleg and the posterior hook-circlet, thus they move in a looping manner. When larvae are disturbed they can deposit sticky saliva on a submerged object, release their hold and be swept downstream for some distance at the end of a silken thread. They can then either swallow the thread of saliva and regain their original position, or reattach themselves at sites further downstream larvae normally orientate themselves to lie parallel to the flow of water with their heads downstream. They are mainly filter-feeders, ingesting, with the aid of large mouthbrushes, suspended particles of food. However, a few species have predacious larvae and others are occasionally cannibalistic. Larval development may be as short as 6-12 days depending on species and temperature, but in some species may be extended to several months, and in other species larvae overwinter.

Mature larvae, which can be recognized by a blackish mark, termed the gill spot (respiratory organ of the future pupa) on each side of the thorax, spin, with the silk produced by the salivary glands, a protective slipper-shaped brownish cocoon. This cocoon is firmly stuck to submerged vegetation, rocks or other objects and its shape and structure vary greatly according to species. After weaving the cocoon the enclosed larva pupates. The pupa has a pair of, usually prominent, filamentous or broad thin- walled, respiratory gills. Their length, shape and the number of filaments or branches provide useful taxonomic characters for species identification. These gills, and the anterior part of the pupa, often project from the entrance of the cocoon. In both tropical and non-tropical countries the pupa period lasts only 2-6 days and is unusual in not appearing to be dependent on temperature. On emergence adults either rise rapidly to the water surface in a protective bubble of gas, which prevents them from being wetted, or they escape by crawling up partially submerged objects such as vegetation or rocks. A characteristic of many species is the more or less simultaneous mass emergence of thousands of adults. On reaching the water surface the adults immediately take flight.

The empty pupa cases, with gill filaments still attached, remain enclosed in their cocoons after the adults have emerged and retain their taxonomic value. Consequently, they provide useful information on the species of simuliids that have recently bred and successfully emerged from various habitats.

A few African and Asian blackfly species have a very unusual aquatic existence. For example, in East Africa larvae of S.neavei (except first instar) and pupae do not occur on submerged rocks or vegetation but on other aquatic arthropods, such as the bodies of immature stages (nymphs) of mayflies (Ephemeroptera), and various crustacean including freshwater crabs. Such an association is termed a phoretic relationship. Eggs, however, are never found on these animals; they are probably laid on submerged stones or vegetation.

The nuclei of the larval salivary gland cells have large polytene chromosome which have banding patterns that are used to identify otherwise morphologically identical species within a species complex. For example, chromosomal studies have shown that there are about 40 cytologically different entities in the s.damnosum complex, several of which are distinct species, whereas other forms are best referred to as cytotypes until their reproductive isolation, or otherwise, is determined.

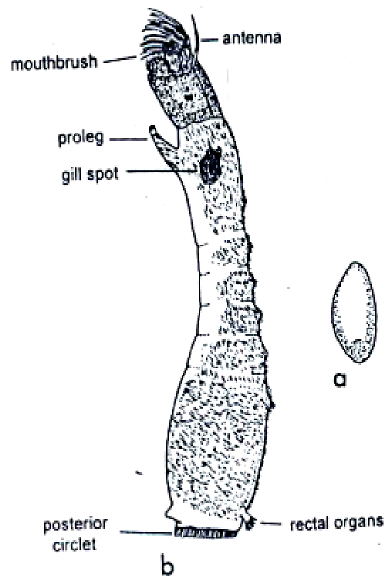

Figure 4.3 (a) Simuliid egg; (b) last instar larva of a simuliid species of the *Simulium damnosum* complex, showing body covered in minute dark setae and dorsal tubercles.

Adult Behaviour

Both male and female blackflies feed on plant juices and naturally occurring sugary substances, but only females take blood- meals. Biting occurs out of doors at almost any daylight hour, but teach species may have its preferred times of biting. For example, in Africa S. damnosum has a biting peak in the morning and another in the afternoon, whereas in South America S. ochraceum bites predominantly early in the morning between 08.00-10.00 hours. Many species seem particularly active on cloudy, overcast days and in thundery weather. Species may exhibit marked preferences fro reeding on different parts of the body, for example, s.damnosum feeds mainly on the legs whereas S.ochraceum prefers to bite the head and torso. When feeding on animals, adults crawl down th fur of mammals, or feathers of birds, to bite the host's skin, they may also enter the ears to feed.

Many species of black fly feed almost exclusively on birds (ornithophagic) and others on non-human mammalian hosts(zoophagic). However, several species also bite people. Some human-biting species seem to prefer various large animal such as donkeys or cattle and bite human only as a poor second choice, whereas others appear to find humans almost equally attractive hosts; no species bites people alne. In many species sight seems important in host location but host odours may also be important. After feeding, blood-engorged females shelter and rest in vegetation, on trees and in other natural outdoor resting places until the blood-meal is completely digested. In the tropics this takes 2-3 days, in non-tropical areas it may take 3-8 days or longer, the speed of digestion depending mainly on temperature. Relatively little is known about blakfly longevity, but it seems that adults of most species live for 3-4 weeks.

Female blackflies may fly considerable distances (15-30kb) from their emergence sites to obtain blood-meals and may also be dispersed large distances by winds. For example, it is not exceptional for adults of S. damnosum to be found biting 60-100 km from their breeding places, and in west Africa there is evidence that prevailing winds can carry adults up to 400-600 km. The long distances involved in dispersal have great reliance in control programmes, because areas freed from blackflies can be reinvaded from distant breeding places.

In temperate and northern areas of the palearctic and Nearctic regions biting nuisance from simuliids is seasonal, because adults die in the autumn and new generations do not appear until the following spring or early summer. Although in many tropical areas there is continuous breeding throughout the year, there may nevertheless be dramatic increases in population size during the rainy season.

3.4 Public Health Importance

1. Nuisance

In both tropical and non tropical areas of the world black flies can cause a very serious bitting problem, since there bites can be painful. Although the severity of thereaction to bites is different in different individuals, localized swelling and inflammation frequently occurs, accompanied by in tense irritation lasting for several days or even weeks.

2. Onchocerciasis

Onchocerciasis / river blindness is the disease transmitted by the female black fly. Repeated infection affects the eyes that lead to blindness. South western Ethiopia is confirmed to have the vector: Jimma, Shebe**.** Bonga, Gore, Gardula, Lekemt are believed to be endemic.

Onchocerciasis is the world's second leading infectious cause of blindness. Rarely life threatening, the disease causes chronic suffering and severe disability. In Africa, it constitutes a serious obstacle to socioeconomic development. It is often called river blindness because of its most extreme manifestation and because the black flies that transmit the disease abound in riverside areas, where they breed in fast-flowing waters. Fertile riverine areas are frequently abandoned for fear of the disease.

Distribution

35 countries in total. 28 in tropical Africa, where 99% of infected people live. Isolated foci in Latin America (6 countries) and Yemen.

Causative agent

A parasitic worm, *Onchocerca volvulu*s, of the family filariidae, which lives in the human body for up to 14 years. Each adult female worm produces millions of microscopic larvae (microfilariae), that migrate throughout the body to cause a variety of symptoms.

Transmission

Transmission of the disease is via the bite of infected black flies *(Simulium spp*.) that carry immature larval forms of the parasitic worms from human to human.

The life-cycle begins when a parasitized female black fly takes a blood-meal from a human host. The host's skin is stretched by the fly's apical teeth and sliced by its mandibles. A pool of blood is pumped up into the black fly, saliva passes into the pool, and infective *Onchocerca* larvae pass from the black fly into the host's skin. The larvae then enter the host's subcutaneous tissue, where they migrate, form and lodge in nodules, and slowly mature into adult worms. New worms form new nodules or find existing nodules and cluster together. It is thought that the smaller male worms may migrate between nodules to mate. After mating, eggs formed inside the female worm, develops into microfilariae and leave the worm one by one. A female worm may produce 1000 microfilariae per day. Many thousands of microfilariae migrate in the subcutaneous tissue. When the microfilariae die, they cause skin rashes, lesions, intense itching and skin depigmentation. Microfilariae also migrate to the eye and can cause blindness.

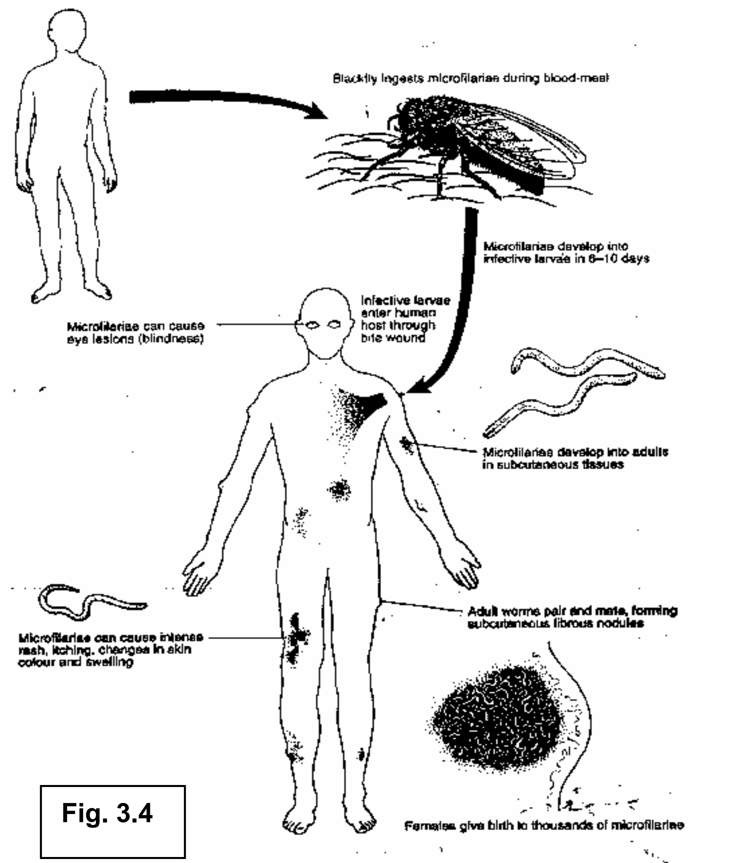

Fig. 3.4

Life cycle of *Onchocerca volvulus* (by Taina Litwak for the United States Agency for International Development's VBC Project).

Symptoms

Adult worms lodge in nodules under the skin, releasing large numbers of microfilariae into surrounding tissues. Immature worms move through the body and after dying, cause a variety of conditions including serious visual impairment and blindness, skin rashes, lesions, intense itching and depigmentation of the skin, lymphadenitis (resulting in hanging groins and elephantiasis of the genitals) and general debilitation.

Prevention and control of Onchocerciasis

Drug treatment: the development of ivermectin in the 1980s provided a safe, effective drug for killing microfilariae in infected people. A single dose of the drug needs to be taken annually.

Vector control: insecticide spraying to control black flies has proved successful in certain areas.

Onchocerciasis Control Program's (OCP's): principal method for controlling onchocerciasis involved interrupting transmission by eliminating the black fly vector. *Simulium* larvae are killed by applying insecticides via aerial spraying over breeding sites in fast-flowing rivers. Following interruption of transmission, the reservoir of adult worms dies out in humans after 14 years. To complement vector control activities, OCP also distributes ivermectin.

African Programme for Onchocerciasis Control (APOC)

Following the success of the OCP, the same co-sponsors and donors created APOC in 1995. The objective is to create, by 2007, sustainable community-directed distribution systems using ivermectin. These will ultimately cover 59 million people in 17 non-OCP countries, where the disease remains a serious public health problem and some 15 million people are infected. In a few isolated foci, APOC aims to eliminate the black fly through insecticide spraying.

3. Mansonella Ozzardi

Mansonella ozzardi is a filarial parasite of humans that is usually regarded as non-pathogenic, although it has been reported as causing morbidity in Colombia and Brazil.

3.5 Control of Black flies

There are few reports on the effectiveness of repellents against blakfly attacks. It seems that some protection, usually lasting up to 2 hours, can be gained by use of repellents such as diethyltoluamide (DEET), dimethylphthalate (DIMP) and butyryl-tetrahydro quinoline.

Although insecticidal fogging or spraying of vegetation though to harbour resting adult blackflies has occasionally been undertaken, this approach results in very temporary and localized control. The only practical method at present available fro the control of blackflies is the application of insecticides to their breeding places to kill the larvae. Insecticides need be applied to only a few selected sites on watercourses for some 15-30 min, because as the insecticide is carried downstream it kills simuliid larvae over long stretches of water. The flow rates of the water and its depth are used to calculate the quantity of insecticide to be released. Applying DDT by this method has resulted in good control of S.damnosum in areas of Nigeria and Uganda. If treatment is not repeated at intervals throughout the year, gravid female adult dispersing into the area from untreated areas will probably cause recolonization. In Kenya S.neawei has been eradicated by the application of DDT to he relatively small sterms in which this vector occurred, together with bush clearing. Because of its accumulation in food chains DDT is no longer recommended for larval control, instead organophosphate, such as temephos (Abate),are usually recommended

In many areas ground application of larvicides is difficault, either because of the enormous size of the rivers requiring treatmdnt or because breeding occurs in a large network of small streams and watercourses. Under these conditions aerial applications from small aircraft or helicopters have been used. Considerable information has been gained in North America on the chemical control of pestiferous blackflies.

Because of the severity of river blindness in the Volta River Basin area of West Africa and its devastating effect on rural life the world's most ambitious and largest vector control programme was initiated in 1997 by the world Health organization, and is called the Onchocerciasis control programme (OCP). This programme originally involved seven west African countries but has now expanded to cover 11 countries. Some 50,000 km of rivers over an area of 1.3 million km^2 that are breeding the S.damnosum complex are dosed at weekly intervals with temephos (Abate), which is usually dropped from helicopters or small aircraft. Because of the appearance of temephos resistance (in 1980) in some populations and species of the S.damnosum complex, some rivers are treated instead with chlorphoxim or Bacillus thuringiensis subsp. israelensis (=B. thuringiensis H-14). Results have been spectacular. And transmission or river blindness has ceased over most of the OCP area. Larviciding will continue in the newer areas covered by the programme until the year 2000, thus giving insecticidal control in these areas fro 14 years, the period required to eliminate O.voluulus from the human population.

Review questions

1. Describe the identification characteristics of black fly.
2. Discuss the transmission cycle of human onchocerciasis.
3. Describe socioeconomic impact of the disease river blindness.
4. List the applicable control techniques of black flies.

CHAPTER FOUR

Phlobotaminae /Sand Fly/

Learning objectives

At the end of this chapter the reader will be able to

- describe the identifying characteristics and lifecycle of phlobotaminae sand flies
- list the different types of diseases transmitted by sand flies
- discuss the modes of transmission of these diseases
- Discribe the applicable control methods of sand flies

4.1 Sand flies (*Phlebotomus* and *Lutzomyia* spp.)

Class: Insecta;

Order: Diptera;

Family: *Psychodidae*;

Genus: Phlebotomous, Psychoda

Species : *Ph. Longipes , Ph. Longerni, Ph. Orientalis, Ph. Papatasi, Ph. Chinesis;*

Ps. Phalaenoides, *Ps. Alternata*

There are some 700 species of phlebotomine sandflies in five genera within the subfamily phlebot00 ominae of the family psychodidae. Species in three genera, phlebotomus, Lutzomyia and Sergentomyia, suck blood from vertebrates, the former two are the more important medically as they contain disease vectors. The genus phlebotomus occurs only in the Old World, especially in southern parts of the northern temprate areas such as the Mediterranean region. The genus also occurs in the Old world tropics, but there are not many species in tropical Africa, especially West Africa. Most phlebotomus species inhabit semiarid and savannah areas in preference to forests. Lutzomyia species by contrast are found only in the New World tropics, occurring mostly in the forested areas of Central and South America

Sergentomyia species are also confined to the Old World, being especially common in the Indian subregion, but also occurring in other areas such as Africa and Central Asia. A few species of sergentomyia bite people, but they are not disease vectors.

4.2 External Morphology

No details are given for distinguishing between the adults of phlebotomus, Lutzomyia and sergentomyia because this requires specialized knowledge and detailed examination; generally species biting people in the Old World will be phlebotomus and in the New World Lutzomyia.

Their minute size (1.3-3.5 mm in length), hairy appearance, relatively large black eyes and their relatively long and stilt-like legs can readily recognize adult phlebotomine sandflies. The only other blood-sucking flies which are as small as this are some species of biting midges (Ceratopogonidae), but these have non-hairy wings and differ in many other details. Phlebotomine sandflies have the head, thorax, wings and abdomen densely covered with long hairs. The antennae are are long and composed of small bead-like segments with short hairs; they are similar in both sexes. The mouthparts are short and inconspicuous and adapted for blood-sucking. At their base are pair of five-segmented maxillary palps which are relatively conspicuous and droop downwards.

Wings are lanceolate in outline and quite distinct from the wings of other biting flies. The phelebotominae can be distinguished from other subfamilies of the family psychodidae, which they may superficially resemble, by the wings. In sandflies the wings are held erect over the body when the fly is at rest, whereas in non-biting psychodid flies they are folded, roof like, over the body. The wing venation also differs. In phlebotomine sandflies, but not in the other subfamilies of psychdidae, vein 2 branches twice, although this may not be apparent unless most of the hairs are rubbed from the wing veins (Figure 4.1).

4.3 Life history and habits

Four stages of development (complete metamorphosis). Limited home range- Horizontal flight: maximum 200 meters. Vertical flight: about 6 meters. Like dampness. Only females bite man, livestock, rodents, dogs, hyrax, cats and other mammals. They deposit their eggs in humid place on damp soil rich in humus. The larvae feed on decaying organic matter. Life cycle lasts from 1-4 months depending on spp, and temperature. Although it usually lasts less than 45 days, Breeding is in the soil independent of surface water. Sand flies usually rest in the day time in dark and humid sites such as termite hills, animal burrows, cracks in mud walls and masonry, on decaying vegetations etc

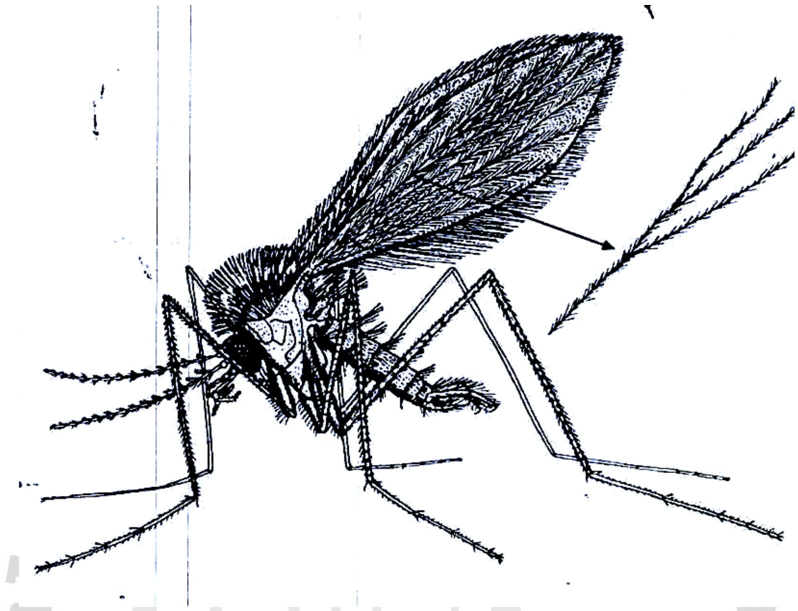

Figure 4.1 Adult male phlebotomine sandfly, terminal abdominal claspers of the genitalia, and diagrammatic representation of double branching of wing vein 2.

Adult Behavior

Both sexes feed on plant juices and sugary secretions but females in addition suck blood from a variety of vertebrates, including livestock, dogs, urban and wild rodents, snakes, lizards and amphibians; a few species feed on birds. In the Old World many phletobomus species bite people whereas most species of sergentomyia feed mainly on reptiles and rarely bite humans. In the tropical Americas Lutzomyia species feed on a variety of mammals including humans. Biting is usually restricted to crepuscular and nocturnal periods but people may be bitten during the day in darkened rooms, or in forests during overcast days. Most species feed out of doors (exophagic) but a few also feed indoors (endophagic). Adults are weak fliers and do not usually disperse more than a few hundred metres from their breeding places. Consequently biting may be localized to a few areas. However, it is known that adults of at least some species can fly up to 2.2 km over a few days. Sandflies have a characteristic hopping type of flight so that there may be several short flights and landings before females settle on their hosts. Windy weather inhibits their flight activities and biting. Because of their very short mouthparts, they are unable to bite through clothing.

During the day adult sandflies rest in sheltered, dark and humid sites, but on dry surfaces, such as on tree trunks, on ground litter and foliage of forests, in animal burrows, termite mounds, tree-holes, rock fissures, caves, cracks in the ground and inside human and animal habitations. Species that commonly rest in houses (endophilic) before or after feeding on humans are often referred to as domestic or peridomestic species. Examples are phlebotomus papatasi in the Mediterranean area and Lutzomyia longipalpis in South America.

In temperate areas of the Old World sandflies are seasonal in their appearance and adults occur only in the summer months. In tropical areas some species appear to be common more or less throughout the year, but in other species there may be well marked changes abundance of adults related to the dry and wet seasons.

4.4 Public Health importance of phlebotamus sand fly

1. Nuisance

Apart from their importance as disease vectors, sand flies may constitute a serious, but usually localized bitting nuisance. In previously sensitized people their bite may result in severe and almostintolerable irritations, a condition known in the middle east as harara.

2. Leishmaniasis

This is a term used to describe a number of closely related diseases caused by several distinct species, subspecies and strains of Leishmania parasites.

Leishmania parasites are named after W.B. Leishman, who developed one of the earliest strains of Leishmania in 1901.

Distribution

Leishmaniasis is wide spreaded in 22 countries in the New World and in 66 nations in the Old World, it is not found in South-east Asia. Human infections are found in 16 countries in Europe, including France, Italy, Greece, Malta, Spain and Portugal. Occurring in several forms, the disease is generally recognized for its cutaneous form, which causes non-fatal, disfiguring lesions, although epidemics of the potentially fatal visceral form cause thousands of deaths. It is endemic in 88 countries on 4 continents. More than 90% of cutaneous leishmaniasis cases occur in Iran, Afghanistan, Syria, Saudi Arabia, Brazil and Peru. More than 90% of visceral leishmaniasis cases occur in Bangladesh, Brazil, India and Sudan

The disease is widely spread in different area in Ethiopia: Gondar, Tigrai, Jimma, Diredawa, Lekempt, Harar, Arbaminch, Dessie.

Causative agent

Parasitic protozoa of the genus *Leishmani*a, transmitted to humans by sand flies. Over 20 species and subspecies infect humans, each causing a different spectrum of symptoms. These range from simple, self healing skin ulcers (e.g. due to infection with *Leishmania majo*r), to severe, life-threatening disease (e.g. visceral leishmaniasis caused by *L. donovani*

Life cycle of *Leishmania*

The life cycle starts when a parasitized female sand fly takes a blood meal from a human host. As the sand fly feeds, promastigote forms of the leishmania parasite enter the human host via the proboscis. Within the human host, the promastigote forms of the parasite are ingested by macrophage where they metamorphose into amastigote forms and reproduce by binary fission. They increase in number until the cell eventually bursts, then infect other phagocytic cells and continue the cycle.

Clinical Forms

The diseases occur in three main clinical forms: cutaneous, mucocutaneous, and visceral leishmaniasis and a fourth less common form termed diffuse cutaneous leishmaniasis. Phlebotomine sandflies are the only vectors. The epidemiology of leishmaniasis is too complex to be adequately described here.

Basically parasites (amastigotes) are ingested by female sandflies with a blood-meal and multiply in the gut. They develop a flagellum and attach themselves to either the mid-gut or the hindgut wall. After further development they become infective metacyclic promastigotes and migrate to the anterior part of the mid-gut and from there to the oesophagus. After 4-12 days from taking an infective blood-meal the metacyclic forms may be found in the mouth parts from which they are introduced into a new host during feeding. Infective flies often probe more often than uninfected flies, thus maximizing transmission of parasites during blood-feeding. Previous feeding by females on sugary substances, mostly obtained from plants, is essential not only for the survival of the sandfly but the development of the parasites to the infective form.

Most types of leishmaniasis are zoonoses. The degree of involvement of humans varies greatly from area to area. The epidemiology is largely determined by the species of sandflies, their ecology and behaviour, the availability of a wide range of hosts and also by the species and strains of Leishmania parasites. In some areas, for example, sandflies will transmit the disease almost entirely among wild or domesticated animals, with little or no human involvement, whereas elsewhere animals may provide an important reservoir of infection for humans. In India the disease may be transmitted between people by sandflies, with animals taking no identifiable part in its transmission.

Cutaneous leishmaniasis in the Old World, known also as Oriental sore, occurs mainly in arid areas of the Middle East to northwestern

India and central Asia, in North Africa and various areas in East, West and southern Africa. In the New World it is found mainly in forests from Mexico to northern Argentina. Several species of parasites are involved, including Leishmania major and Le. Tropica in the Old World, and Le. braziliensis and Le. mexicana in the Americas. Leishmania major is usually zoonotic and in most of its range gerbils are the reservoir hosts; Le. tropica occurs in densely populated areas and, although dogs are also infected, humans are the main reservoir host. Important vectors of cutaneous leishmaniasis include phlebotomus papatast (Le. major), P. longipes (Le. aethiopica) and P. sergenti (Le. tropica).

Mucocutaneous leishmaniasis (espundia) is a severely disfiguring disease found from Mexico to Argentina. It is manly caused by Leishmania braziliensis and Le. panamensis, parasites which normally infect a wide variety of forest rodents, marsupials, armadillos, edentates, primates, sloths and also domestic dogs. The disease is spread by several species of Lutzomyia including L. welcomei, L. amazonicus.

Diffuse cutaneous leishmaniasis is a form that causes widespread cutaneous nodules or macules over the body and usually results from infection with Leishmania aethiopica in Ethiopia and Kenya or with Le. amazonensis in South America.

Visceral leishmaniasis, often referred to as kala-azar, is caused by Leishmania donovani in most areas of its distribution, such as India, Bangladesh, Sudan, East Africa, And Ethiopia. Among the vectors are P. argentipes and P. orientalis. In Sudan rodents have beeen found infected but most transmission seems to be from person to person. In the Meditrranean basin, Iran, and central Asia, including northern and central China, Leishmania infantum is the parasite, and the vectors include P. ariasi, P. perniciosus and P. chinesis. Dogs and foxes are most important reservoirs. Visceral leishmaniasis also occurs sporadically in Central and South America, where the parasite is Leishmania infantum (= Le. chgasi of some authors) and is transmitted by Lutoaomyia longipalpis. Wild foxes and domesticated dogs are reservoirs.

Fig. 2.7
A typical clinical sign of visceral leishmaniasis is enlargement of the spleen and liver.

Fig. 2.8
Cutaneous leishmaniasis may typically cause ulcers which, after healing, leave permanent depressed scars.

fig 2. clinical features of cutaneous leishmaniasis

(Source: Jan A. Rozendaal: WHO 1997)

Fig. 2.9

Mucocutaneous leishmaniasis may cause severe mutilations of the face through progressive destruction of soft tissues in the cavities of the mouth and nose.

Prevention and control of leishemaniasis

Most cases of CL heal without treatment, leaving the person immune to further infection. In many parts of South-west Asia, infections were deliberately encouraged on the buttocks of babies in order to immunize them (avoiding disfiguring scars on the face or elsewhere). Prevent sand fly bites through the repellents and Insecticides.

Management. Survey methods for sand flies include aspirators, sticky paper and CDC traps.Look for immature forms in soil, rock piles and stone fences. Collect adults as they rest in animal houses and shelters.

Fortunately, given their limited flight range and a tendency to stop frequently (these pests actually fly in a series of short hops), the sand fly is easily controlled by residual sprays applied to walls, screens, fences, etc.

Contingency considerations

Unit pest management measures such as residual spraying and enforcing individual protective measures are normally sufficient to keep this pest from becoming a major problem. If a unit is operating in a jungle or tropical forest areas where sand fly-borne disease is endemic, additional area-level pest management units may be needed to apply residual pesticides to vegetation near contaminated areas.

3. Bartonelliosis

This disease is sometimes called Oroya fever or Carrion's

4. Sandfly Fever

Sandflies can transmit several viral diseases, but the most important is sandfly fever, sometimes called papataci fever or 3-day fever, of which there are two distinct virus serotypes. Females become infective 6-10 days after taking an infected blood-meal. Infected females can lay eggs containing the virus and these eventually give rise to infected adults. This is an example of trans-ovarious tick-borne diseases. Sandfly fever occurs mainly in the Mediterranean region, but also extends up the Nile into Egypt and the Middle East, the most important vector is P. papatasi. The disease also occurs in India, Pakistan and probably China, and in some of these areas phlebotomines other than P. papatasi are the vectors.

4.5 Control Measures of sand fly

Leishmaniasis has in the past not usually been considered a sufficiently important disease to justify much expenditure on controlling the vectors, and consequently there have been relatively few campagns devoted to sandflies control. Phlebotomine sandflies are, however, very susceptible to insecticides; the only reported case of resistance is P. papatasi to DDT in northeastern India. In nearly all areas where residual insecticides, particularly DDT, have been used to control Anopheles vectors of malaria there have apparently been drastic reductions in sandfly populations followed by interruption of leishmaniasis transmission.

With the cessation of spraying, sandflies usually return, and transmission is renewed. In addition to DDT, HCH, malathion, fenitrothion (Simuthion), propoxur (Baygon) and synthetic pyrethroids have been used to try and control sandflies. Where sanddflies bite and rest out of doors such control strategies are not feasible.

If the outdoor resting sites are known (e.g. animal shelters, stone walls, tree trunks, termite hills) these can be sprayed with residual insecticides. Insecticidal fogging of outdoor resting sites is used in Jordan for the control of P. papatasi, although this approach usually gives only temporary control.

Personal protection can be achieved by applying efficient insect repellents, such as diethyltoluamide (DEET), dimethylphthalate (DIMP) or trimethyl pentanediol. Mesh screens or nets with very small holes can afford some protection, but a disadvantage is that they reduce ventilation causing it to be unpleasantly hot in screened houses or under sandfly bed –nets. Such nets, or even mosquito nets with larger holes, can be impregnated with pyrethroids such as permethrin and deltamethrin to give protection against biting for up to six monthes, so long as the nets are not washed.

Control of sand fly larvae remains impossible because the breeding sites of most species are unknown, and even when they can be identified it is usually impractical to do any thing to reduce larval numbers.

Because most leishmaniasis transmission involvolves reservoir animals, e.g. rodents and dogs, in some areas control focuses on killing such hosts. For example in some areas of north Africa clearing vegetation around villages reduces gerbil populations.

Review questions

1. describe the distinguishing features of sand flies
2. list the types of diseases transmitted by sand flies
3. mention the applicable control methods of sand flies

CHAPTER FIVE

GLOSSINIDAE /TSETSE FLY /

Learning objectives

At the end of this chapter the reader will be able to

- describe external morphology of tsetse fly
- list the major diseases transmitted by tsetse flies
- describe the life cycle, habit, and public health importance of tsetse flies
- discuss the basic prevention and control techniques applied in the control of sleeping sickness

5.1 Introduction

Class: Insecta;

Order: Diptera;

Family: Glossinidae;

Genus: *Glossina*;

Species: - The six different *Glossina spp*. considered primary vectors of the disease are *Glossina palpalis, G. morsitans, G. tachinoides, G. pallidipes, G. swynnertoni and G. fuscipes*.

The tsetse is the vector of African trypanosomiasis or African sleeping sickness, which may be caused by either *Trypanosoma brucei gambiense* or *Trypanosoma brucei rhodesiense*.

Occurrence Tsetse flies are generally confined to the area of tropical Africa, south of the Tropic of Cancer.

5.2 Identification

Size: they are larger than the CHF; **Color**: dark; **Proboscis** (mouth): long and slender; Occur only in tropical Africa. They are Yellowish or dark brown in colour and medium sized flies (6-15mm). Their wing at rest is closed over one another like a closed scissors, and the tip of the wing is then extended beyond the abdomen. They can be distinguished from other large biting diptera by their forward, pointing mouth part and high pitched buzzing sounds.

They are somewhat more restricted between the thorax and the abdomen than most other flies and have wings that fold over the abdomen in a scissor-like fashion that extends well beyond the abdomen. The bayonet-like proboscis extends outward in front of the head when the fly is in a resting position.

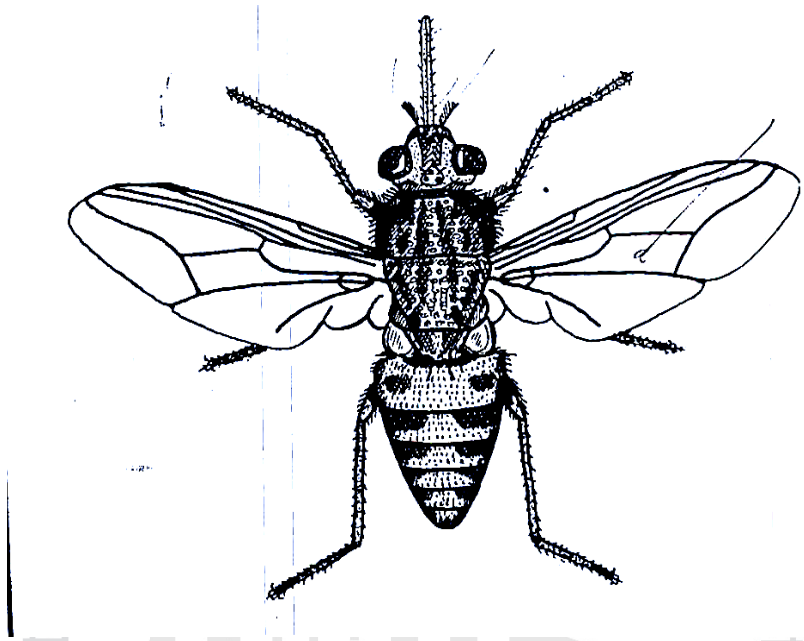

Fig. 5.1 Adult Tsetse fly

5.3 Life history and habits

Tsetse flies pass through complete metamorphosis. They are larviparous i.e they retain fertilized egg in a kind of uterus and hatch the matured larvae. The matured larvae after deposited burrow in to the ground and pupate and finally emerge as adult fly. The egg and larva develop in uterus of the insect. Matured larvae are laid in bush under fallen trees and rotten trees to pupate. The adult lives in shady forest areas.

Adult behaviour

Both sexes are blood suckers. They bite by day or at dusk Tsetse fly is greatest single hindrance to animal production and agricultural development in tropical Africa. 30 African countries are affected by Tsetse fly. The affected area in Africa covers 45 million square miles. Adult tsetse flies can transmit trypanosomiasis (African sleeping sickness) to man and animals.

Both males and females are avid blood feeders and can fly at speeds over 20 miles per hour. Unlike most flies, the female tsetse fly gives birth to a full grown larva, one at a time every 10 to 12 days over her lifetime. She must take a new blood meal before a new larva will develop.

All tsetse flies, both male and female feed on blood having their mouth parts adopted to pierce and suck blood of their hosts. The proboscis is connected with salivary duct that brings salivary secretion and salivary secretion contains anti-coagulants that keep blood liquid during passage to the digestion portion

- They are attracted by large moving objects and carbon dioxide.
- They are exophagic

The habitat of adult fly is vegetation surrounding villages; in sacred forests or forests on cemeteries forest edges surrounding plantation Eg. Coffee and savanna habitats

5.4 Public Health importance

1. Nuisance -cause painful bites
-buzzing sound

2. Human trypanosomiasis

It is usually divided in to two. These are humanAfrican trypanosomiasis which is called sleeping sickness. Another human form of trypanosomiasis (Human American Trypanosomiasis) occurs in the Americas and is known as Chagas disease.

Human African Trypanosomiasis or Sleeping Sickness

Human African trypanosomiasis, known as sleeping sickness, is a vector-borne parasitic disease. *Trypanosoma*, the parasites concerned, are protozoa transmitted to humans by tsetse flies (*glossina*). Tsetse flies live in Africa, and they are found in vegetation by rivers and lakes, gallery-forests and vast stretches of wooded savannah. Human trypanosomiasis caused by protozoan parasites. The following are the species responsible for causing sleeping sickness.

Trypanosoma gambiense	*Trypanosoma. vivax*
Trypanosoma rhodesiense	*Trypanosoma. Congolense*

Sleeping sickness occurs only in sub-Saharan Africa, in regions where tsetse flies are endemic. For reasons as yet unknown, there are many regions where tsetse flies are found, but sleeping sickness is not.

The rural populations that live in such environments and depend on them for agriculture, fishing, animal husbandry or hunting are the most exposed - along with their livestock - to the bite of the tsetse fly. Sleeping sickness affects remote and rural areas where health systems are least effective, or non-existent. It spreads with socio-economic problems such as political instability, displacement of populations, war and poverty.

It develops in foci whose size can range from a village to an entire region. Within a given focus, the intensity of the disease can vary considerably from one village to the next.

Human African trypanosomiasis takes two forms, depending on the parasite involved:

Trypanosoma brucei gambiense (T.b. gambiense) is found in central and West Africa. It causes chronic infection, which does not mean benign. A person can be infected for months or even years without obvious symptoms of the disease emerging. When symptoms do emerge, the disease is already at an advanced stage.

Trypanosoma brucei rhodesiense (T.b. rhodesiense) is found in southern and east Africa. It causes acute infection that emerges after a few weeks. It is more virulent than the other strain and develops more rapidly, which means that it is more quickly detected clinically.

Major epidemics

There have been three severe epidemics in Africa over the last century: one between 1896 and 1906, mostly in Uganda and the Congo Basin, one in 1920 in several African countries, and one that began in 1970 and is still in progress. The 1920 epidemic was arrested due to mobile teams systematically screening millions of people at risk. The disease had practically disappeared between 1960 and 1965. After that success, screening and effective surveillance were relaxed, and the disease has reappeared in endemic form in several foci over the last thirty years.

The geographical distribution of the disease

Sleeping sickness threatens over 60 million people in 36 countries of sub-Saharan Africa. Only 3 to 4 million people at risk are under surveillance, with regular examination or access to a health centre that can provide screening.

Detection of the disease calls for major human and material resources, such as well-equipped health centers and qualified staff. Because such resources are lacking, most people with sleeping sickness die before they can ever be diagnosed.

Almost 45 000 cases were reported in 1999, but the World Health Organization (WHO) estimates that the number of people affected is ten times greater. The 45 000 case figure shows not the true situation but rather the lack of screening in many foci. The real number of cases seems to be between 300 000 and 500 000. Reported cases in recent years are from countries where surveillance coverage is no more than 5%. In certain villages of many provinces of Angola, the Democratic Republic of Congo and southern Sudan, the prevalence is between 20% and 50%. Sleeping sickness has become the first or second greatest cause of mortality, ahead of HIV/AIDS, in those provinces.

Countries are placed in four categories in terms of prevalence. In each country the spatial distribution of the disease is very diverse; it is found in foci and micro-foci.

Countries where there is an epidemic of the disease, in terms of very high cumulated prevalence and high transmission: Angola, Democratic Republic of Congo and Sudan;

Highly endemic countries, where prevalence is moderate but increase is certain: Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, Guinea, Mozambique, Uganda and United Republic of Tanzania.Countries where the endemic level is low: Benin, Burkina Faso, Equatorial Guinea, Gabon, Kenya, Mali, Togo and Zambia;

Countries whose present status is not clear: Botswana, Burundi, Ethiopia, Liberia, Namibia, Nigeria, Rwanda, Senegal and Sierra-Leone.

Infection and symptoms

The disease is transmitted with the bite of the tsetse fly. At first the trypanosomes multiply in the blood, and that process can last for years with *T.b. gambiense*.

- Mother-to-child infection: the trypanosome can cross the placenta and infect the fetus, causing abortion and perinatal death.

Accidental infections can occur in laboratories, for example, through the handling of blood of an infected person, although this is fairly rare.

Causative agent

Protozoan parasites of the genus *Trypanosom*a, which enter the blood stream via the bite of blood Feeding tsetse flies *(Glossina spp*.). *Trypanosoma brucei rhodesiense* occurs mainly in east and southern Africa. *T.b. gambiense* mainly in west and central Africa. A third subspecies, *T.b. brucei* is responsible for the cattle disease but does not infect humans.

Transmission

Its transmission is via the bite of infected bloodsucking male and female tsetse flies that transfer the parasites from human to human. Cattle and other wild mammals act as reservoir hosts of the parasites. Tsetse flies can acquire parasites by feeding on these animals, or on an infected person. Inside the human host, trypanosomes multiply and invade most tissues.

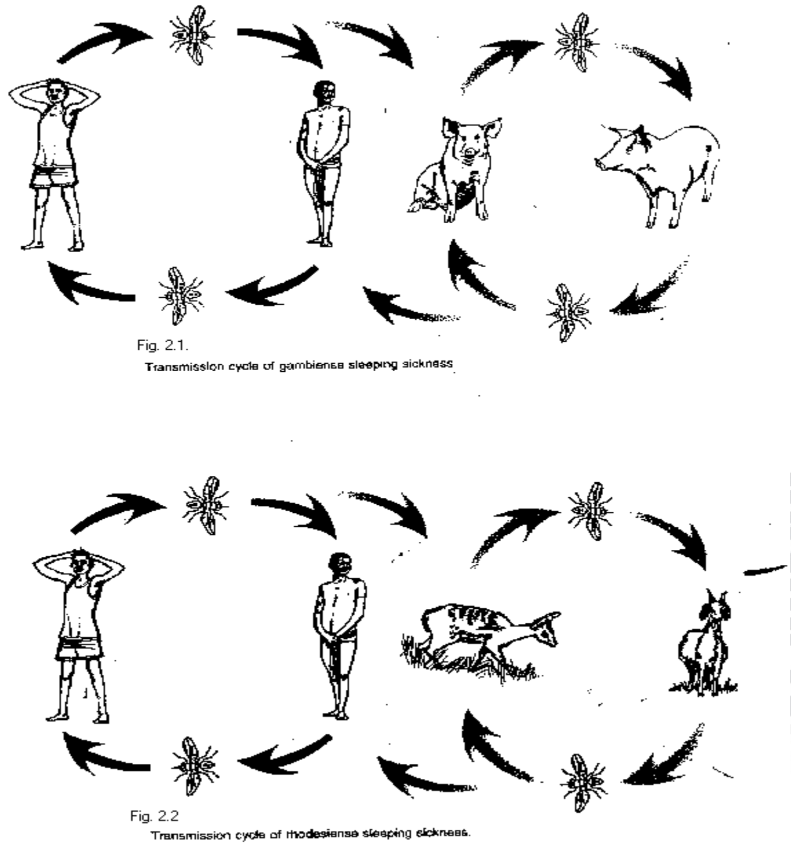

Fig. 5.2 Transmission cycle of sleeping sickness

Symptoms

Infection leads to malaise, lassitude and irregular fevers. Early symptoms, which include fever and enlarged lymph glands and spleen, are more severe and acute in T.b. rhodesiense infections. A range of symptoms including headache, anaemia, joint pains and swollen tissues follows early signs; advanced symptoms include neurological and endocrine disorders.

As the parasites invade the central nervous system, mental deterioration begins, leading to coma and death. *T.b rhodesiense* infection is usually acute, causing severe symptoms and death within a few days or weeks. *T.b. gambiense* infections tend to progress more slowly (over several years) and are less severe. The early phase entails bouts of fever, headaches, pains in the joints and itching. The second, known as the neurological phase, begins when the parasite crosses the blood-brain barrier and infests the central nervous system. This is when the characteristic signs and symptoms of the disease appear: confusion, sensory disturbances and poor coordination. Disturbance of the sleep cycle, which gives the disease its name, is the most important feature.

Without treatment, the disease is fatal. If the patient does not receive treatment before the onset of the second phase, neurological damage is irreversible even after treatment.

The role of the World Health Organization

Faced with this resurgence of sleeping sickness, WHO coordinates activities in endemic countries and mobilizes a wide range of partners for this purpose.

The Programme for Surveillance and Control of African Trypanosomiasis (PSCAT) includes national control programmes, nongovernmental organizations (NGOs), donor countries, private foundations, regional institutions, research centers and universities.

The objectives of PSCAT are:

- Coordination of the sleeping sickness control network to ensure that field activities are sustainable;
- Strengthening of existing surveillance systems;
- Development of the network for study of treatment and drug resistance;
- Promotion of inter-agency collaboration for example with the FAO;

Animal trypanosomiasis

Other sub-species of the parasite cause animal trypanosomiasis, which are pathogenic to animals and are often different from those that cause the disease in humans. Animals can carry parasites, especially *T.b. rhodesiense*; domestic and wild animals are a major reservoir. They can also be infected with *T. b. gambiense*, though the precise role of this reservoir is not well known. The two human and animal forms of the disease remain a major obstacle to the development of rural regions of sub-Saharan Africa: human loss, decimation of cattle and abandonment of fertile land where the disease is rife.

Although tsetse flies are limited in their distribution to sub-Saharan Africa, the importance of the animal trypanosomiasis (nagana of cattle) on that continent ranks tsetse as one of the world's major arthropod-vector groups. The very complex developmental cycle of the trypanosome within the tsetse vector is further complicated by several of other factors related to the biology of the vector, pathogen, and host. Not only are the various species of tsetse flies

characterized by differences in their distribution, biology, and host preferences, but even within the same species environmental factors (especially humidity, temperature, and vegetation), densities and composition of mammalian hosts, and vector population densities affect their epidemiological role. In addition, there are wide intraspecific variations in both morphology and pathogenicity of trypanosomes. Certain parasite antigens that stimulate production of protective antibodies by the host change before the parasites are completely eliminated; new antibodies are then produced by the host, and the parasites change their antigenic constitution again to maintain themselves.
Animal trypanosomiasis is greatest hinderance in animal production and agricultural development in tropical Africa.

5.5 Prevention and control

Reduction of tsetse fly numbers plays a significant role, especially against the rhodesiense form of the disease. In the past, this has involved extensive clearance of bush to destroy tsetse fly breeding and resting sites, and widespread application of insecticides

Control Measures: - Clearing forest and bushy habitat of tsetse clear 10 - 12 meters on both sides of forest crossing roads. Close highway of tsetse infested areas. Trapping adults, killing pupa use nets or / odor attracted traps, use animals as bait / visual targets to trap, Inspection of people and treating cases. Genetic control: sterile males by radiation. Insecticide application / with care (Arial spraying, Ground spraying, Fumigation, DDT, and BHC), Use of repellents: Oils, lotions or creams applied to exposed body parts or applied lightly on clothing.

Management Insect sweep nets or biconcial, ox-odor-baited traps are the most effective way to survey for these insects, even though such techniques aren't species specific. Since the vector ecology varies, it is necessary to identify the species common to a specific area before taking appropriate pest management measures. Strict vegetation management includes clearing dense brush along waterways and around contaminated areas (preferably up to a mile away if possible). Aircraft pesticidal applications that give a small droplet size (approximately 250 microns or less) can be effective in areas where it is not practical to eliminate or reduce thick brush for at least a quarter of a mile.

Contingency considerations The only time human trypanosomiasis is a contingency consideration is when operations are necessary in the tsetse fly infested areas. If this is the situation, troop staging, and as much of the support operations as possible, should be kept outside of the known fly breeding areas. Aircraft spray operations should be applied to brushy areas surrounding containment areas and strict brush control should be practiced within the containment area itself and within a mile of a large containment Strict use of individual protective measures such as the repellent jacket and proper uniform wear must be strictly enforced. To date the only cost-effective success has been with large scale use of ox-odor-baited traps.

Review Questions

1. List the favourable breeding site for tsetse fly.
2. Write at least four features typical to tsetse flies.
3. Describe the possible applicable environmental friendly control measures of tsetse flies.
4. List at least two medical important species of glosina which are found in Africa.

CHAPTER SIX

MUSCIDAE /HOUSE FLY/ AND OTHER DIPTERANS

Learning objectives

At the end of this chapter the reader will be able to

- discuss all possible diseases transmitted by house fly
- describe the possible factors affecting the distribution of house fly
- list the applicable control techniques of house fly

6.1 Physical Characteristics/identification

The common House fly is medium sized (1/6 to 1/4 inch long,) generally gray in color with the female usually large than the male. The thorax bears four narrow black stripes. The female fly has a much wider space between the eyes than the male.

Eggs

The eggs are white, elongate and about 1/20" long.

Larva

The larva is also referred to as a maggot. When it first emerges from the egg it is transparent. As it grows it assumes a creamy white color. Maggots have no legs and are somewhat carrot shaped. Two small openings used for breathing are located at the hind end. They're about 2/5" long.

Pupa

The pupae are reddish-brown in color. They are barrel-shaped and about 3/8" long. Pupal cases are sometimes mistaken for American cockroach egg capsules.

Adults

The adults have two wings (most adult insects have four). There are four narrow black stripes located on the thorax or area just behind the head. The adult is 1/4" long.

Biting

Adult house flies do not bite. They have sponging mouthparts for feeding. In order to feed on a piece of food, the fly must first regurgitate some saliva on the food to soften it. The food is transformed into a liquid and sponged up.

Wings: two-membranous. Swift strong flyers (up to 30 mph.) with wing beats of up to 1000 times per second. Hind wings are not developed and are reduced to 2 short slender threads with a knob at the end (may be used for balancing).

Metamorphosis: Complete (egg, larva, and pupa, adult). Maggots are usually small, white legless worms without an obvious head.

Features: Soft-bodied insect. Head, thorax and abdomen are very distinct. Thorax is generally quite small. The head is dominated by two enormous compound eyes and the legs are clawed. Antennae are small.

The mouth parts and feeding habits

The structure of the mouth part is made in such a way that the fly is unable to feed any solid matter except in liquid form. The proboscis looks like a funnel turned upside down. Because of this, the fly feed by what is known sponging method. It can to ingest food particles larger than about 0.05 mm in diameter. Hence the food to be eaten must be transformed into solution or soluble forms. The solvent (liquid) for dissolving the food (solute) into solution form is stored in a special container called crop, connected to the proboscis by the crop duct. Thus whenever the fly tries to feed it vomits the crop through the proboscis on to the surface of the food in order to dissolve it and eat it. This have it of feeding by vomiting and sucking is known as regurgitation and is commonly employed on almost all surfaces the fly test with its proboscis. As a result, yellowish coloured spots or drops are deposited on nearly every surface where the fly rests. These spots called vomit spots are visible on window panes of kitchens and other places visited by the fly. Similarly around unsanitary kitchens and food service areas, one can observe rather dark minute pellet like spots, which are the faeces of flies. Flies feed once about every 4-5 hours and may produce around 15 to 30 vomit sports in 24 hours. It is important to realize that the crop is known to contain thousands of micro-organisms, which are deposited where ever the fly lands. It is also worth noting that because of the nature of its mouth part, water is essential fro a fly's existence. It is believed that they can stay without water for a maximum period of 48 hours. Because of this necessity the fly is often attracted to wherever liquid is available such as exposed milk and other fluid, to human eyes, exposed wound etc.

The hairy body and sticky legs

The housefly has a hairy body and peculiar type of legs. All the ends of the six legs have tiny pad-like attachments, which are known as Pulvilli. The pulvilli contain sticky secretion and easily flatten out and hold firmly to the surfaces on which the fly rests. They enable the fly to rest or walk on walls, edges, ceilings, slippery surfaces, and overhead structures without being affected by gravity.

In addition to its hazardous habits of breeding in filth, feeding on filth and regurgitation, the fly's hairy body and sticky legs help to spread microorganisms from foci of infections (human excreta, animal wastes etc.) to exposed food, food contact surfaces, human eyes and other exposed spots.

Phototropism

The housefly is instinctively attracted towards light: It in fact avoids darkness and does not breed in totally dark places, such as deep pt latrines etc. This knowledge is employed in some of the fly control measures such as use of ventilated improved pit latrine (VIP) and baited traps. During the night the housefly is normally inactive and rest on edges or similar surfaces.

The compound eyes

The eyes occupy prominent place on the front of the housefly. The compound eyes consist of facets known as ocelli and enable the fly to see in all directions simultaneously. These eyes help the fly to search fro food as well as to escape easily from enemies.

Flight range

Housefly populations can disperse rapidly from their place of breeding to a radius of significant distances. Flight range tests using flies tagged with radio-active materials have been performed in different parts of the world. Based on these tests their average flight ranges is reckoned to be between 10 and 20 km per 24 hours. However, a large proportion of the fly populations are generally limited to about 200 to 300 meters of their breeding media. From this fact is can be seen that effective fly control programme calls for the involvement of all the neighborhoods or the community at large rather than households or food establishments alone.

6.2. Life cycle

Houseflies go through 4 stages of development: egg, larva, pupa and adult. The entire life cycle can be completed in 7-10 days under ideal conditions. Adult females can lay as many as 2,700 eggs in 30 days but more commonly lay 350-900 in 5 or 6 different batches. The eggs which are laid singly but often appear in clusters hatch in 6 to 24 hours. The maggot remains in the breeding media for 4-10 days, feeding and growing. In wet breeding areas, full grown larvae climb to the surface or sides of the breeding media before pupating. There have been cases of the larva crawling a distance of 150 ft. from the breeding source in order to pupate. The pupal stage lasts 3-6 days. The adult female is ready to lay eggs 2 days after emergence and continues to lay eggs for about one month. Adult flies live from 30-60 days during warmer months. In Northern areas, some adults may survive indoors for several months. It appears that flies continue to breed all year in low numbers in heated buildings such as dirty restaurants or incinerator rooms. In the spring these flies disperse to other buildings and increase in numbers rapidly.

The female of the species can be seen depositing their eggs on suitable breeding materials. Often, the females can be seen in clusters of up to 50 individuals. The female house fly lays individual eggs that pile up in masses of 75 to 150 eggs; in her lifetime, a single female house fly may lay up to 900 eggs. The female fly begins laying her eggs anywhere from 4 to 12 days from emerging from her pupae. She may lay 5 or 6 batches at intervals of several days between each.

In warm weather, the leg-less white pupae (or maggots) emerge from their eggs in 8 to 20 hours. This larva goes through three instars (or stages of development) in 1 week or less during warmer seasons, up to 8 weeks during cooler times. The house fly maggot and eggs depend on damp organic material in which to develop and feed. When it has completed its last instar, the fly maggot will move to a cool dry area in which to pupate. These larvae have confused many people by showing up far away from any possible breeding site. They have been known to travel over 100 feet to locate a suitable place to pupate. The pupa transforms into an adult in as little as 3 days or as long as 5 weeks. This pupation period besides conducive environmental conditions, such as availability of adequate food and moisture, **temperature** is an important determinant for breeding ranges from 29°C to 32°C, temperatures of 46°C or above will kill the eggs and larvae; while temperatures below 7°C will retard or inactivate the development process. Under the climatic conditions of most parts of Ethiopia and that of most tropical countries, flies can breed throughout the year and the average life cycle may be completed between 8 and 16 days. Depending on environmental conditions, the average life span ranges from 30 to 45 days. Given the large number of eggs laid and the rapid rate of development, fly populations reach alarming proportions unless control measures are taken at an appropriate time.

Breeding places

Houseflies can breed practically in any moist, decaying or fermenting human, animal and plant wastes. The following are some of the favourite breeding media:

1. **Human excreta**: whenever exposed in open latrines, seepage pits, septic tanks or in open field.
2. **Animal wastes**: horse manure, cow-dung,etc. whenerer moist and decomposing.
3. **Garbage**: whenever moist and exposed.
4. Practically in any moist, rotting organic matter.

6.3. Public Health importance

Flies have been implicated as disease vectors fro thousands of years. Specially the housefly has been known to be the most dangerous contaminant of food, and transmitter of food borne and other diseases. The explanation for this trait lies in its anatomical structure, peculiar breeding and feeding habits, and its close companionship to human beings and his habitations. The housefly is known as a **mechanical transmitter** of disease agents, which means that it carries through its body parts disease agents (pathogens) from sources of infections to foods, food contact surfaces, to human eyes, and other exposed body parts. In mechanical transmission of disease, the biological pathogens do not undergo developmental changes or multiplication, i.e. they are simply transferred from the sources of infection to new places. An example of this is indicated in Figure 11.1. The fly breeds in open latrine, then carries pathogenic organisms from the faeces with its mouth part, legs and body, and crawls over the exposed food. The faeces-fly contaminated food is consumed by healthy persons, who eventually develop the diseases, in this case, enteric infections.

Greenberg (1973) in his comprehensive volume on **" FLIES AND DISEASE"** as well as in a research publication (1965) has indicatedteh following diseases transmitted y flies: Dysentery (amoebic and bacillary), typhoid, cholera, salmonellosis, tuberculosis, leprosy, anthrax, polio-myelitis, coxsackie virus infections, infectious hepatitis, yaws, trachoma, conjunctivitis and various infections by parasitic worms. (3,4) . Many investigators have also shown that outbreaks of diarrhoeal diseases and trachoma etc. correspond closely with the seasonal rise in fly population density (4,5,6,7).

Albertsen, et al. (1957) stated that houseflies experimentally fed on a suspension of a food poisoning strain of staphylococcus were found to have these organisms on their feet and proboscis 3 days later, while the same organisms survived in their digestive tracts fro 8 days. (8)

In addition to disease transmission, houseflies affect human in being one of the persistently annoying insects, landing in undesirable places. E.g. face, eyes, wounds, foods etc.

6.4 Prevention and Control

House fly elimination is accomplished through good integrated pest management (IPM) procedures.The following steps will rid your home of house flies: Sanitation, Exclusion, Sprays, Baits.

Sanitation for the House Fly

Sanitation procedures not only include the obvious (clean trash receptacles, etc.) but also doing the little things that can help reduce the number of house flies in and around a structure. Indoors, make sure that all trash cans are thoroughly cleaned before trash bags are used. All trash bags need to be secured before disposing in an outdoor container.

All outdoor receptacles (dumpsters, trash cans) need to be cleaned regularly; they also need to have properly operating covers. What good is a trash can without a lid? If possible, move dumpsters far away from structures. This will help cut down the number of house flies inside homes and businesses. Keep the areas around dumpsters as clean and dry as possible; house fly eggs and pupae need damp material to develop and survive.

Exclusion

House flies enter homes by several means: doors which do not close properly or that do not have a good fit; windows without screens or with screens in ill repair. Flies also enter buildings through tiny cracks around windows and doors; seal or caulk these areas.

Sprays

Space sprays and pheromone traps can be helpful tools in eliminating indoor blowflies, but the elimination of their breeding sources is the only guaranteed way to eliminate them. Make certain that all possible sanitation measures have been implemented before relying on chemical sprays to eliminate flies. Space sprays can be used to knock down existing house fly infestations, but this is only a temporary fix. If breeding sites have not been eliminated or altered, house flies will continue to be a problem. Surface sprays can be used around windows and doors and should also be used on dumpsters. Any area where flies "rest" or enter in building can be treated with a good surface spray. However, do not spray areas that humans constantly come into contact with or on surfaces where food is prepared or served.

Baits

Use baits inside dumpsters and the area around such trash containers, if there are no non-target animals (dogs or children) in the immediate area. Are there homeless people going through the trash at night? If so, do not bait inside the container, but bait the area surrounding the receptacle. Baits should be re-applied after every cleaning or rainfall.

Common House Fly and Other Related Flies

Biology

The common house fly, is a pest all over the world. The adult has the fourth wing vein sharply angled and four length-wise dark stripes on the top of the thorax. Its face has two velvety tripes which are silver above and gold below. Each adult female begins laying eggs a few days after hatching, laying a total of five to six batches of 75 to 100 small, white oval eggs. In warm weather these hatch in 12 to 24 hours into cream-colored larvae which burrow into the food material on which they hatched. These larvae grow and pupate in 4 to 7 days in warm weather. The mature larva contracts until its skin forms a case about 1/4 inch long. Inside this case, the true pupa forms. When fully formed, the adult fly breaks open the end of the pupal case and emerges. It is ready to mate within in a few hours after merging. The hardened larval skin which is left behind still exhibits most of the characteristics which are used in larval identification; thus determination can often be made on the basis of the skin alone. During warm weather two or more generations may be completed in a month. Normally the population builds up and is greatest in early fall months. The method of over wintering is not well understood, but in some areas populations develop indoors throughout the winter. House fly eggs are laid in almost any warm moist material which will furnish suitable food for the growing larvae. Animal manure, human excrement, garbage, decaying vegetable material and ground contaminated with such organic mater are suitable materials. Although they are attracted to a wide variety of food materials, house flies have mouthparts which enable them to ingest only liquid materials. Solid materials are liquefied by means of regurgitated saliva. This liquefied food is then drawn up by the mouthparts and passed onto the digestive tract.

During daylight hours house flies will rest on floors, walls and ceilings indoors. Outdoors they will rest on plants, on the ground, on fence wires, garbage cans and other similar surfaces. At night they will rest principally on ceilings, electric wires and dangling light cords indoors. In all situations they prefer corners and edges or thin objects such as wires and strings. Night resting places are usually near daytime sources of food and are usually 5 to 15 feet off the ground.

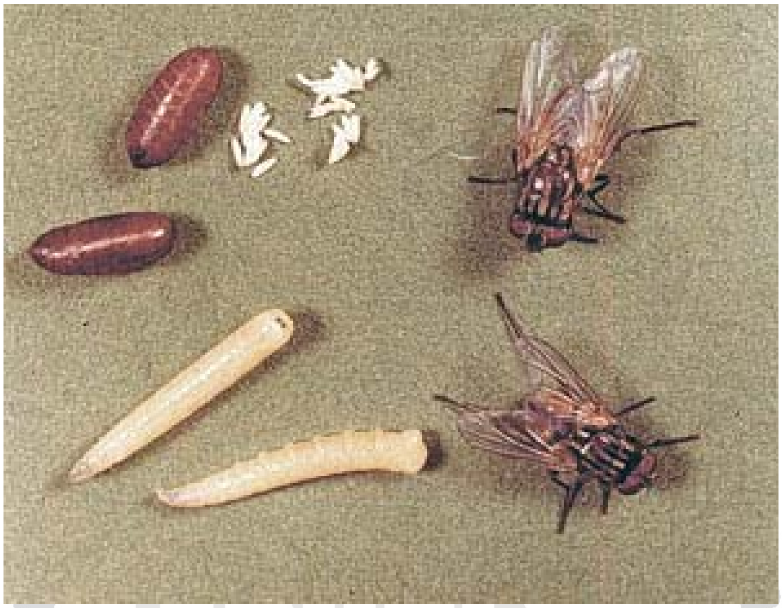

Fig. 6.1 Egg, larvae, pupae and adult of common house fly

6.5 Recommended Control Measures

1. Exclusion and Sanitation:

- Sanitation is the first measure of defense, even though there are various traps and sprays that are used to kill flies, it is necessary to eliminate the source in order to eliminate them.
- Whenever possible, food and materials on which the flies can lay their eggs must be removed, destroyed, as a breeding medium, or isolated from the egg-laying adult. Killing adult flies will reduce infestation, but elimination of breeding areas is necessary for good management.

- The key to controlling these infestations is to locate and eliminate their breeding sources.
- Garbage cans and dumpsters should have tight-fitting lids and be cleaned regularly.
- Drainage will often aid control, getting rid of extra moisture.
- Openings of buildings should be tightly screened with screen.

2. Trapping-Glue and Outside

Window Fly Trap-allows you to use a trap to stick on the window, without using an insecticide.

Advantage of fly trap is an excellent trap for the outside, with a unique attractant lure included. It will trap house flies, blow flies and a broad range of other fly species:

3. Electronic traps: Inside Use electronic fly traps are very efficient and functional:

Properly fitting screen doors and windows are essential to exclude flies from homes and other areas where food is prepared. UV insect lights and air curtains used in industrial applications are effective but maybe cost prohibitive in a domestic situation. A combination of good sanitation and mechanical exclusion will produce the same effect and keep fly populations under control. Elimination of potential breeding sites will help in the general reduction of fly numbers. Pet faeces should be removed and fresh manure and other compost dug into garden beds. Routine emptying and cleaning of all garbage receptacles will reduce breeding. People traveling to destinations that may include rural areas of Africa, Central and South America, should be aware of possible infection by the immature stages of several exotic flies.

The three basic principles of house fly control are sanitation, exclusion and non-chemical measures. Sanitation will provide the best long-term control, followed by exclusion and non-chemical measures, which provide shorter-term management.

Sanitation: Flies can't breed in large numbers if food sources are limited. Don't allow materials such as manure, garbage or other decaying organic matter to accumulate. Keep trash cans clean and tightly covered. If garbage becomes infested with maggots, dispose of it immediately.

Exclusion: Flies can be kept outside of homes by the use of window and door screens. Make sure screens are tight fitting and without holes. Keep doors closed, making sure there are no openings at the top or bottom. Check for openings around water or gas pipes or electrical conduits that feed into the building. Caulk or plug any openings. Ventilation holes should be screened, as they can serve as entryways for flies as well.

Non-chemical Measures: The use of devices such as ultraviolet-light traps, sticky fly traps, fly swatters, and baited fly traps can eliminate many flies inside a home, but the fly swatter is the most economical control method for the occasional fly.

6.6 Other Dipterans

Blue or Blow fly

Class - Insecta	<u>Classification</u>
Order- Diptera	
Family- Calliphoridae-	Blue or blow fly.
Genus 1: Calliphora.	
Species- Calliphora vicina-	Blue bottle fly.
Genus 2: Cynomyopsis	
Species - Cynomyopsis cadverina-	Blue bottle fly.
Genus 3: Lucilia	
Species- Lucilia illustries -	Green bottle fly.
Genus 4: Phaenica	
Species- Phaenica sericata -	Green bottle fly.
Phaenica cuprina	" " "
Genus 5: Phormia	
Species - Phormia regina -	Black blow fly.
Genus 6: Cochliomyia	
Species - Cochliomyia hominivorax -	Screw worm fly.

General Features of Calliphoridae: Blue or Blow flies

All *calliphoridae* have world wide distribution. As common house fly they are also mechanical disease vectors. Their breeding place is on waste, decaying animal matter, and some lay their egg on flesh and make human food unfit. The *phormia regina* species usually lay their eggs on flesh. The female *cochliomia hominivorax* lay their eggs on wound and result in myiasis particularly on sheep, goat and cattle. *Calliphora* species also lay their egg on wound and the developing maggot damage the neighbouring tissues example Lucilia illustries.

Public Health Importance:

Generally calliphorids are responsible to cause myiasis.

Prevention and Control of Calliphoridae:

► **Basic sanitation:-**

By proper disposal of both human and animal wastes, it is possible to control the immature stages of these flies.

► **Application of Insecticide:**

Residual Insecticides like DDT (5% or 10%) used. From the non-residual insecticide the pyrethrins are the best to kill adult flies while flying or resting.

Sarchophagidae /Flesh Fly/

Class Inseca
Order- Diptera
Family - Sarcophagidae
Genus-Sarcophaga.
Species - S. occidua
Common Name- Flesh fly

General Feature and Identification:

Flesh flies are synanthropic (domestic) flies because of their close association with man. When compared to Common House Fly they are larger in size, and have grayish colour. Their abdomen is a grayish black. There is a black strip on the thorax.

Adults are attracted towards feces and other wastes, in which they normally breed and / or settle. Larvae, however, found on flesh, decaying organic matter, and dead body. They sometimes infest wounds or sores and cause intestinal myiasis.

Life Cycle:

Flesh flies pass through complete metamorphosis. Adults are larviparous and therefore, the immatured larvae laid on flesh, dead body and offals, etc. After the larvae changed to pupa, it dropped on the ground and with favorable condition, the adult comes out of it.

Public Health Importance

1. Myiasis: is an illness condition that occurs while the larvae of the Diapterans burry it self under the skin.
   Flesh flies can bring intestinal or wound myiasis occasionally. They are killer of sheep, goat, cattle and other animals.
2. Nuisance: The presence of flesh flies in the living environment is undesirable. Because particularly when their number is large they can make out door activities difficult.

Control Measure:

1. Application of Basic Sanitation:
   Control of the immatured stages of flesh flies is linked with sanitation. By proper disposal of refuse, the breeding place of the fly can easily be abolished.

2. Application of Insecticides:

Both residual insecticides like DDT and non-residual insecticides such as pyrethrum are commonly used. The pyrethrins used as a space spray to knock-down and kill adults when they are flying or resting in an enclosed space.

Review Questions

1. Describe the important characterstics of the common house fly.
2. List the potential breeding sites for common house fly.
3. Discuss the contol mechanisms against house fly.
4. List the common sources of food, breeding places and resting places of house fly
5. Write all possible factors that affect the distribution, of house fly in a certain environment.
6. Discuss the applicable control methods of house fly
7. Describe the public health importance of caliphoridae?
8. What is myasis?
9. How can we control Caliphoridae

CHAPTER SEVEN

SIPHONAPTERA (FLEAS)

Learning objectives

At the end of this chapter the reader will be able to:

-Describe the identification features of flea.

-Discuss the medical importance and control methods of fleas.

-Design the applicable control strategies of fleas.

7.1 Introduction

There are some 2500 species and subspecies of fleas belonging to 239 genera but only relatively few are important pests of humans. Fleas are found throughout most of the world but many genera and species have a more restricted distribution, for example the genus *Xenopsylla* which contains important vectors of plague (*yersinia pestis*), and flea-borne endemic typhus (*Rickettsia* typhi). Some fleas such as ctenocephalides species are intermediate hosts of cestodes (*Dipylidium caninum*),(*Hymenolepis nana*, H.*diminuta*). Fleas may also be vectors of tularaemia (*Francisella tularensis*), and the chigoe or jigger flea (*tunga penetrans*) enters in to the feet of people.

7.2 External Morphology

Adults are relatively small (1-4mm), and more or less oval insects, compressed laterally and varying in color from light to dark brown. Wings are absent, but there are three pairs of powerful and well-developed legs, the hind pair of which are specialized for jumping. The legs and much of the body parts are covered with bristles and small spines. The head is roughly triangular in shape, bears a pair of conspicuous black eyes (a few species are eyeless), and short three segmented more or less club-shaped antennae, which lie in depressions behind the eyes.

7.3 Life Cycle

Both sexes of fleas take blood –meals and are there fore equally important as vectors of disease. The present account is a generalized description of the life cycle of fleas which may occur on humans or animals, such as dogs, cats and commensal rats. The life cycle of the chigoe (*tunga penetrans*) is described separately. A female flea, which is ready to oviposit, may leave the host to deposit her eggs in debris, which accumulates in the host's dwelling place, such as rodent burrows or nests.

With species which occur on humans or their domestic pets, such as cats and dogs, females often lay their eggs in or near cracks and crevices on the floor or amongst dust, dirt and debris. Sometimes, however, eggs are laid while the flea is still on the host and these usually, but not always, fall to the ground. The eggs are very small, oval, white or yellowish and lack any pattern. They are thinly coated with a sticky substance, which usually results in them becoming covered with dirt and debris. Adult fleas may live for up to 6-12 months, or possibly 2years or more, and during this time a female may lay 300-1000 eggs mostly in small bathes of about 3-25 a day.

Larvae are very active. They avoid light and seek shelter in cracks

and crevices and amongst debris on floors of houses, or at the bottom of nests and animal burrows. Sometimes, however, larvae are found amongst the fur of animals, and even on people who have unclean habits and dirt-laden clothes, and occasionally in beds. Larvae feed on almost any organic debris including the host's faeces, and partly digested blood evacuated from the alimentary canal of adult fleas. In a few species feeding on expelled blood seems to be a nutritional requirement for larval development. In some species larvae are scavengers and feed on small dead insects or dead adult fleas of their own kind. There are usually three larval instars, but in some species there are only two instars.
The larval period may last as little as 10-21 days, but this varies greatly according to species, and may be prolonged more than 200 days by unfavorable conditions such as limited food supply and low temperatures. Mature larvae are 4-10 mm long. Unlike adult fleas, larvae cannot tolerate large extremes in relative humidity and they die if humidities are either too low or too high.

At the end of the larval period the larva spins a whitish cocoon from silk produced by the larval salivary glands. Because of its sticky nature it soon becomes covered with fine particles of dust, organic debris and sand picked up from the floor of the host's home. Cocoons camouflaged in this way are very difficult to distinguish from their surroundings. About 2-3 days after having spun a cocoon around it self the larva pupates within the cocoon.

Adults emerge from the pupa after about 7-14 days, but this period depends on the ambient temperature. After having emerged from the pupa the adult flea requires a stimulus, usually vibrations, such as caused by the movements of the host within its home, burrow or nest, before it escapes from the cocoon. If, however, animal shelters or houses are vacated, then adult fleas fail to escape from their cocoons until their dwelling places are reoccupied. In some species, carbon dioxide emitted from hosts or a seasonal increase in humidity stimulates emergence. Adult may remain alive in their cocoons for about 1 year. This explains why people moving in to buildings which have been vacated for many months may be suddenly attacked by large numbers of very bloodthirsty fleas, these being newly emerged adults seeking their first blood-meal.

The life cycle from eggs to adult emergence may be as short as 2-3 weeks for certain species under optimum conditions, but frequently the life cycle is considerably longer, such as 20 months or more.

Fleas avoid light and are therefore usually found sheltering amongst the hairs or feathers of animals, or on people under their clothing or in the bed.

If given the opportunity many species of fleas feed several times during the day or although most species of fleas have one or two favorite species of hosts, they are not entirely host-specific, for example, cat and dog fleas (*ctenocephalides felis* and C.*canis*) will readily feed on humans, especially in the absence of their normal hosts. Human fleas (*pulex irritans*) feed on pigs and rat fleas of the genus *xenopsylla* will attack people in the absence of rats. Most fleas will in fact bite other hosts in their immediate vicinity when their normal hosts are absent or scarce. However, although feeding on less acceptable hosts keeps fleas alive, their fertility can be seriously reduced by continued feeding on such hosts. Fleas rapidly abandon dead hosts to seek out new ones, the behavior which is of profound epidemiological importance in plague transmission. Fleas can withstand both considerable desiccation and prolonged periods of starvation, for example 6 months or more when no suitable hosts are present. On their hosts, fleas move either by rapidly crawling or by jumping. But host they tend to jump more than crawl in their search for new hosts. Fleas can jump about 20 cm vertically and 30 cm or more horizontally. (Such remarkable feats are achieved through a rubber- like protein called resilin, which is very elastic and can become highly compressed with rapid expansion of the compressed of state that gives the power for jumping.)

7.4 Public Health Importance

1. Flea Nuisance

Although certain species of fleas may be important vectors of disease, the most widespread complaint about them concerns the annoyance caused by their bites, which in some people lead to considerable discomfort and irritation. The three most widespread and common nuisance fleas are the cat and dog fleas *ctenocephalides felis* and C.canis, and to lesser extent the so-called human flea, *pulex irritans*. In some areas other species such as the European chicken flea (*ceratophyllus gallinae*) and the western chicken flea (*ceratophyllus Niger*) may be of local importance.

Fleas frequently bite people on the ankles and legs but at night a sleeping persons is bitten on other parts of the body. In many people the bite is felt almost immediately but irritation usually becomes worse some time after biting. In sensitized people intense itching may result. Because fleas are difficult to catch this tends to increase the annoyance they cause, and people attacked by fleas frequently spend sleepless nights alternately scratching themselves and trying to catch the fleas. There is evidence that children under 10 years generally experience greater discomfort than older people.

2. Plague

Plague is caused by *yersinia pestis* and is primarily a disease of wiled animals, especially rodents, not people. Over 220 rodent species have been shown to harbor plague bacilli. The cycle of transmission of plague between wild rodent, such as gerbils, marmots, voles, chipmuks and ground squirrels, is termed sylvatic, campestral, rural or endemic plague transmission amongst them. When people such as fur trappers and hunters handle these wild animals there is the risk that they will get bitten by rodent fleas and become infected with plague.

An important form of plague is urban plague. This describes the situation when plague circulating among the wild rodent population has been transmitted to commensal rats, and is maintained in the rat population by fleas such as *xenopsylla cheopis* (Europe, Asia Africa and the Americans), X. astia (south-east Asia) and X. *brasiliensis* (Africa, South America and India). When rats are living in close association with people, such as rat- infested slums, fleas normally feeding on rats may turn their attention to humans. This is most likely to happen when rats are infected with plague and as a result rapidly develop an acute and fatal septicaemia. On death of the rats the infected fleas leave their more normal hosts and feed on humans. In this way plague is spread by rat fleas to the human population. The most important vector species is X. *cheopis* but other species including *Xenopsylla astia*, X. *brasiliensis*; and more rarely *Nosopyllus fasciatus Leptopsylla aethiopica*, *Ctenocephalides felis*, C.canis as well as other species in another 45 genera have been incriminated in some parts of world with plague transmission. In addition to humans becoming infected by the bite of fleas which have previously fed on infected rats the disease can also be spread from person to person by fleas such as *Xenopsylla* species and *Pulex irritans*, feeding on a Plague victim then on another person. This latter method, however, appears to play a minor role in the transmission of plague.

Transmission cycle of plague

Plague bacilli sucked up with the blood meals of male and female fleas are passed to the stomach where they undergo so great multiplication that they extend forwards to invade the proventriculus. In some species, especially those of the genus *Xenopsylla* further multiplication in the proventriculus may result in becoming partially, or more or less completely, blocked. This prevents the proventriculus from functioning normally and results in fleas regurgitating some of the blood meal during later feeds. Thus, plague bacilli obtained from a previous feed are passed down the flea mouthparts in to the host. In the case of completely blocked fleas blood is sucked up with considerable difficulty about as far as the proventiculus, where it mixes with the bacilli and is then regurgitated back in to the new host. Blocked fleas soon become starved and repeatedly bite in attempts to get a blood – meal, and are therefore potentially very dangerous. Even if there is no blockage of the alimentary canal, plague transmission can nevertheless occur by direct contamination from the flea's mouthparts.

Another, but less important, method of infection is by the flea's faeces being rubbed in to abrasions in the skin or coming in to contact with mucous membranes. Plague bacilli can remain infective in flea faeces for as long as 3years. Occasionally the tonsils become infected with plague bacilli due to crushing infected fleas between the teeth.

In pneumonic plague the bacilli occur in enormous numbers in the sputum. This form of plague is highly contagious due to the ease by which bacilli are transmitted from patients to others by coughing and the inhalation of droplets; insects are not involved in the spread of pneumonic plague.

3. Flea-Borne Endemic Typhus

Flea borne or murine typhus is caused by R*ickettsia typhi* (*mooseri*) which is ingested by the flea with its blood-meal. Within the gut the *rickettsiae* multiply, but unlike plague bacilli they do not cause any blockage of the proventriculus or stomach. Infection is caused by infected faeces being rubbed in to abrasions or coming in to contact with delicate mucous membranes, and also by the release of rickettsiae from crashed fleas. Feaces may remain infective under ideal conditions for as long as 4-9 years. Murine typhus is essentially a disease of rodent, particularly rats and especially *Rattus rattus* and R. *norvegicus*. It is spread among rats and other rodents by Xenopsylla species, especially X. cheopis, but also by *Nosopsyllus faciatus*, *leptopsylla segnis* and by a few ectoparasites which are not fleas, such as the rat louse *polyplax spinulosa* (possibly also *Hoplopleura* spp.) and maybe by the tropical rat mite *Ornithonyssus bacoti*. People become infected mainly through *Xenopsylla cheopis*, but occasionally *Nosopsyllus fasciatus*, *Ctenocephalides canis*; C. *felis* and *pulex irritans* may be involved. *Leptopsylla segnis* does not attack humans, but it is possible that murine typhus is sometimes spread to them by an aerosol of infective faeces of this species.

The rickettsia of murine typhus can pass across in the flea's ovaries, in to the eggs and then to the larvae, a form of trans-ovarial transmission. But whether this is epidemiological important remains unknown.

4. Cestodes

Dipylidium caninum is one of the more common tapeworms of dogs and cats and occasionally occurs in children, and *Hymenolepis diminuta* infects rats and mice and occasionally people. These tapeworms can be transmitted by fleas to both rodents and humans. Eggs of these parasites are passed out with excreta of rats and domestic pets and may be swallowed by larval fleas feeding on excreta. Larval worms hatching from the ingested eggs penetrate the gut wall of the larval flea and pass across in to the body cavity (coelom). They remain trapped within this space and pass on to the pupa and finally to the adult flea where they encapsulate and become cysticercoids (infective larvae). Animals can become infected by licking their coats during grooming and thus swallowing the infected adult fleas. Similarly, young children fondling and kissing dogs and cats can become infected with D. *caninum* by swallowing cat and dog fleas or by being licked by dogs which have crushed infected fleas in their mouths thus liberating the infective cysticercoids Adult rat fleas (*xenopsylla*, *Nosopsyllus*) occasionally get mixed with food or drink and swallowed by humans, who may then become infected with *Hymenolepis diminuta*.

Another tapeworm of humans, H. nana is spread through contaminated food or water, and possibly also by fleas but their role in transmission is unclear because a morphologically identical parasite, H. *fraterna* of rats and mice, has fleas, especially *Xenopsylla* species, as intermediate hosts. *Hymenolepis* nana is known to be capable of developing in insects, and it is possible that fleas and rodents some times serve intermediate as hosts and reservoirs of infection, respectively

5. Less Important Diseases

In addition to the above diseases and parasites spread by fleas, these insects may play some small part in the transmission of *Francisella tularensis*, *Rickettsia conori*, *Coxiella burneti* and some other rather minor infections. However, it should be stressed that their role as vectors of these pathogens is at the most minimal.

7.5 Tunga Penetrans

External Morphology

Tunga Penetrans is found in the tropics and subtropics, having a distribution stretching from central and South America, the West Indies across Africa to Madagascar. It has occasionally been reported in persons in India returning from overseas, mainly Africa, but the flea is not indigenous to India or elsewhere in Asia. *Tunga penetrans* is sometimes referred to as the Chigoe or Jigger or sand-flea. Tunga penetrans does not transmit any disease to people but is a nuisance because females burrow in to the skin.

Adults of both sexes are exceedingly small, only about 1 mm long. They have neither general nor pronotal combs and are easily separated from other fleas of medical importance by their very compressed first three (thoracic) segments and the paucity of and bristles on the body.

Life Cycle and Medical Importance

Eggs are dropped on to the floor of houses or on the ground outside. They hatch within about 3-4 days and the larvae inhabit dirty and dusty floors or dry sandy soils especially in areas frequented by hosts of the adult fleas. Under favorable conditions larval development is completed within about 10-14 days. The pupal period lasts about 5-14 days, and complete life cycle can be as about 18 days.

Newly emerged adults are very agile and jump and crawl about on the ground until they locate a suitable host which is usually a person or pig. Both sexes feed on blood but whereas the male soon leaves the host after taking a blood-meal. The female after being fertilized burrows in to the skin where it is soft as between the toes or under toe-nails. Other areas of the foot including the sole may also be invaded. In people habitually sitting on the ground such as beggars or infants the buttocks may often be infected and particularly heavy infections have been recorded from leprosy patients. In heavily infected individuals the arms especially the elbows may also be attacked and occasionally the females burrow in to the soft skin around the genital region. Burrowing in to the skin appears to be accomplished by the flea's sharp and well-developed mouthparts. The result is that the entire flea with exception of the abdomen bearing the anus genital opening and large respiratory spiracles becomes completely buried in the host's skin. In this embedded position she continues to feed. The area surrounding the embedded portion results in ulcerations and accumulation of pus. While the blood-meal is being digested the abdomen distends to an enormous size (about 1000 times a small pea. This expansion is accomplished in some 8-10 days. Towards the end of this period of abdominal enlargement the ovaries are composed of thousands of minute eggs. Over the next 7-14 days about 150-200 eggs are passed out of the female genital opening most of which eventually fall to the ground and hatch after about 3-4 days.

When the fleas die they remain embedded within the host. This frequently causes inflammation and may in addition result in secondary infections which if ignored be able to lead to loss of the toes tetanus or even gangrene. Male fleas cause no such trouble as they do not borrow in to the skin. These fleas are most common in people not wearing shoes such as children. Because they are feeble jumpers wearing shoes is a simple but in some communities' relatively costly method of the likelihood of flea infection.

Females embedded in the skin should be removed with fine needles under aseptic conditions and wounds formed by their extraction is sterilized and dressed. They are removed with in the first few days, before they are becoming established as they are difficult to extract when they have greatly distended abdomens containing numerous eggs without rupturing them and this increases the risk of infections.

Pigs in addition to humans are often commonly invaded by Tunga and they may provide a local reservoir of infection. Other animals such as cats dogs and rats are also readily attacked.

7.6 Control of Fleas

1. Insecticide application

Cat and dog fleas (*Ctenocephalides felis* and C.*canis*) can most easily be detected by examination of the fur round the neck or on the belly of the hosts. Proprietary insecticidal powders containing 1%HCH ,2-5% malathion 2-5% carbaryl (sevin) or 1% permethrin can be applied to the coat of an animal. A simple but not always very efficient procedure is to place a proprietary plastic collar impregnated with 20%dichlorvos (DDVP) or fenthion round the necks of cats and dogs. Flea collars remain effective for 1-2 months, but they may cause skin problems in the animal. Alternatively insecticides like fenthion can be formulated as a 'Spot-on' solution that is applied to the pet's skin in just one small area. The insecticide is absorbed through the skin and passes to the animal's blood so that blood-feeding fleas ingest the insecticide. One treatment lasts for about a month.

However an important consideration is that most fleas are found away from the host not on it. For example it has been said that a typical colony of cat fleas consists of only about 25 adult fleas on the cat than on the floor and bedding. There may be 500 adult fleas 500 cocoons and as many as 3000 larvae and 1000 eggs. Clearly control measures should not be restricted to the cat but applied to the total environment. Flea cocoons are not very susceptible to insecticides consequently insecticidal treatments should be repeated about every 2 weeks for about 6 months. Beds, kennels or other places where pets sleep or spend much of their time should be treated either with insecticidal powders or lightly sprayed with solutions containing 0.5% HCH, 2% Malathion, 0.5% diazinon or 2% dichlorvos (DDVP) to kill both adult and larval fleas. For more general control of fleas, powders of 5-10% DDT, 1%HCH or 0.5% dieldrin can be liberally applied to floors of houses and runways of rodent. Insecticidal dusts can also be blown in to rodent burrows. In many parts of the world however *Xenopsylla cheopis* and *pulex irritans* have developed resistance to DDT, HCH and dieldrin. In such cases organophosphate or carbamate insecticides such as 2% diazinon, 2% fenthion (Baytex), 5% Malathion, 2% fenitrothion (sumithion) 5% iodofenphos (jodfenphos) or 3-5% carbaryl (sevin) can be used. India X.cheopis has developed resistance to malathion, and trials in that country have shown carbaryl (sevin) to be the most effective insecticide.

Insecticidal fogs or aerosols containing 2% malathion or 2% Ronnel have sometimes been used to fumigate houses harbouring fleas. Insecticidal smoke bombs containing HCH, DDT permethrin or pirimiphos-methyl (Actellic) can also be used to disinfest houses.

For the control of fleas in urban outbreaks of plague or murine typhus extensive and well-organized insecticidal operations may be necessary. At the same time as insecticides are applied rodenticides such as the anti-coagulants, for example warfarin and fumarin can be administered to kill the rodent population. However if fast- acting one-dose rodenticides such as zinc phosphide, sodium flouroacetate or strychnine or the more modern fast-acting anticoagulants like bromadiolone and chlorophacinone are used then it is essential to apply these several days after insecticidal applications. Otherwise the rodents will be killed but not their fleas which will then bite other mammals including people and this may result in increasing disease transmission.

2. Insect growth regulators

More recently insect growth regulators such as methoprene have been incorporated in to sprays often combined with a pyrethriod such as permethrin for treating household infestations such sprays may remain effective for 10 week. Insect growth regulators are virtually non-toxic to pets and other mammals and some have been formulated as tablets or syrup that is given to cats or dogs orally. Methoprene kills fleas by interfering with their cycle of development for example by preventing larvae reaching adulthood or eggs from hatching. Other insect growth regulators are chitin- inhibitors that prevent the insect's exoskeleton formation properly. When pets are dosed with methoprene or chitin inhibitors fleas ingest small quantities of the chemical with their blood-meal when they blood-feed and their life cycle cannot be completed.

Insecticidal repellents such as dimethyl phthalate, diethyltoluamide or benzyl benzoate may afford some personal protection against fleas.

Fleas can be found on the pet and in its environment. As a result an effective flea control program must address both the pet and its premise. The key to understanding effective control, or treatment, is knowledge of the flea lifecycle. In the past flea control was directed towards removing adult fleas from the pet. This was not effective because the pre-adult stages matured and the pet was reinfected from its environment. To address these products, such as adulticide collars, sprays, mousses and dips, with residual actions were developed. This helped the situation with respect to the pet, however, they did not address the environmental source and were work intensive to maintain. As a result these methods were still not very effective. People became aware of the importance of environmental (premise) control and products became available for treating the home and yard. This, combined with regular on pet treatment with residual effect products made great strides in the battle against fleas. Compliance was often a problem as it was a work intensive approach and many did not like the idea of insecticides on their pets and in the home. In any case it did not address the insecticide resistant pupal stage of the flea lifecycle. As an alternative to topical insecticides oral products became available. These early products, such as Ectoral and Proban, were based on inhibiting enzymes that were common to both the flea and animals. As a result inadvertent overdose, or use during medical compromise, could result in injury to the pet as well as the flea! Another approach was the use of topical products, such as ProSpot, that were dropped onto and absorbed into the skin. These products were potentially hazardous to the pet and those applying them. Instructions were to apply it in a well ventilated room wearing rubber gloves, and to avoid handling the pet for some time afterward! Needless to say these products were not the answer to safe flea control.

Shampoos, Adulticide collars, sprays, mousses and powders are still available and can be useful under certain circumstances. They contain such ingredients as pyrethrins, pyrethroids, carbamates and organophosphates.

Natural insecticides are available, however most claims of effectiveness are purely anecdotal. The include ingredients such as rosemary, wormwood, pennyroyal, eucalyptus, citronella and diatomaceous earth. Products derived from citrus pulp such as d-limonene and linalool have been marketed but have also been implicated in some cat deaths! Although safe Brewer"s yeast, thiamine and garlic have not proven effective in clinical trials. Avon Skin So Soft, in diluted form (5%), has proven to act as an insect repellant but does not kill fleas.

Premise and environmental control products are useful in affecting a rapid start when combating an existing flea infestation.

Review Questions

1. List different types of diseases that are transmitted by fleas
2. What is the medical importance of Tunga penetrans?
3. Explain why people entering to houses evacuated for months are attacked by massive fleas
4. Explain the transmission ways of vector born plague
5. Describe the techniques applied in the survey of flea infestation.
6. Describe the different strategies used in the control of fleas

CHAPTER EIGHT

ANOPLURA/ LICE/

Learning objectives

At the end of this chapter the reader will be able to

- identify different species of lice
- discuss the different types of diseases transmitted by lice
- describe the control methods of lice

8.1 Introduction

Class Insecta

Order Anoplura

Family Pediculidae - the lice.

Identification

Lice are grayish in colour, are characteristically dorso-ventrally flattened and both sexes feed on blood through mouthparts designed for piercing and sucking. They are apterous (wingless). Until recently in human history, lice were such common companions of *Homo sapiens* that they were considered one of life's inevitable nuisances for rich and poor alike. Lice are very host specific and are still very common in developing countries.

Fig 8.1 human lice

There are two species parasitizing humans

1.*Pediculus humanus* (head & body lice)

2.*Phthirus pubis* (crab louse)

There are two forms of *Pediculus humanus*

Pediculus humanus humanus (sometimes known as *Pediculus humanus corporis*) - the body louse.

Pediculus humanus capitis - the head louse.

Pediculus humanus corporis (the body louse) and *P. h. capitis* (the head louse) are common ectoparasites of humans around the world.

Body lice - *Pediculus humanus humanus*

Lifecycle

Body lice spend most of the time in their host's clothing. Eggs or nits are cemented to fibers in the clothes. Females lay about 9-10 eggs per day (about 300 in her lifetime). Crowding conditions facilitate transmission and infestation (think about situations like times of civil unrest, crowding due to poverty, refugee camps etc).

Head Lice-*Pediculus humanus capitis.*

Head lice are smaller than body lice. Nits are cemented to hairs and lice and nits are more prevalent on the back of the neck & behind the ears. Not life threatening but causes considerable discomfort. Scratching leads to dermatitis or secondary infection, & matted hair.

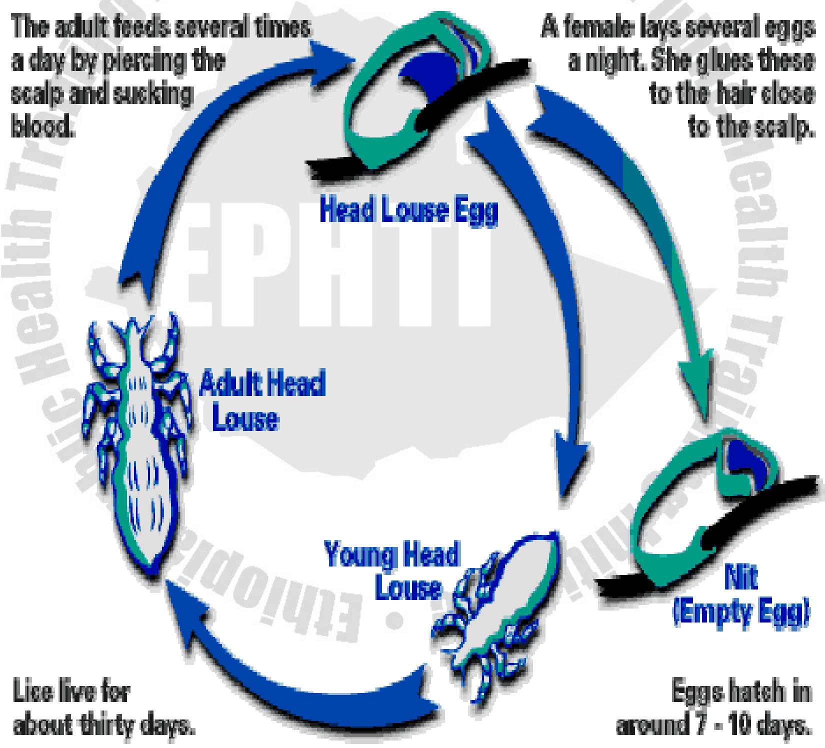

Fig 8.2: life cycle of head lice

Crab lice or crabs *Phthirus pubis*.

Crab lice (*Phthirus pubis*) are small whitish insects with a short abdomen and a large second and third pair of legs. This species is most commonly found on the hairs in the pubic region, but they may be found on the hairy regions of the chest and armpits. Infestations in eyebrows and eyelashes are also frequently reported. The crab louse's life cycle is similar to that of head and body lice. Eggs are glued to hairs but they are smaller and have a more convex cap. All stages of this louse are more sedentary than head or body lice. A crab louse tends to settle down at one spot, grasp on to body hairs, insert its mouthparts and feed intermittently for hours at a time. This species survives only a short time away from the host. Nits are cemented to the hair. Females deposit about 30 eggs during her lifetime. Infection is through contact with bedding or other objects, especially in crowded conditions. Transmission of the lice can be through sexual contact.

8.2 Public health Importance

The body louse is the vector for the spirochete *Borrelia recurrentis* (relapsing fever), *Rickettsia prowazeki* (typhus) & *Rochalimaea quintana* (Trench fever). Crushed lice or lice faeces coming into contact with broken skin leads to transmission of these diseases. **1. Pediculosis** –the presence of body, head or pubic lice on a person is some times reffered as pediculosis. The skin of people who habitually harbour large number of body lice may become pigmented and tough, a condition known as vagabond's disease or sometimes as morbus errorum. Because lice feed several times aday, saliva is repeatedly injected in to people harboring lice, and toxic effects may lead to weariness, irritability or a pessimistic mood: the personfeels lousy.

2. Louse borne epidemic Typhus - caused by *Rickettsia prowazekii.* Epidemics associated with conditions that favour heavy infestations of body lice. Interestingly, typhus is fatal for lice. Head lice are secondary vectors. The reckettisi of louse borne typhus, *Rickettisia prowazeki*, are ingested with blood meal taken by both male and female lice and also their nymphs. They invade the epithelial cells lining the stomach of the louse where they multiply enormously and cause and the cells to become greatly distended. About four days after the blood meal, the gut cells rupture and release the reckettisia back into the lumen of the insect's intestine. Due to these injuries to the intestinal wall, the blood meal may seep into the hemocoel of the louse, giving the body an overall reddish color. The reckettsia are passed out with the feaces of the lice, and people become infected when these are rubbed or scratched in to abrasions, or come in to contact with delicate mucus membranes such as the conjunctiva. Infection can also be caused by inhalation of the very fine powder dry feaces. And if a louse is crushed, due to persistent scratching because of the irritation caused by its bites, the reckettesia are released from the gut and may cause infection through abrasions. The reckttesia may remain alive and infective in dried lice feaces for about 70 days.

An unusual feature of epidemic typhus is that it is a disease of the louse as well as of humans. The rupturing the epithelial cells of the intestine, caused by the multiplication of the ricketisa, frequently kills the louse after about 8-12 days. This may explain why people suffering from typhus are some times found with no, or remarkably few, lice on their bodies or clothing. Asymptomatic carriers remain infective to body lice for many years. Recrudescences as Brill-Zinsser's disease, many years after the primary attack, may occur in a person and lead to the spread of epidemic typhus.

3. **Trench fever** –Trench fever is a relatively uncommon and non fatal disease. It is caused by another Rickettsia (*Rochalimaea quintana)*. The reckettsia is being ingested by the louse during feeding. The pathogens are attached to the walls of the gut cells where they multiply: they do not penetrate the cells as do typhus reckttesia and consequently they are not injurious to the louse. After 5-10 days, the feaces are infected. Like typhus the disease is conveyed to humans either by crushing the louse, or by its feaces coming in to contact with skin abrasion or mucus membranes. The pathogens persist for many months, even a year in dried louse feaces, and it is suspected that infection may commonly arise from inhalation of the dust like feaces. The disease may be contracted by those who have no lice but are handling louse infected clothing contaminated with feaces. It it is a debilitating disease transmitted by *Pediculus humanus humanus*.

4. **Louse borne epidemic Relapsing fever** – it is caused by a spirochete, *Borrelia recurrentis*. it is ingested with louse's blood meal

from a person suffering from epidemic relapsing fever. Within about 24 hrs all spirochets have disappeared from the lumen of the gut. Many have been destroyed, but the survivors have succeeded in passing through the stomach wall to the heamocoel, where they multiply greatly, and reaching enormous numbers by days 10-12. The only way in which humans can be infected with louse borne relapsing fever is by the louse being crushed and the released spirochtes entering the body through abrasions or mucus membranes. The habit of some people crushing lice between the figure nails, or even the teeth is clearly dangerous if the lice are infected with relapsing fever or recketisia. The method of transmission of epidemic relapsing fever must make it very rare for more than one person to be infected by any one infected louse. Hence epidemics of louse-borne relapsing fever will rarely occur unless there are large louse populations.

8.3 Control of louse

Insecticides (permethrin), Personal hygiene, laundering of garments.

In current times, in situations where there is overcrowding (e.g. due to poverty, during political & civil unrest, during mass migration & in refugee situations) laundering of garments and personal hygiene may not be easy or a major priority. Often in these situations, basic needs such as food, water & shelter are the priority.

Insecticides

Medications that kill head lice are called pediculicides. All pediculicides except malathion are applied to the scalp and hair and left on for 10 minutes, then rinsed off. Pediculicides kill nymphs and adult lice, but do not destroy nits. For this reason, they may need to be reapplied 7-10 days after the first application to kill newly emerged nymphs. Because some pediculicides have significant toxicities, it is important to follow application directions carefully.

Permethrin – Permethrin is the preferred first-line treatment for head lice. Permethrin 1% (Nix) is available over the counter, and permethrin 5% (Elimite) is available by prescription. Permethrin is a cream rinse that is designed to leave a residue after rinsing that kills emerging nymphs, so reapplication is usually not needed.

Pyrethrins Plus Piperonyl Butoxide (Rid) – This pediculicide is a shampoo that can cause an allergic reaction in people who have plant allergies, especially allergies to chrysthanthemums.

Malathion – Malathion is a prescription lotion that is applied as Lindane (Kwell). Lindane is available only by prescription. It should only be used cautiously if a first-line treatment has failed because several cases of seizures in children have been reported to the hair, left to air dry, then washed off after 8-12 hours. Because it has a high alcohol content, it is highly flammable and can cause difficulty in breathing if it is ingested. For these reasons, it should only be used for resistant cases of head lice.

Oral Agents - Trimethoprim-sulfamethoxazole (Septra, Bactrim) is an oral antibiotic, given as a 10-day course, which has been shown to be effective at treating resistant infestations of head lice. Ivermectin (Stromectol) is an antiparasitic drug given as a single dose that has also been shown to effectively treat resistant head lice infestations. However, neither of these drugs is FDA approved for use as a pediculicide.

Nit Removal

Treatment with a pediculicide kills adult lice and nymphs preventing the spread of head lice infestation to other people. Removal of nits is recommended to reduce confusion about the effectiveness of treatment. Nits within 1 cm of the scalp should be physically removed by a fine toothed comb. A variety of agents are available to break down the cement holding the nit to the hair shaft including distilled white vinegar, formic acid preparations, and enzymatic nit removal systems. Using one of these agents prior to nit combing makes it easier to remove nits. Nits that are present on the hair shaft greater than 1 cm from the scalp are not considered to be viable and do not have to be removed.

Treatment of Head Lice Contacts

According to the American Academy of Pediatrics, if a case of head lice is identified, all household members should be checked for head lice. Only those with live lice or eggs within one cm of the scalp should be treated. It is also recommended that all hair care items and bedding belonging to the infested person be cleaned.

8.4 Survey methods: As with any other type of survey, a louse survey involves finding insects or their eggs in a given host population. Head lice should be sought in the hair while body lice will be found in the clothing, most commonly on the layer next to the skin. Crab lice are found in pubic and axillary regions. Given their limited and specialized habitat, surveys are not normally conducted specifically for human lice. However, if medical treatment is sought because of lice, qualified medical practitioners will examine the head and pubic areas for lice. it's important to inspect the infested individual's bedding and clothing articles and those of any people sharing quarters for the presence of lice. Give special attention to seams of clothing, particularly trousers and to wool blankets for the presence of both lice and eggs.

Management: it includes delousing individuals and disinfesting clothing, equipment, facilities, ships, etc. All management operations for individual treatments for lice infestations are directed and conducted by medical personnel.

Mass delousing Bulk-issue louse powders are used in mass delousing with hand and power dusters. Use manual dusting equipment such as plunger-type hand dusters to treat individuals without requiring clothing removal. This item has a 6-inch metal extension tube and delivers an even flow of powder. It's a standard equipment item for many military preventive medicine and engineering teams. One duster three-fourths full holds enough to treat about ten people. For best results, do not completely fill the duster. To treat more than 10 to 12 people at a time, use power equipment if it is available. A power delouser has a small portable gasoline engine and air compressor, 10 lengths of hose and 20 dusters. It is easy to detach dusters and attach extra units to aid refilling while others are in use. A complete unit can delouse 600 or more people in an hour.

Contingency considerations Individual protective measures against lice include issuing standard issue louse powder to individuals and properly laundering uniforms in a laundry unit. Louse powder is normally stocked by operational units. Use of a standard laundry unit (operating at 140^0 F for 20 minutes) normally ensures that any nits and living forms are killed. Woolen blankets used by infested individuals should be thoroughly dusted with louse powder and aired, but not beaten before they're returned to bunks. Only trained pest managers should conduct chemical treatments. Mass delousing is always indicated when louse-borne disease is endemic and either large numbers of prisoners of war or displaced persons come under U.S. military forces jurisdiction.

Control Measures Good personal hygiene- Regular and frequent bathing, Washing and ironing of cloths, Disinfestations of cloths by boiling or steaming, Sunshine exposure of clothing, Hair hygiene;

Better housing and facilities; Health education**;** Delousing with insecticide dusts (10 % DDT dust); Better economy and living standard.

- Personal hygiene

The most obvious way to eradicate lice from a person is by changing and washing of clothing, preferably followed by ironing and regular body bathing. Regular washing and combing hair may reduce the nymph and adult. Shaving of hair (head and pubic) can eradicate both the adults and nymph

Review Questions

1. Write the principal diseases transmitted by lice.
2. Describe the mode of disease transmission in lice.
3. Draw the strategy of controlling the epidemic of relapsing fever in a certain community.

CHAPTER NINE

HEMIPTERA / BED BUGS /

Learning objectives

At the end of this chapter the reader will be able to

- Identify different species of bed bugs
- Describe the life cycle, behavior and habitat of bed bugs.
- Discuss the medical importance of bed bugs

9.1 Introduction

Bedbugs are temporary ectoparasites of human. They are common in places with poor housing conditions. Bedbugs have a dorsoventrally flattened body. They are oval in shape with no wing Shinny reddish to brown in color (after blood meal they become dark brown) 4 - 7 mm long. They have 3 pairs of well developed legs, which enable them to crawl rapidly. Both sexes suck blood including the nymphs

9.2 Adult behaviour

Feed mainly at night (they are nocturnal feeder). While the host is sleeping .During the ten minute or so feeding period they take 2- 5 times their body weight blood from their host. Once fed, bugs return to the cracks behind wall paper, furniture and crevices in which they hide. Bed begs are heavily reliant on passive dispersal from one home to another. They can with stand starvation for months, particularly the later nymphal instars attached by the exhaled CO_2

9.3 Life cycle

- Pass through incomplete metamorphosis
- Lay 2-3 eggs per days
- Hatch in 8-11 days at room temperature (20^oc)
- There are five nymphal stages

9.4 Public Health importance

Biting nuisance

- Intense itching

-Sleepless night

- No evidence that bed bugs are vectors of any diseases under natural condition

9.5 Control

Difficult to control bed bugs, because they tend to hides deep in to their harborages.

1. proper house maintenance

- detaching houses
- furniture cleanliness –pouring boiled mater, oven , infested goods
- Eradicating cracks & crevices in walls. Exposing articles to sun light

2. Application of insecticide like Carbonyl, Propoxur, Deltamethrin, Bendiocarb

Review questions

1. Discuss the lifecycle, habit of the bedbugs
2. Mention the medical importance of bedbugs
3. Describe the basic control strategies of bed bugs

CHAPTER TEN

BLATTIDAE /COCKROACHES/

Learning objectives

At the end of this chapter the reader will be able to

- discuss the specific features of cockroaches
- describe the different species of cockroaches and their distributions
- address the medical importance and the control methods of cockroaches.

10.1 Introduction

There are almost 4000 species of cockroaches. About 50 species have become domestic pests and the most important medically are *Blattela germanica* (the German cockroach), *Blattella orientalis (*the oriental cockroaches*)* and *periplaneta Americana* (the American cockroach). Cockroaches are some times called roaches or steambugs. They have almost a world-wide distribution. Cockroaches almost certainly aid in the transmission and harbourage of various pathogenic viruses, bacteria, protozoa and helminthes. They can be intermediate hosts of certain nematodes.

10.2 External Morphology

Cockroaches are usually chestnut brown or black in color, 1-5 cm long, flattened dorsoventrally and have a smooth shiny and tough integument. They have a long and prominent filiform antenna. The cockroach's mouth parts are developed for chewing, gnawing, and scraping. In adults of both sexes there are two pairs of wings- they are not used in flight but serve as protective covers. Cockroaches are most readily distinguished from beetles by having the fore wings placed over the abdomen in a scissor like manner. They are adapted for omnivorous feeding.They like warmth and nocturnal in their activities. During the day they hide among behind radiator, hot water pipes, behind refrigerator, cupboard, decayed food, fabrics, book bindings, inner living of shoe soles, their own cast off skins, dead and crippled cockroaches etc. They regurgitate fluid while feeding.

10.3 Life Cycle

Eggs are laid encased in a brown bean shaped case or capsule called an ootheca which contains 12-50 eggs. Cockroaches are often seen running around with an ootheca partly protruding from the tip of the abdomen. The ootheca are deposited in cracks and cervices in dark and secluded places. Cockroaches have a hemimetabolous life cycle. Nymphs are hatching out from the eggs after about 1-3 months, depending on both temperature and species. There are usually six nymphal instars. The duration of the nymph stage varies according to temperature, abundance of food, and species.

10.4 Public Health Importance

1. Nuisance- the presence of cockroaches in houses and hotels, etc has for a long time been regarded as highly undesirable because of their dirty habits of feeding indiscriminately on both excreta and

foods, and their practice of excreting and regurgitating their partially digested meals over food

2. Mechanical disease transmission E.g. Typhoid fever, diarrheal diseases, etc

The presence of cockroaches in houses and hotels has for a long time been regarded as highly undesirable because of their dirty habits of feeding indiscriminately on both excreta and foods, and their practice of excreting and regurgitating their partially digested meals over food.

Many of the parasites and pathogens isolated from cockroaches are spread directly from person to person with out the aid of intermediary insects because of this it is very difficult to prove that cockroaches are the prime cause of any disease out break. Nevertheless because of their unsanitary habits they have been suspected as aiding the transmission of various illnesses. For example they are known to carry pathogenic viruses such as poliomyelitis, protozoa such as *entamoeba histolytica* and bacteria such as *E*,*coli*, *staphiloccocus aureus, shigella* and *salmonella.*

There is little doubt that cockroaches contribute to the spread of a number of diseases mainly intestinal and they may sometimes be more important as mechanical vectors than houseflies. However it is nevertheless difficult to assess their real importance as vectors because many of the pathogens which cockroaches carry can be transmitted by many other different ways.

10.5 Control Measures

1. Sanitation

Ensuring that neither food nor dirty kitchen utensils are left out over-night will help to reduce the number of cockroaches but if they are present in adjoining or near-by houses, good hygiene in itself will not prevent cockroaches from entering houses.

2. Insecticide application

Insecticidal spraying or dusting of selected sites such as cup-boards, kitchen furniture and fixtures, stoves, refrigerators and near-by dust bins is recommended. Various commercial insecticides having a residual effect can be painted to walls and other surfaces and remain effective for several months in killing cockroaches. Boric acid powder (borax) still remains a very safe and useful chemical, acting both as a contact insecticide and a stomach poison.

Review questions

1. Describe the role of cockroaches in the disease transmission
2. Discuss the possible effective control methods of cockroaches.

CHAPTER ELEVEN
OTHER CLASSES OF PUBLIC HEALTH IMPORTANCE ARTHROPODS

Learning Objectives:

At the end of this chapter the student (reader) will be able to:
- Describe the control methods for ticks, mites and crustaceans.
- Draw the transmission cycle of guinea worm and schistosomiasis.
- List the different diseases transmitted by crustaceans

11.1. Arachnids

General feature or Identification characterstics

The Arachnids with the exception of certain mites, which adapted to live in water, are terrestrial or land dwellers. All species under this class lacks antennae, wings and compound eyes. Their body is divided into two segments- that is cephalothorax and abdomen. In place of antennae they have the pedipalps- which do what antennae do. Respiration is by trachea or "lung books". All arachnids have four pairs of legs. Species like ticks, mites, scorpion and spider belongs to this class.

11.1.1. Ticks

Class Arachnida
Order- Acarina   Common Name.
Family - 1. Ixodidae________ Hard tick
               2. Argasidae_______ Soft tick.

Genus Ixodidae:	Species:	Common Name.
1. Dermacenter	D. andersoni	Wood tick
2. Bophilus	B. annulatus	Cattle tick
3. Amblyomma	A. americanum	Lonestar tick
4. Rhipicephalus	R. sanguineus	Brown dog tick.

Genus Argasidae:	Species:	Common Name:
1. Ornithodorus	O. moubata	Human tick
	O. turica	Human tick
	O. tholozon	Human tick.

General Feature and Identification:

Ticks are the largest acarines and cosmopolitan in distribution. The majority of them are external parasites of terrestrial vertebrates. They suck blood from animals and humans, and are important as a vector for a large number of diseases. All post embroyonic stages, with few exceptions, feed on the blood and tissue fluids of the host. There are about a total of 800 species of ticks in the world.

The adult soft ticks are flat and oval in outline and have tough, leathery and wrinkled bodies. The mouthparts are situated underneath the body and are not visible from above. Most species can survive for more than a year with out blood meals, and some for more than 10 years.

The soft ticks live apart from their hosts and are most common in the nests and resting places of the animals on which they feed. Species that commonly feed on humans are found around villages and inside houses. Their habits are comparable to those of bedbugs.

The adult hard ticks are flat and oval in shape and between 3 and 23 mm long, depending on the species. The mouthparts are visible at the front of the body, differentiating them from the soft ticks. In contrast to the soft ticks they have a shield like plate or scutellum behind the head on the back of the body, and there is only one nymphal stage.

Most species of hard tick feed on three different hosts: one each for the larva, nymph and adult. For instance, some species feed on only one or two hosts. The Argasids are a multi-host ticks and therefore, nymphs as well as adults may take several short blood meals from different hosts.

Life Cycle and Adult behaviour

Ticks pass through gradual metamorphosis. They have one nymphal instar and six legged larva. Ixodidae have one eight-legged nymphal instar, however, the argasidae may have up to eight nymphal instars. The immature stages resemble the adults and each of them need a blood meal before it can proceed to the next stage. Adult ticks live for several months with out food and resist starvation. Both sexes feed on blood, the males less frequently than the females, and both can be vectors of diseases.

11.1.1.3 Public Health Importance:

In tick species, the female ticks can pass on certain disease agents to their offspring's, in addition to transmitting diseases from one host to another during blood feeding.

1. Nuisance

Ticks can cause discomfort and irritation by their bite. They may cause local traumatic and inflammatory damage when they puncture the skin and suck blood.

In public health ticks are important largely because of their activity as vector of pathogenic organisms. Transovarian transmission has been observed to a greater or lesser extent in the case of all the major categories of ticks. The majority of ticks are essentially ectoparasites of wild animals, and humans must be regarded as an incidental host, for both the ticks and the organisms which they transmit.

2. Tick borne relapsing fever

The disease is caused by a microorganism of the genus Borrelia. It is transmitted by the bite soft ticks of the genus Ornithodoros in many countries in the tropics and sub-tropics. The ticks usually feed quickly at night in or near houses and then leave the host.

3. Tick borne rickettsial infection

This group of diseases is caused by closely related Rickettsia microorganisms transmitted by tick bites or contamination of the skin with crushed tissues or faces of the tick, such as:-

- Spotted fever - caused by *Rickettsia rickettsii* and R. *sibirica* and due to R. *conori*, and R. *australis*.
- Q. fever - caused by *coxiela burnetii*.

The disease is transmitted mostly by Ixodes ticks, commonly, in the summer when the nymphs are abundant. Some rodents, especially mice, serve as reservoirs of infection while large mammals serve principally as hosts maintaining tick populations.

4. Tularaemia

Tularaemia is caused by the infectious agent francisella tularensis (pasteurella tularensis). The symptoms are headache, chills, fever and the swelling of lymph nodes. The responsible tick species are anblyomma americanum and dermacenter.

Transmission takes place through the bites of ticks and deer flies, or as a result of handling infected animals such as rabbits and other game. Hunters and forest workers are at the highest risk of infection.

5. Tick paralysis

Hard ticks inject in to the body with their saliva certain toxins that can cause a condition in people and animals called tick paralysis. It is an acute intoxication characterized by elevation of temperature up to 40^0C and difficulty in swallowing and respiration. It occurs worldwide and is most common and severe in children aged up to two years.

6. Tick borne viral encephalitides:

It is a group of viral diseases causing acute inflammation of the brain, spinal cord and meninges. The symptoms vary in severity with the type of disease. Severe infections may cause violent headaches, high fever, nausea, coma and death.

These diseases are transmitted by biting ticks and by the consumption of milk from infected animals. The diseases are usually transmitted by hard ticks (Ixodes species).

Prevention and Control Methods*:*

1. Self protection through the application of basic sanitation.

Personal protection measures and animal care in fields, forests, in the shed, stable and in other places that are infested with ticks should be taken. Children or adult who walk through tick infested area should remove all clothing as soon as they return to their home, and all attached or crawling ticks should be removed to minimize danger. Some times repellents can be used to prevent ticks from attaching to the body.

2. Application of Insecticides:

Spraying of appropriate chemicals over ticks directly in their natural habitats such as forests and fields may control them. Large areas may be treated by ultra-low-volume spraying of liquid acaricide concentrates. Small areas may be sprayed by means of motorized knapsack spraying or mist blowers.

11.1.2. Mites

Class - Arachnida

Order- Acarina

Family	Genus	Species	Common name
1. Trombiculidae	Trombicula	T. akamushi	Chigger mites
2. Sarcoptidae	Sarcoptes	S. scabies	Scabies mite.
3. Demodicidae	Demodex	D. follicle	Follicle mite
4. Dermanyssidae	Dermanyssus	D. gallinae	Hen mite.

11.1.2.1 General Features*:*

Mites are generally very small in size and barely visible. They suck the blood of man and other animals.

- *Trombiculidae* biology and their medical importance*:*

Adult trombiculid mites are about 1-2 mm in length, bright red or reddish-brown in color, and of velvety appearance. Larval trombiculids commmonly known as chigger or red bugs, are very small , being 0.15 - 0.3 mm in length, and ectoparasites of vertebrate and to a lesser extent to arthropod hosts, but the nymphs and adults are free living predator's feeding mainly on soil arthropods. After emerging from the egg, the larvae crawl on grasses or low laying vegetation and leaf litter to wait for an animal or human host. They attach themselves to the skin of reptiles, birds, mammals and humans walking or resting in the habitat. On humans they seek out areas where clothing is tight against the skin, the waist and ankles being the parts most commonly attacked. The larvae remain attached to the skin of the host between two days and a month, depending on the species. They then drop to the ground and enter the soil to develop in to the harmless nymphal and adult stages.

Generally over 700 species have been described and about 20 of these are important either as a cause of dermatitis (scrab- itch) in man or as a vector of human pathogens.

Scrab-itch in man, which is the result of an allergic reaction to the saliva of the chigger, can be caused by many trombiculid species.

- **Prevention and Control measure**

1. Treatment of infected person with tetracycline or its derivatives.
2. Prevention of bites and application of repellents.

Biting can be prevented by avoiding infested terrain and applying repellents to skin and clothing. Chigger mites can be prevented by treating clothing, particularly socks or stockings, cuffs and collars with mite repellents. The most efficient chigger repellent is diethyl toluamide, but also dimethyl phthalate, dibutyl phthalate and benzyl benzoate are efficient.

3. Removal of vegetation:

The control of mites by killing them in their habitats is very difficult because of the patchy distribution of their population. It may be possible or advantageouse to remove vegetations that harbor larval mites by cutting or burning and then scrape or plough the top soil.

4. Application of insecticide:
Mite infested land (vegetation can be sprayed with suitable residual insecticides. Compounds like diazinon, fenthion, malathion, propoxur and permethrin are a suitable chemicals against mites.

- **Sarcoptidae biology and medical importance:**

The sarcoptids are skin parasites of warm blooded animals. They are between 0.2 and 0.4 mm long and virtually invisible to the naked eye. It has world wide distribution.

► **Life Cycle:**

Practically the scabies mite spent its life cycle on and in the skin of humans. In order to feed and lay eggs, fertilized females burrow winding tunnels in the surface of the skin. It takes about two weeks to complete the cycle.

The scabies mites are commonly found where the skin is thin and wrinkled, for instance between the fingers, on the sides of the feet and hands, the bends of the knee and elbow, the penis, the breasts and the shoulder blades.

► **Public Health Importance**

The scabies mite, sarcoptes scabies, infest mammals like humans and cause an itching condition of the skin known as scabies. There are different forms of mites occurring on different mammalian host. Scabies is usually transmitted by close personal contact, as between people sleeping together, and during body contact. Transmission mostly takes place within families. Scabies occurs throughout the world in persons of all ages and social groups. In developing countries like ours, up to a quarter of the population may be affected. It is most common in young children.

► Prevention and Control methods

1. Treatmentofcases:

For the control of scabies mite acaricide such as benzyl benzoate 25% emulsion splash or painted over the body can be used. Treatment of all family members is necessary to prevent re-infestation.

► Demodicidae and Its Public Health Importance

These mites commonly known as follicle mites. The members of the genus Demodex burrows into the hair follicles of mammals and feed on subcutaneous secretions. Treatment of this mite is rarely necessary because cleanliness is enough to get rid of the mite.

But it can be noted that a case of scalp demodicidosis was easily cured with an ointment containing 10% sulphur and 5% peruvian balsam.

► Dermanyssus Gallinae and Its Public Health Importance

This species is commonly known as the red mite of poultry, and is an obligatory blood sucking parasite with a wide host range amongst wild and domestic birds. In temperate regions it is an important pest of poultry, turkeys. This mite may also attack man, causing a sever irritation and it may cause a skin ailment resembling animal scabies.

11.1.3. Scorpion

Class - Insecta

Order - Scorpionida

Family	Genus	Species:
1. Buthidae	Buttus	B. occitanus
		B. androctomus australis
2. Diplocentridae	Diplocentrus	D. whitei
3. Scorpionidae	Opisthocanthus	Op. lepturus
4. Chactidae	Euscorpius	Eus. flavicandis
	Chactidus	Ch. suffusus
		Ch. limpidus
5. Vejovidae	Vejovis	V. spinigerus

General features

Scorpions are relatively large heavily arachnids in which the prosoma is covered dorsally by a compact shield. They are carnivorous and occur most commonly in the warmer parts of the world. They are nocturnal and they feed principally on insects and other arthropods. Scorpions do not attack man spontaneously and even the most dangerous species can be allowed to walk over the back of the hand with little risk. Accidents occur commonly when scorpions hide themselves in clothing and when dark corners are being cleared of rubbish.

Scorpions have a long upturned tail and they can live in different habitats such as under stone, in crevices, under rubbish, under leaves, in barns etc. They are sensitive to climatic change and usually live alone. They feed on chilopoda, diplopoda, spider, etc. Ants and baboons are the dangerous enemies of scorpions.

The medical importance of scorpions varies considerably and is dependent on their habits and venom potency rather than on their size. The nature and effects of venom on man are not the same. In general there are two type of venom:-

1. The one that produces a local reaction of varying severity with only mild or with no systemic effects. There is very little danger of death from stings of scoropions with venom of this type.
2. The second type of venom is the production of neurotoxin and its effects can be lethal particularly in children.

Most scorpions under family Buthidae have a dangerous neurotoxin venom. But there appear to be a considerable biological differences between scorpions of family Buthidae. The venom of the north Africa and middle eastern populations is much more toxic to man and in these regions a number of deaths were recorded to the sting of scorpions.

► **Treatment of scorpion sting**

Symptomatic medication has been reported to be of little value for the treatment of scorpion stings of the neurotoxic type and it can even been harmful because certain drugs can synergise the venom. Antivenins are very effective when administered early and in sufficient quantity.

11.1.4. Spider

► **Biology and Habits of Spider**

The specialized and microhabitats and food resources available in and around the house hold environment are often utilized by spiders. The basic structural features of houses and other buildings, such as the corners and overhangs adjacent to out door lights, and undisturbed areas. Indoors provide adequate harbourage and hunting grounds for the predatory arthropods. Insects and other arthropods that invade household habitats are their foods.

The prosoma is joined to the opisthosoma by a narrow pedicel. The genital orifice is located on the suck-like opisthosoma. The openings of the abdominal silk glands are situated ventrally on the opisthosoma. Antennae and wings are absent. They exhibit gradual metamorphosis and have four pairs of legs. Size seems to determine the number of eggs produced by the female. Some of the very large spiders produce thousands of eggs a time, while small ones rarely lay more than 12 legs.

The copulatory procedure among spiders involves the transference of sperms to the female genital orifice by the use of the specially modified first pair of legs of the male. Copulation is a hazardous and some times fatal for the male.

► **Public Health Importance**

Spiders are equipped with a pair jaws (chelicerae) and possess venom glands. The immobilization of prey is assisted by the use of silk and by the injection of venom in the body cavity of the captured animal. Spiders can not ingest solid food. They have a low rate of metabolism compared with other arthropods of equal body.

The danger of spiders bite is largely over stated. The majority of spiders, whether indoor or out door species, are harmless to man because their mouth part can not penetrate human skin or because their venom is not toxic to man. Of all spiders species the Lactrodactus mactans (black-widow-spider) and Loxoceles species are the most important spiders that have a neurotoxin and mouth parts are strong enough to threaten human life.

► Control measures

The distraction of spiders hiding place in the indoor environment through proper house cleanliness may decrease the abundance of spiders. Removing spider egg sacs when they appear may also decrease their population. Application of insecticides to the food sources (insects) of spiders and the spider themselves.

11.2. Centipedes

Class - Chilopoda (Centipedes)

Order- 1. Scutigeromorpha
2. Scolopendromorpha
3. Geophilomorpha.

Family.	Genus	Species	Common name.
1. Scutigeromorphidae	Scutigera	Su. coleoptrata	House centipeds
2. Scolopendromorphidae	Scolopendra	Sco. cingulata Sco. meorsitants	
3. Geophilomorphidae		Geo. epimorpha	

General Information

Centipeds are elongated, many legged, one leg per segment, worm, like animals. They have one pair of antenna with gradual metamorphosis. Their distribution is world wide and have chewing mouth part.

They live in damp dark habitats such as under stone, in crevices of the upper layers of soil, in forest litter and under the bark of trees. Some are cave dwellers and a few are marine dwellers. The majority are nocturnal predators feeding mainly on insects and other small arthropods which they capture and kill with their poison claws.

For species of this group living in temperate zones are able to pierce human skin with their poison claws. The large scolopendromorphs which are abundant in tropical and subtropical regions are generally regarded as venomous. No centipede bite caused serious effects and many suffering centiped victims were quickly relieved after local anesthetics were injected in the vicinity of the bite.

11.3. Millipedes

Class - Diplopoda

The millipedes are elongated tracheate arthropods with a distinct head and a clear trunk composed of a large pair of legs. The head bears a single pair of antennae, a pair of mandibles and maxillae. They have bright color and simple eye-ocelli.

Millipedes are predominantly saprophagous and lack the poison claws of the centipedes. These species have a secretion which is unpalatable to predators and in the case of some large tropical species the secretion have been reported to have a strong caustic action. Pentazonia, colobognata, julida etc., are some examples of order diplopoda.

11.4. Crustacean

General Features:

Their body is divided in to prosoma and opisthosoma, and have 5 pairs of legs and 2 pairs of antennae. They have a compound eye-called ommantidia. Crustaceans are aquatic arthropods and breath by means of gills or through general body surface. Cyclops are tiny crustaceans of the family cyclopidae, also called water fleas. They are usually found in stagnant bodies of fresh water such as wells and ponds in poor agricultural communities in rural or peri-urban areas.

Public Health Importance:

1. Poisoning

Many crustaceans particularly decapods are eaten by man and a number of them are known to cause poisoning when eaten raw due to the phenomena called biological magnification. Lobsters, crab and shrimps are good examples of crustaceans that cause poisoning.

2. Transmission of human parasite*:*

a. Lung fluke (Paragonimiasis)

The causative agent for the disease is *paragonimus westermani* and the decapoda species are the secondary intermediate host. The first intermediate host is snail. Men get infected by eating uncooked infected river crabs and fresh water cray fish.

b. Diphyllobothriasis:

The responsible parasite *Diphyllobothrium latum* (broad fish tape worm of man) is acquired by eating fish that have swallowed cyclopid, capepods infested with the second stage of the developing worm.

C. Guinea-worm disease (Dracunculiasis):

Guinea worm disease is rarely fatal but is severely debilitating. The lower limbs are most commonly affected, but the worms, which are up to a meter in length, can emerge from any part of the body.

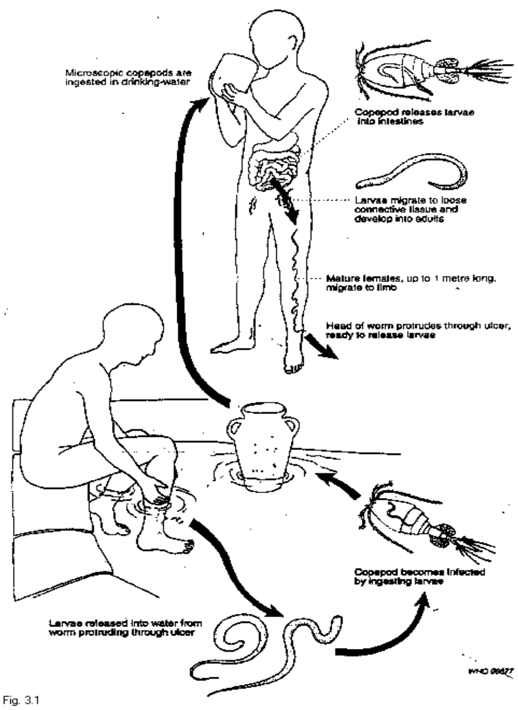

Fig. 3.1

Life cycle of guinea worm (by Taina Litwak for the United States Agency for International Development's VBC Project).

(Source: Jan A. Rozendaal: WHO 1997)

For the disease

to be transmitted, Larvae of the guinea worm enter the human body when people drink water contaminated with cyclops containing infective larvae. Cyclops infected with guinea-worm larvae also suffer from the infection and tend to sink to the bottom of the water. As a result, people in humid savanna areas in sub-saharan Africa are most likely to become infected during the dry season when water levels are lowest and they scoop to the bottom of ponds or wells in order to obtain water.

Prevention and Control Measures:

1. Cook food:

Avoid eating of uncooked crustacean to prevent the possible transmission of parasitic diseases and poisoning.

2. Avoid drinking of water from suspicious sources:

In guinea worm disease the only available treatment is to extract the worm. This has to be done very slowly to prevent the worm from breaking.

3. People with an emerging guinea worm should never put any part of their body in to water used for drinking.

4. Installation of safe drinking water supplies.

5. Filtration of drinking water.

6. Application of larvicides:

Cyclops and other crustaceans can be killed by treating water sources with temephos, an insecticide that is safe to apply in drinking water if used at the correct dosage.

7. Boiling of drinking water:

Boiling is a simple and effective method for killing Cyclops in drinking water.

Molluscus

Many species of fresh water snail belonging to the family planorbidae are intermediate hosts of highly infective fluke (trematode) larvae of the genus schistosoma which cause schistosomiasis in Africa, Asia and the Americas.

The snails are considered to be intermediate hosts because humans harbour the sexual stages of the parasites and the snails harbor the asexual stages. People serve as vectors by contaminating the environment. Transfer of the infection requires no direct contact between snails and people.

Most intermediate hosts of human schistosoma parasites belong to three genera, Biomphalaria, Bulinus and Oncomelania. The species involved can be identified by the shape of the outer shell. The snails can be divided in to two groups by way of habitat.

1. Aquatic snails that live under water and can not usually survive else where (Biomphalaria, Bulinus), and
2. Amphibious snails adapted for living in and out of water
   E.g. Oncomelania

Life Cycle:

All species of Biomphalaria and Bulinus are hermaphrodite, possessing both male and female organs and being capable of self or cross-fertilization. A single female specimen can invade and populate a new habitat. The eggs are laid at intervals in batches of 5 - 40, each batch being enclosed in a mass of jelly-like material. The young snails hatch after 6 - 8 days, and reach maturity in 4 - 7 weeks, depending on the species and environmental conditions.

Public Health Importance:

1. Schistosomiasis:

Schistosomiasis is one of the most widespread of all human parasitic diseases, ranking second only to malaria in terms of its socioecomonic and public health importance in tropical and subtropical areas.

The transmission route of the disease is eggs are released into water body from feces of an infected person; after the eggs hatch taken by snail host and continue the development inside the host. Then thousands of the new cercariae break out of the snail and swim in the water. The cercariae after being released into water, they must penetrate the skin of human being within 48 hours to continue their life cycle. Within seven weeks the young parasite matures to an adult male or female worm.

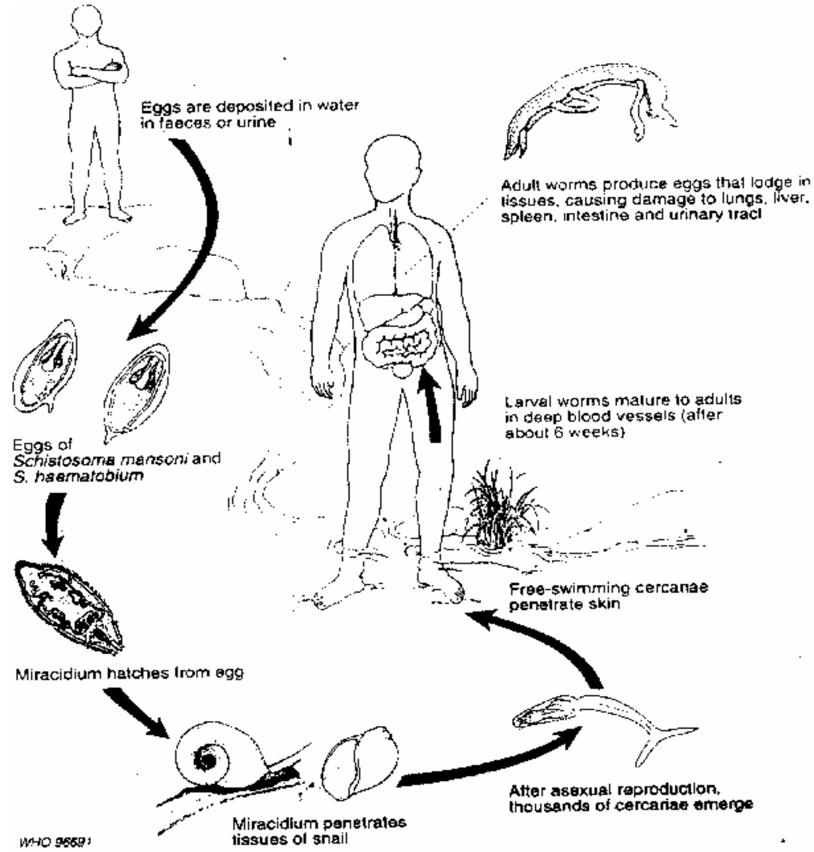

Fig. 3.2.

Life cycle of schistosomes (by Taina Litwak for the United States Agency for International Development's VBC Project).

Prevention and control

1. Detection and treatment of sick people
2. Safe disposal of human excreta through the provision and proper utilization of sanitary latrine.
3. Provision of safe drinking water:

   Individual protection from infection can be achieved by avoiding contact with unsafe water.
4. Snail control through environmental modification:

   Reduction of snail habitat by removal of vegetation; alteration of water levels and flow rates, etc. helps to reduce the number of snail host.

Review Questions

1. List at least two control methods against ticks.
2. What are the diseases or health problems caused by mites.
3. Write the medical importance of crustaceans.
4. Write the possible control and preventive measure against Guinea worm infection.
5. Write the transmission route of schistosomiasis and list the possible control technique for it.
6. Practical Exercise:

   Go to the field and collect insects and other arthropods regardless of their public health importance. Classify the collected arthropods by their class and order. Finally Sort out the public health importance insects from the collected species.

CHAPTER TWELVEE

RODENTS

Learning objectives

At the end of this chapter the reader will be able to

- discuss the similarity and difference between black rats, brown rats, and house mouse
- investigate the presence of rats and mouse in a given area
- identify the medical importance and possible control techniques against rats and mouse.

12.1 Identification characteristics

Class – Mammalia;

Order – Rodentia;

Family – Muridae;

Genus- Rattus and Mus;

Species-Rattus rattus (Roof rat), Rattus norvegicus (Norway rat), and Mus musculus (house mouse).

Rats are identified by their peculiar shape and arrangement of the teeth. They have no canine teeth but two pairs of strongly developed incisors (a pair on each jaw). Rats have diastema between the incisors and the molors. These 4 teeth (incisors) grow continuously throughout the life of the rats.

The growth rate is reckoned to be around 13 cm per year. In order to keep them short and fit, the rats have to gnaw persistently any material in their access. If they don not do this, then their incisors would grow through their lips, exposing them to the risk of death. The gnawing capacity of the rats is remarkable. They gnaw and at the same time destroy wooden materials, wood floors, plastic materials, fabrics, bed mattresses, valuable cloths, skins and hides, crops , plants, grain in sack, electric wires etc. In fact the presence of rats in premises may be detected by the finding of gnawed material. This gnawing habit makes the rats the most destructive enemy of humans.

Table 12.1 Field identification of the three murine rodents: Rattus rattus, Rattus norvegicus and Mus musculus are shown in the following table.

S.No	Character	Rattus rattus	Rattus norvegicus	Mus musculus
1.	Average adult weight.	8 – 12	16	1/2
2.	Fur	Black	brown	gray
3.	Body	Slender	Heavy set	Small
4.	Muzzle (mouth part, nostril)	Pointed	Blunt	Slender (sharp)
5.	Tail	Longer than body + head.	Shorter than body + head	Equal to body + head.
6.	Ears	Large and prominent.	Small closely set.	Very large.
7.	Fecula	Round and 1/2	Capsular and	Round and

		of an inch.	3/4 of an inch.	1/8 of an inch.
8.	Sexual maturity.	3 - 5 months.	3 - 5 months.	11/2 month.
9.	Gestation period.	22 days.	22 days.	19 days.
10.	Number of gestation.	4 - 6 / year.	4 - 7 / year.	8 / year.
11.	Number of litter/ gestation	6 - 8	8 - 12	5 - 6
12.	Life span.	One year.	One year.	1 year.
13.	Harbourage	Above ground	Under ground.	Both.
14.	Home range.	100 – 150 ft.	100 - 150 ft.	10 - 30 ft.
15.	Feeding	Omnivorous	Same	Same.
16.	Water	15 -20 ml/ day	Same	Same.

If all the offspring were to survive, one couple of rats could-theoretically produce 350 million descendants within 3 years on the bases 6 litters annually. Fortunately, rat survival rate is low due to natural pressures such as scarcity of foods, competition among rats for food and shelter and humans relentless attack on their species.

Rats are nearly omnivorous, but they would prefer grains if choice are possible. They are attracted to indiscriminately dumped garbage, carelessly exposed foods and other materials. They can travel a long distance in search of food and shelter from their breeding sites. Food intake of an average adult rat is estimated to be about 28 grams of dry food and about 15 to 25 ml of water per day. They destroy far more than they consume.

A number of vertebrate animals will invade domestic and commercial premises in search of food and shelter. In doing so, they may be involved in the transmission of disease, soiling and destroying commodities. The most important of these pests are undoubtedly the rats and mice.

To know the vast infestation a careful inspection of premises should be carried on the surrounding building and open space, as well as sewers and drains. Signs to look for are damage caused by gnawing and feeding, holes, dropping.

12.2 Investigation of rodent infestation

The presence of rat in a given house can be investigated by

1. Rat fecula (droppings)

A fresh fecula is soft, moist and bright in color while old fecula is dry, hard and fray to touch. Generally the color and size of rat fecula depends on what the rat has eaten and the type of rodent species respectively.

2. Foot print and tail marks – for fresh fecula the foot print and tail mark is clean and greasy, where as for old fecula it is old and dusty.
3. Rat run ways – if a given area is infested by rats there exist a greasy markings on the pipe, beam, wire, floor, wall, rafter etc. Habitually rat follow the same run way between food, water, and harborage.
4. Distraction marks- rat distract human properties like furniture, food, and clothing's due to their gnawing property.

12.3 public health importance

Rats are capable of transmitting several important diseases to human. These diseases can be grouped into three categories: Those diseases or injuries which are **directly** caused by rats.

Rat bite: Bites inflicted by rats can cause serious injuries to the victims. Infants, children and adults may be exposed to the risk of rat- bite,

Rat - bite fever: This is a disease caused by a spirochete organism which may be harbored in the mouth, particularly on the gum of rats. The organism enters through wounds inflicted by the rat - bite.

The organism does not affect the rodent; those diseases which are transmitted **indirectly** by foods or water contaminated by the rat's excreta and urine- e.g. Salmonellosis: - a common food borne disease due to contamination of the food by faeces / urine containing salmonella organism, Trichinosis: is contracted by eating infected pork. The pig acquires the disease from rats, either by ingesting dead infected rat or through contaminated rat excreta or urine,

Leptospirosis: a spirochetal disease contracted by handling or eating food infected with faeces or urine of domestic and wild rodents; Those which are spread by insects, fleas etc for which rats act as reservoir- e.g. Plague: caused by the bacillus *pasteurella pestis* by the bite of rat flea known as *xenopsyella cheopis*,

Murine typhus:- caused by a rickettsial organism transmitted by the bite of or excreta of rat flea (xenopsylla cheopis).

12.4 Control Measures of Rodents

Before selecting a control method it is necessary to make a survey of the place in order to: Determine the species and population density of rats in the area; determine the frequency of occurrence of rats' infestation, their harborages, food sources etc. Once the survey data are compiled, the following control methods can be applied: Environmental management (control) to deprive rats' food, water shelter and harborage, Rat proofing and rat stoppage, Rat trapping: snap or cage trap, Poisoning using rodenticides of acute or chronic actions.

Acute poisons include compounds of arsenic, strychnine, phosphorous, barium carbonate- they kill rats in less than 24 hours.

Chronic poisons include such as warfarin which is anticoagulant that needs to be ingested at intervals for a period of days or weeks. Here it should be noted that poisons are to be used with the highest precautions to prevent danger of poisoning man and other domestic animals, and use of natural enemies like cats.

Review Question

1. Write at least four points that help to investigate rat infestation.
2. List the public health importance of rats and mouse.
3. Discuss the identification features of different species of rats.

CHAPTER THERTEEN

CONTROL OF DISEASE VECTORS-CURENT PERSPECTIVE

Learning objectives

At the end of this chapter the reader will be able to

-Discuss the different approaches in controlling disease vectors

- Differentiate between the different classes or types of insecticides
- Describe the ways of insecticide formulations
- Describe the different types of manually operated and power operated sprayers.
- Discuss the possible safety measures during insecticide handling

13.1 Introduction

The use of pesticides in public health has been mainly to control vector-borne diseases. Vectors are small animals, mostly insects that transmit pathogens from one host to another. Insects were incriminated as vectors of human disease as early as 1878, when Manson connected mosquitoes with filariasis. Soon afterwards, Ross and others showed that mosquitoes transmitted malaria some of the tropical diseases that most affect human well-being are vector borne.

Table 13.1 Prevalence and distribution of some vector-borne diseases of humans.

Disease	Vectors or intermediate hosts	Estimated world prevalence[a]	Main areas of distribution[b]
Malaria	Mosquitoes (*Anopheles* spp.)	100×10^6/yr	Pantropical
Filariasis	Mosquitoes (*Anopheles, Culex, Aedes, Mansonia*)	90×10^6	Africa, Asia
Yellow fever	Mosquitoes (*Aedes* spp., *Haemagogus*)	–	Africa, South America
Dengue	Mosquitoes (*Aedes* spp.)	–	Pantropical
Japanese encephalitis	Mosquitoes (*Culex* spp.)	–	Asia
Onchocerciasis	Blackflies (*Simulium* spp.)	18×10^6	Africa, Central and South America
Leishmaniasis	Sandflies (*Lutzomyia, Phlebotomus*)	12×10^6	Africa, mid-East, Asia, South America
Sleeping sickness	Tsetse flies (*Glossina* spp.)	20×10^3 [c]	Africa
Chagas' disease	Triatomine bugs (*Triatoma, Panstrongylus, Rhodnius*)	$16\text{-}18 \times 10^6$	Central and South America
Schistosomiasis	Snails (*Biomphalaria, Bulinus, Oncomelania*)	200×10^6	Africa, Southeast Asia, Middle East
Guineaworm	Crustacean (*Cyclops*)	$5\text{-}15 \times 10^6$ [d]	Africa, mid-East, India, Pakistan

[a] WHO (1989a) unless otherwise stated.
[b] WHO (1989b).
[c] Number of new cases reported each year, but "...the real incidence is certainly much higher" (WHO 1989a).
[d] Hopkins (1988).

Most of these diseases are associated with bloodsucking insects, and many are associated with water, because the vectors spend all or part of their life cycles in or near it. For example, culicine mosquito vectors of filariasis and Japanese encephalitis breed in water, ranging from organically polluted drains to rice fields; anopheline vectors of malaria in seepage puddles, ponds, and streams; Cyclops, the intermediate host in guineaworm disease, in wells and ponds; Bulinus, Biomphalaria, and Oncomelania snails, the intermediate hosts in schistosomiasis, in streams, low earth-dam reservoirs, and rice-irrigation systems; and Simulium vectors of onchocerciasis (river blindness) in fast-flowing waters including spillways of dams.

Other vector-borne diseases that have caused disastrous epidemics are typhus (Rickettsia prowazeki), transmitted by body lice (Pediculus humanus), and bubonic plague (Yersinia pestis), transmitted from rodents to humans by fleas (Xenopsylla cheopis and Pulex irritans). These diseases are not major problems now, but they continue to threaten; typhus, especially, soon becomes epidemic in times of war, famine, and overcrowding.

Once their role was established, it was soon realized that the most effective way to control the diseases was to control their vectors. In earlier times, yellow fever was controlled by draining, destroying, oiling, covering, or burying all water containers in which Aedes aegypti could breed. Malaria was controlled by draining the marshes that the Anopheles larvae inhabited, applying the larvicide Paris Green (copper acetoarsenite), releasing larvivorous fish (Gambusia), and screening windows.

13.2 The insecticide era

Although dichlorodiphenyl trichloroethane (DDT) was only discovered to kill insects in 1939, by 1944 this insecticide was being used to control typhus and malaria, and its use soon became worldwide to control pests and vectors of all kinds. For the control of malaria, houses and cattle sheds were sprayed twice a year with DDT wettable powder (WP) to kill resting Anopheles adults.

World Health Organization (WHO) inaugurated a global malaria-eradication program. By 1958, 75 countries had joined and, in 1961-1962, at the peak of the campaign, 69 500 t of pesticides, mainly DDT, were applied each year by 130 000 spraymen to 100 million dwellings occupied by 575 million people. The number of people contracting malaria fell from about 300 million/year before 1946 to about 120 million/year by the late 1960s; in a population that had doubled in size, malaria was eradicated from 10 countries.

After 1965, however, malaria made spectacular "comebacks" in many countries, especially India, Pakistan, and Sri Lanka. Between 1972 and 1976, the number of malaria cases increased 2.3 times worldwide, although the late 1970s saw some improvement as control campaigns were revived. The resurgence of malaria was due to a variety of factors, including

·Premature slowing of the eradication campaigns;

·Poor management and unsustainable approaches;

· Inadequate understanding of the habits of the mosquitoes (many spent too little time indoors to be vulnerable to the spray deposits); and · Insect resistance.

By 1980, resistance to at least one insecticide had been reported in over 150 species of arthropods of public-health importance, including 93 species of mosquitoes (WHO 1984). This led to failure of some control programs and a switch to alternative insecticides, although "in some instances, resistance has become a convenient scapegoat for failures due to other factors" (Davidson 1989). DDT has been banned in some countries, but is still used for vector control in others. Where resistance has become a problem, DDT has been replaced by organophosphates (e.g., malathion and fenitrothion), carbamates (e.g., propoxur and bendiocarb), or synthetic pyrethroids (e.g., permethrin and deltamethrin). These insecticides are, for the most part, less persistent and much more expensive than DDT. Antimalaria campaigns continue in many countries, but the goal is no longer eradication, just control.

Other vector control campaigns have also been based mainly on insecticides. Attacking larvae with the organophosphate temephos and perifocal spraying (for emerging adults) with another organophosphate, fenthion, supplemented during dengue epidemics by fogging or aerial spraying with malathion.

Many countries have promoted house-spraying with dieldrin and other residual insecticides to control house hold insects and tsetse flies by aerial spraying, especially with endosulfan.

The most successful campaign using insecticides in recent years was the onchocerciasis control program in West Africa, which now covers 14 000 km of rivers in 11 countries. Launched in 1974, the program has involved aerial spraying of blackfly-breeding sites with the organophosphate insecticide, temephos, now replaced in some areas by Bucillus thuringiensis because of resistance to temephos. Onchocerciasis control has been good in the central area, but reinvasion by black flies in the periphery is still a problem.

An international campaign against guineaworm involved treating drinking-water sources with temephos to kill Cyclops, the intermediate host.

13.2.1 Side effects of pesticides used in public health

In spite of the millions of houses sprayed with DDT for malaria control, no accidental deaths of spraymen or householders due to DDT poisoning have been reported. However, some domestic animals were killed, especially cats, with the result that rat populations increased in some sprayed areas. Bedbugs, cockroaches, and other household pests soon developed resistance to DDT, and became more abundant because the DDT had killed many of their predators. This led some householders to oppose spraying.

In the past, it was claimed that environmental contamination by DDT used in malaria control was relatively minor because it was sprayed inside houses, and the quantities were much smaller than those used in agriculture. However, washing of equipment, containers, and overalls, and the unauthorized use of DDT for other purposes (e.g., fish poisoning) spread the substance outside the houses. DDT used for malaria control accounted for an estimated 8% of global DDT contamination. Where pesticides are stockpiled for use in epidemics (e.g., dengue), environmental contamination due to leaking containers (some insecticides are highly corrosive), fire, theft, war, or natural disasters is always a danger.

Extensive studies in the effects on non target organisms of aerial spraying of endosulfan against tsetse flies and temephos used in rivers against blackfly larvae have revealed no permanent damage to treated ecosystems. In the case of tsetse fly control, it has been argued that any changes to the ecosystems caused by spraying are insignificant compared to the changes that will follow human settlement of tsetse-cleared land. However, there is no need for complacency in these matters, and further studies are required.

13.3 Agriculture and vector-borne diseases

The links between agricultural development and human health are poorly documented and "the health sector has up to now had minimal involvement in agricultural policies or projects". However, people who clear forests for cultivation are at a high risk of infection with diseases such as malaria, leishmaniasis, African trypanosomiasis, and other diseases, because of increased exposure to the vectors. Moreover, insecticide resistance in mosquito vectors has been induced by the use of the insecticides in agriculture. Selection acts upon the mosquito larvae as they develop in insecticide-contaminated waters. Particularly implicated in this context have been dieldrin, DDT, malathion, parathion, and propoxur (used mainly on rice and cotton crops). Irrigation presents a special problem, because many vectors live or develop in water. Some vectors develop directly in irrigated fields, others in canals, seepages, artificial lakes, or dam spillways. Increasing vector populations and more human contact with them have increased the transmission of malaria and schistosomiasis..

Poorly planned resettlements of people displaced by artificial lakes have also increased the transmission of vector-borne diseases.

13.4 Integrated vector control

From 1945 on, DDT, lindane, and other residual insecticides provided a single, highly effective method of vector control that eclipsed all other methods until about 1970. Since then, the development of resistance, concerns about environmental contamination and human safety, and the high cost of alternative insecticides have led to a revival of interest in other methods of vector control. Some of these methods were already known, but were neglected during the DDT era: personal protection (e.g., screens and repellents), source reduction (e.g., draining or removing artificial breeding sites), the use of fish to prey on mosquito larvae, and community-based health education. Other methods, such as genetic control, synthetic attractants, insect growth regulators, and the use of remote sensing by satellite to detect vector habitats have also been attempted experimentally and in endemic situations.

Integrated vector control has been defined as "the utilization of all appropriate technological and management techniques to bring about an effective degree of vector suppression in a cost-effective manner" (WHO 1983). It demands an adequate knowledge of the biology, ecology, and behaviour of the vector, non target organisms, and the human population to ensure not only effective control of the vector, but also human safety and prevention of other unacceptable side effects, including environmental damage. Although there are many integrated approaches to vector control, only some of the more promising ones are considered here, with emphasis on those that could be used in community programs to achieve greater sustainability.

1. Pesticides

Although DDT and other organochlorines have been banned in many countries and replaced in others because of vector resistance or adverse effects, many other synthetic insecticides are still available. WHO listed 37 compounds in common use for the control of vectors and pests of public-health importance. In some places, such as vast amounts of insecticides are still used each year for mosquito control. DDT was replaced initially by organophosphates, such as malathion, and more recently by synthetic pyrethroids, such as permethrin, which are costly but effective at very low doses. Unfortunately, there are already many reports of mosquito and biting-fly resistance to pyrethroids, some of them also because of cross-resistance to DDT.

Table 13.2 some pesticides used in public health.

Pesticide class and name	Vectors and modes of application	Remarks
Insecticides		
Organochlorines		
DDT	*Anopheles* spp.; house spray	Banned in many countries
BHC (lindane)	*Anopheles* spp.; house spray	Banned in many countries
Endosulfan	*Glossina* spp.; aerial spray	
Organophosphates		
Malathion	*Anopheles* spp.; house spray	
	Aedes spp.; fog, aerial spray	
Fenitrothion	*Anopheles* spp.; house spray	
	Aedes spp.; fog, aerial spray	
Chlorpyrifos	*Culex quinquefasciatus* larvae	Used in polluted waters
Temephos	*Aedes aegypti* larvae, *Cyclops*	Used in drinking water
	Simulium larvae; aerial spray	Used in OCP,[a] W. Africa
Carbamates		
Bendiocarb	*Anopheles* spp.; house spray	
	Triatomines; house spray	
Propoxur	*Anopheles* spp.; house spray	
Pyrethroids		
Pyrethrum extract	Mosquitoes; coils	
Permethrin	Mosquitoes; nets, clothing, soap	
Deltamethrin	*Anopheles* spp.; house spray, nets	
Microbials		
Bacillus thuringiensis israelensis	*Aedes* spp. larvae	
	Simulium larvae; aerial spray	Used in OCP, W. Africa
B. sphaericus	*Culex* spp. larvae	
Molluscicides		
Niclosamide	Snail hosts of *Schistosoma*	
Endod	Snail hosts of *Schistosoma*	Extract of *Phytolacca* seeds

[a] OCP = onchocerciasis control program.

2. Biological Control

Pathogens

Some effective microbial pesticides are now available for vector control especially spore/crystal preparations of B. thuringiensis serotype H-14 var. israelensis (Bti) and B. sphaericus. These microbials are highly toxic and specific to the targeted larvae of mosquitoes and blackflies. However, they are relatively expensive and difficult to formulate because the toxic crystals sink and become inaccessible to most larvae, although floating, slow-release formulations of Bti are now available. Bti is widely used in the onchocerciasis control program in West Africa and, increasingly, for mosquito control. Because these microbial pesticides are virtually nontoxic to mammals, they can be applied by community volunteers.

Plant extracts

Endod, an extract of seeds of the Ethiopian plant *Phytolacca dodecandra*, and *damsissa*, a product of Ambrosia maritima in Egypt, are effective against the snail intermediate hosts of Schistosoma. Other local natural products could be developed for vector control. For example, fruit pods of the tree Swartzia madagascarensis, widely used in Africa as a fish poison, were also found to be toxic to Anopheles larvae and Bulinus snails; Alpha T from the marigold flower (Tagetes) is toxic to mosquito larvae.

Predators

Larvivorous fish such as Cambusia affinis have been used for controlling mosquito larvae for many years. Among the more promising recent developments is the use of young Chinese catfish (Clarias fuscus) to control Ae. aegypti in household water containers in China and a community-based malaria-control scheme in India, which paid for itself by selling carp and prawns that were reared in the same group of ponds as the guppy fish used for controlling mosquitoes .

Many other organisms have been tested for the biological control of vectors. Candidates for controlling larvae of Ae. aegypti and other mosquitoes that develop in small containers are dragonfly larvae, the copepod crustacean Mesocyclops aspericornis, and the predatory mosquito species, Toxorhynchitis

3. Personal protection

Personal protection includes all measures taken at the individual or the household level to prevent biting by vectors. Anklets impregnated with repellents significantly reduced biting rates of mosquitoes. Washing with soap containing a repellent (diethyl toluamide, DEET) or an insecticide (permethrin) reduced mosquito biting rates. Bed netting has been used for centuries to give personal protection against biting insects. When impregnated with insecticides, the netting provides community protection as well; mosquitoes rest on the treated fabric and are killed. In numerous large-scale trials in various parts of the world, malaria transmission appears to have been reduced by the systematic use of nets impregnated with permethrin or deltamethrin. House improvements such as screening, insecticidal paints , and filling in cracks in the walls could provide definitive measures against some house hold insects.

4. Trapping

Mechanical and other types of traps have been used to reduce populations of tsetse flies. Several designs have been developed, some of them incorporating chemical attractants and insecticides. In Uganda, an effective tsetse trap has been made from old tires and locally available plant materials. Light traps, installed in pig sites, have been tested for the control of Culex tritoeniorhynchus in Japan.

5. Environmental management

Changing the environment to prevent vector breeding or to minimize contact between vectors and people can be an effective control mechanism. Environmental management methods include:

· Environmental modification, i.e., any permanent or long-lasting change in land, water, or vegetation, such as filling, draining, or forest clearance;

· Environmental manipulation, e.g., flushing streams, changing water salinity, and removing shade plants; and

· Modifying human habitation or behaviour, e.g., locating new settlements away from vector populations, modifying house design, and changing water supply and waste disposal.

Intermittent irrigation was used to prevent the development of mosquito larvae in rice fields and layers of expanded polystyrene beads prevented Culex quinquefasciatus from laying their eggs in wet pit latrines. Much environmental management work can be done by community volunteers with guidance in the initial stages from vector-control specialists.

6 Training and education

Integrated control strategies require more people trained in vector biology. In addition to the usual sources of health education, such as schools and clinics, information can reach the public through billboards, newspapers, radio, and television.

The role of the community

Many problems and failures in vector control have been due, not only to technical difficulties, poor management, and lack of continuity, but also to the fact that not enough attention had been paid to the beliefs and attitudes of the affected communities. For example, many Ae. aegypti control campaigns in the past 20 years have relied too heavily on ultra-low-volume spraying, which is not always effective. The use of this method has given people a false sense of security, reinforced their belief that Ae. aegypti control is the government's responsibility, and taken away the pressure to get rid of larval habitats in their own backyards.

A recent WHO report, explores the ways in which more responsibility for vector control can be transferred from the national to the district level and ways of getting people more involved in protecting themselves against vector-borne diseases because "community participation makes people more aware of their ill-health and general underdevelopment and of how they can overcome these problems." Vector control at the community level has to compete with more basic needs, such as food, shelter, and employment, and the need for it may not be appreciated during periods of little or no disease.

Nevertheless, examples of successful community participation include: setting tsetse traps; draining, filling, or clearing weeds from mosquito breeding sites; rearing larvivorous fish; source reduction of Ae. aegypti; and distribution of nylon filters to keep Cyclops out of drinking water. Vector-control campaigns should work closely with primary health-care programs to achieve greater effectiveness and sustainable results.

Despite promising results, long-term community participation in vector control must be secured, because operations, such as the control of container-breeding mosquitoes, may have to be continued indefinitely. Little is known about extending pilot projects into permanent national programs. Community volunteers may become victims of political struggles or professional rivalries if their work is not given proper recognition. The best chance of maintaining community support seems to lie in integrating vector control into the primary health-care system, which is now established in many countries. More research is also needed on how to coordinate vector control with work in agriculture, forest and water management, and on the role of migrant workers in disease ecology and control.

Community-based vector control is not a way to reduce government spending. Although local initiatives should be encouraged, each country will still need teams of professional vector-control workers, using well-established methods, to meet its obligations under international health regulations.

13.5 Research on community strategies for vector control

Building research capacity, producing new knowledge, and creating linkages among researchers are perceived as essential components of development by the International Development Research Centre (IDRC). However, IDRC-supported projects must contribute to improving the welfare and standard of living, particularly of the poor and disadvantaged who are to be the ultimate beneficiaries of the research. IDRC tries to ensure that the activities it supports meet the long-term goals of development as viewed from the perspective of these beneficiaries: sustainable growth, equity, and participation.

Conclusions

Disease vectors will probably remain with us indefinitely. Optimizing use, doses, and safety of control measures and balancing vector control with consideration for the environment is a challenge we must face. Future considerations must include such questions as whether an insecticide-free environment is possible, or desirable. All development projects should include ecological planning to prevent increases in vector-borne diseases. Environmental management must be considered on both the large and small scale. The role of the primary health-care system must be defined and inter-sectoral cooperation obtained. The goal is to ensure that vector-control strategies satisfy ecological requirements as well as local needs and priorities, that they are shaped around people's lifestyles and living patterns, and that they promote community self-reliance with respect to ongoing development.

Roles of different controls for insect pests and diseases

This section provides background information on the different methods for control of insect pests, diseases as a basis for research on, and implementation of integrated pest management (IPM). It links in particular to Technical/Socio-economic activities, and Advantages of the IPM Approach.

Significance of different controls

In general, the conventional or traditional control components available for an IPM programme are the same for insect pests and diseases - (i) cultural and mechanical; (ii) biological; (iii) host plant resistance; and (iv) chemical. In addition, there are novel **c**ontrols which are specific to a particular kind of pest, for example behavioural or sterilization controls against some insects. Therefore the same set of tools is available for implementing IPM of the different types of pests, but its relative significance varies greatly according to the pest. The nature of the pest fundamentally affects the significance of different control mechanisms. diseases and pests cause direct damage. In general, pathogens have a much more intimate relationship with the host than do insect pests.

Role of different IPM control components

In an IPM approach, it is vital to recognize that absolute resistance, for example immunity, is not necessarily the goal; in fact it may well be the wrong goal because of the likelihood of resistance breaking down. Small degrees of resistance can make other components of the IPM armory much more effective than would be expected from purely additive effects.

Cultural and mechanical controls- These have been the cornerstones of many pest control practices, particularly in arable agriculture throughout the world. They remain the single most widely used control method in both industrialized and developing countries, even though the use of many such controls has been eroded through the substitution of pesticides.

In conclusion, much more attention must be paid to the whole range of cultural controls, especially as they have so often tended to be disregarded because their value has not been appreciated, or because it has seemed easier or more effective to replace them with pesticides.

B Biological controls- The value of biological control is also demonstrated by the resurgence phenomena associated with the use of broad-spectrum insecticides, which kill not only the pest, but also its natural enemies. If the pest is one that re-establishes itself more quickly than its natural enemies, a single treatment of a crop with the pesticide will be followed by a more intensive attack, requiring a further spray, and creating an even greater problem.

Proper understanding of the management of indigenous natural enemies of pests is one area of research which could lead to far more environmentally desirable procedures for pest management. Biological control by indigenous natural enemies of pests is not only environmentally desirable, but is generally compatible with other control procedures, such as cultural controls, host-plant resistance, and proper use of pesticides.

Our understanding of the biological control of pathogens is still in its infancy. There is good evidence that competitors have a major impact on rust pathogens, and cultural controls often work effectively because of their influence on soil-borne pathogens. Retention and enhancement of natural biological controls against most pests must be a major factor in desirably safe and sustainable pest management practices. Much research needs to be done to enable them to achieve their full potential.

Chemical controls-The vast array of pesticides now available, firstly insecticides and then herbicides and fungicides, has transformed pest management. Their very success has led to well-known serious misuses and to a damaging reputation, the context in which IPM developed. However, this has sometimes led to over-reaction: the actual and potential value of chemical pesticides must be recognized, both for food production and for disease control. We must accept that many pesticides have an important role in the IPM armory. The key question is how to use them rationally, as a component of IPM, as and when necessary. At present there are no new alternatives. Moreover, some emerging technologies such as those based on genetic engineering and the use of pathogens may have more serious disadvantages for man and the environment than many currently used synthetic pesticides.

Certain insecticides must be seen as environmentally hazardous through their toxic effects on man and on various biological systems. Many of the worst have been phased out; however there are ironical situations in some countries, whereby some pesticides highly toxic to man are still being recommended, while relatively safe alternatives have been banned because they are harmful to natural enemies of pests. In the foreseeable future, pesticides must be recognized as essential components of many IPM practices. In many cases they are being excessively used or badly applied, and one of the main priorities, often the first priority of an IPM program, is their rational use.

The above comments indicate the vital role of the traditional control components for IPM implementation programs. Such controls are fundamental to any pest management system, though it is disappointing that other kinds of control have so far made relatively little impact on the pest management scene. At present, we must therefore rely heavily on the four basic methods listed above, and on improvements in their integration.

13.6 Insecticides

13.6.1 Introduction

Insects and other arthropods control measures in use today fall in to two broad categories; namely-the chemical and biological control methods. In practice they may be used separately or in an integrated manner.

Insecticides are substances or an agent that kill insects and other arthropods. Theoretically insecticide should have the following characteristics. It has to be cheap in terms of cost, easily prepared for use, on-corrosive and non-odorous. However at present there is no such perfect insecticide that fulfills all the standards mentioned above.

13.6.2 Types of Insecticide

Chemical insecticides are the predominant materials in use today to control insects. They are generally classified in to seven categories based on their chemical composition (formula).

1. Inorganic insecticides

These are one of the oldest group of chemicals employed to control insects, but with certain exceptions, they are not in a widespread use today. One of these exception is the group of arsenical insecticides, the most common one is lead arsenate. Soluble arsenicals, like sodium arsenite are incorporated in to dipping baths for the control of ectoparasites, or in to poison baits for different insects. Various fluorine compounds such as sodium fluoride (NaF) which is water soluble, barium fluosilcate (cryolite), which are insoluble in water, have a similar insecticidal action as that of sodium arsenite.

Elemental sulphur and inorganic sulphur compounds have some insecticidal properties but they are better used as acaricides and fungicides. Lime sulphur, which is a mixture of calcium polysulphides and calcium thiosulphate, and mercurous chloride (Hg_2 Cl_2)are also have insecticidal effect under inorganic insecticides.

2. Botanical insecticides

It has been known for many years that plant extracts have insecticidal properties which cover a wide range of chemical types Alkaloids are one of the best known botanical insecticides, which are basic, cationic compounds containing nitrogen, often in a heterocyclic ring.

Those extracts known as sabadilla, Reania and Quassia give several insecticidal alkaloids. For example when the seeds of sabasilla is crushed and extracted with organic solvent yield a mixture of several insecticidal alkaloids known as veratrin. Ryanodine is the principal in alkaloid present in the stems and roots of the shrub Ryania species while quassia is extracted from the food of the tree Quassia amara These the above extracts have relatively a minor commercial importance today.

The insecticide based on Nicotine, Rotenone and pyrethrum are much more familiar and of these, nicotine has been in use predominantly. It is extracted from the leaf of several nicotine species.

Pyrethroids are some what expensive to produce, and deteriorate rapidly on exposure to air . They have a wide use an insecticide, especially against house hold insects. They are most often formulated as aerosols ad have a rapid paralytic or "Knock-down" effects on insects. They are harmless to man when ingested or touched.

3. Organochlorine Insecticides

DDT (Dichloio-Diphenyl-Trichloroethane) was the first commercially produced chlorinated hydrocarbon insecticide and is still one of the most important substances used in insect control.

The toxic property of DDT, Unlike some of the botanical insecticides persist for some time after application this is because it is non-volatile insoluble in water and not particularly lead to oxidation. Benzene hexachloride (BHC) is also one of the organochlorine insecticides. The crude product is a mixture of about seven isomers and it has unpleasant odour. Due to this unpleasant odour, BHC is best substituted y other product called Lindane, (which is similar with BHC) Toxaphene (chemically quite different from BHC), Chlordane, Heptachlor, are also widely used for the control of house hold insects. Endosulphan, Aldrin, Dieldrin and Endrin (Cyclodi-enes are based on naphthalene), etc. are another examples of organochlorine insecticides.

4. Organophosphorous insecticides:

Tetraethyl pyrophosphate (TEEP) is the organ phosphorus compound demonstrated by Schrader of Germany. This compound has an oral M.L.C to rate of about 1.0 mg/kg, but because it is rapidly hydrolysed by moisture, it is rendered inactive within a few hours of application. Generally Dimefox, Durbsa, Couaphos, Dichlorovos, Parathion, Diazinon, Malathion, Trichlorophos, fenchlorophos, etc, are some examples of insecticides under this group.

5. Carbamate insecticides:

Generally carbamate insecticides are an insecticide that contains esters functional group in common in their chemical structure. Physiostignine, Dimetan, carbaryl, butacarb, isolan are some of the representative insecticides under this group. As with DDT, the first commercially produced carbamate insecticides is esters of dimethyl carbamic acid. Its earliest product was known as Dimetern.

6. Dinitrophenol insecticides:

These insecticides have been known fro a number of years to have insecticidal Properties. All insecticides under this group have a phenol ring in common.

DNOC (Dinitro- ortho- cresol), Dinex (Acyclohexyl phenol derivative), Dinsoeb (An ethyl-n-propyl derivative) etc. are examples of this group of insecticides.

7. Organothiocyanate insecticides

Organothiocyanates were originally developed as possible alternatives to the pyrethrins but have found only a limited market because the pyrethrins can be produced more easily and cheaply.

There are two main groups of insecticides, the various lethanes and Thanite. The lethanes are of moderate toxicity but Thanite is quite safe with an oral M.L.C. of 1600 mg/kg to rats. They are used as “knock-down” agents in aerosol formulations for household and dairy application and as sprays for the control of human lice and bed bugs.

13.6.3 Insecticide formulation and Application

The addition of substances (solvent or diluent) which enable a given chemical insecticide to be used to the greatest advantage in any given situation is known as formulation. The active ingredients of insecticidal products are expensive to produce and it is toxic at low concentration. In order to apply small quantities accurately to the target area, there are many practical difficulties to the distribution of only a few chemicals on the area, therefore, to overcome these difficulties diluting the material until it reaches a manageable volume that is easy to operate is needed.

Generally there are three types of formulation;- liquid, dry (dust) and gaseous formulations.

1. Liquid Formulations

Water, because of its relatively low cost and ease of availability, is most commonly used as a diluent for liquid formulations.

Unfortunately, many organic compounds are insufficiently soluble in water. To solve this problem insoluble solids may be formulated as wettable powders, it is a process which entails their being mixed intimately with an inert carrier, which is easily suspended in water. The application of such formulation could be by dipping, or by forcing out the liquids through fine nozzle so that it emerges as droplets (small diameter size suspend in the air while others drop).

2. Dry (dust) Formulation:

It should be noted that with dry formulations the diluent and insecicide are mixed at the time of manufacture rather than at the site of application. This helps in saving of time. Dusts are usually acceptable for personal application when it is necessary to cntrol human ectoparasites. The disadvantage of dry formulation is dust diluents can be much more expensive than water and also diluents are bulky to transport.

3. Gaseous Formulations:

Certain insecticides which are solids or liquids at normal teperatures can be formmulated so that they can be dispersed or exert their toxic effects in the vapor phase. A heat source is usually required for volatilization and in some case this can be generated by the incorporation of pyrotechnic chemicals in to the formulation. Vapors produced by this methods cool in to aerosol - type droplets which eventually crystallize on cold surfaces if the active ingredient is a solid.

13.6.4 Dilution Formula for Mixing Insecticides

Technical grade insecticides:- are an insecticides that exist in its purest commercial form. These insecticides must be made in proper strength solutions, emulsion, suspensions or dusts before application. Liquid sprays are often purchased as concentrated solutions or emulsifiable concentrates.

Concentrated solution, therefore, may be diluted with oil and emulsifiable concentrates with water to prepare a solutions or emulsions with appropriate strength. Dusts are often diluted with talc, pyrophylite of flour, wettable powders are mixed with water to form suspensions of desired concentration. The following formulae can be used to prepare a finished spray insecticides with desirable concentrations.

A. Formula Number one : (Subtraction formula):- used for mixing liquids with liquids or solids with solids.

I. X = C – S/S, where: C = Percentage of the available concentrate

S = Percentage of the finished spray or dust desired

X = Number or parts of diluent added.

II. X = C/S- 1.i.e., $\frac{\text{Available \%}}{\text{Desired \%}} - 1$

Example: - 1. Dilute 25 % lindane emulsifiable concentrate to 0.25 % finished spray emulsion.

Solution:

$\frac{C}{S} - 1 = \frac{25\%}{0.5\%} - 1$ Answer = 1: 49.

2. Make 50 gallons of 1% lindane spray using 25% lindane concentrate and water. How many gallons of lindane concentrate should be used?

B. Dilution formula Number Two: (" SAC " used for mixing liquids with liquids or solids with solids).

$$Q = \frac{S \times A}{C} = \frac{(\text{Desired})\ (\text{Amount wanted})}{\text{available }\%}$$

Where:- Q = Quantity of a concentrate to use (gals or lbs)

S = % of active ingredient required in the finished spray or dust.

A = amount of spray or dust to be prepared (gals or lbs)

C = % of active ingredient in concentrate.

Example 1: Prepare 100 kg of 2% chloridane dust using talc and 5% chloridane dust.

<u>Given:</u>

S = 2%

C = 5%

A = 100%

<u>Solution:</u>

$$Q = \frac{S \times A}{C} = \frac{2\% \times 100\text{ kg.}}{5\%} = 40\text{ kg} = \text{Active ingredient.}$$

The amount of diluent (talc) = 100 - 40 kg = 60 kg.

N.B: The result can be interpreted as, to get 100 kg of 2% chloridane dust add 40 kg of 5% chloridane dust and 60 kg of talc.

C. Dilution formula Number Three: (“SADSAC” formula) for mixing liquids with solids.

This dilution formula may be used to prepare a solution or suspension using either the technical grade insecticide or a concentrate.

$$Q = \frac{S \times A \times D}{C},$$ where Q = quantity of concentrate to use. (lbs)

S = % of active ingredient desired in finished spray

A = Amount of spray to be prepared (gals)

C = Density or weight of diluent (lbs/gals)

Example:

1. Make 50 gallons of a 2.5 % DDT solution in deodorized kerosene. The kerosene weighs about 6.6 pounds per gallon. Use a technical grade DDT.

Given: Solution:

S = 25% Q = 2.5% x 50 gals x 6.6 lbs/ gals = 8.25 lbs.

A = 50 gals.

D = 6.6 lbs / gals

C = 100 %

N.B: To prepare 50 gallons of 2.5 percent DDT mix 8.25 pounds of DDT with sufficient kerosene to reach the 50 gallon mark on the drum or other container used.

2. Make 100 gallons of BHC suspension containing 1.25 percent BHC use the 75 percent water wettable BHC powder. The water weighs about 8.3 pounds per gallon.

Solution:

Q = 1.25 % x 100 gals x 8.3 lbs/ gal = 13.8 lbs. Therefore, to make 100 gallons of BHC suspension containing 1.25 percent BHC add 13.8 poundss of 75 percent water wettable BHC to a tank partially filled with water, while agitating the mixture until the 100 gallon level is reached.

N.B: The malaria control program of Ethiopia uses 133 gram of 75% water wettable DDT concentrate for every liter of water in order to prepare 10% water wettable suspension, which is the normal finished spray.

13.6.5 Health Impacts of Insecticides:

The effect of insecticides on human health can be divided in to two categories.

A. Short term effects; include acute poisoning and illnesses caused by relatively high dose and accidental exposures, and
B. Long-term effects; suspected to include cancer, birth defects, immunological problems, etc. The long term health effects may be caused by very low doses of a variety of different chemicals.

According to World Health Organization (WHO) estimate that some one million people suffer acute pesticide poisoning and at least 20, 000 die each year. It is further estimated that two-thirds of this illness and death results from occupational exposures in developing countries where people use insecticides without proper wearing of protective clothing.

13.6.6 Classification of Insecticide by Mode of Action

Insecticides can also be classified by their mode of action (ways in which insecticides actually kill insects) or by the ways in which they enter the insect system and cause them to death. This is not the best ways of classification, in that different formulation of the same chemical may penetrate an insect by more than one route.

1. Contact Insecticides (poisoning):

These are insecticides that are able to pass through his insect exoskeleton or egg shell on contact with the organism body wall or tarsi. Death of the insect is either due to the concentration of the poison or due to area of the insect body contaminated.

This contact insecticide may be in the form of air borne droplets (mist, fog) or particles which either fall directly on to the insect from the applicator or in to which tthe insect flies of its own accord. Aerosols are good examples of conact insecticide that has a rapid “knock down” effect .

Sulphur containing insecticides, mercury groups such as mercureous chloride (calomel) and alkaloids are some representative examples of contact poisoning. Surface deposits on the other hand act as protectants in that they will control infestations which arise after application, and the duration of the deposit. Organochlorines are good examples of protectant insecticides.

2. Stomach poison insecticides

These are type of insecticides (poisons) taken in by insects during the coarse of normal feeding activities. The poison must be swallowed to cause death. The death of victim depends on the concentration of poison and on the amount eaten. Mandibulate insects are conveniently controlled by applying toxicants to their natural food material or synthetic baits.

Inorganic insecticides, mainly the arsenicals, and lead, copper, calcium etc are good examples. Both organochlorine and organophosphorous in nature can also be used as stomach poisons. What is important here is, insecticides of this type must not have a repellant effect and must be absorbed from the gut of the insects.

3. Fumigant insecticides

For this type of insecticide the external openings of the respiratory system are the main access points for fumigants although some may pass in across the general cuticular surface, particularly of the egg stage. The entry of the fumigant is thus independent of the structure of the mouth parts. Fumigants do not require an insect to move over a treated surface in order to exert their effect.

The main objective of fumigation is thus to get the fumigant in to the tracheal system, and to do so the spiracles required to be open during treatment.

13.7 Equipment for Insecticidal sprays and safty measures

13.7.1 Equipments for liquid Application

Equipments for chemical application can be sub-divided in to manually operated and power operated equipment's.

Manually operated- sprayers:

1. Hand-carried sprayers:

These sprayers are both held and operated in the hand or hands. They are usually constructed of brass, mild steel, stainless steel or plastic. The liquid capacity varies from 1/4 pint (0.15 litre) to 1 gallon (4.5 litres), but the usual size varies from 1to 2 pint (0.5 - 1 litre).

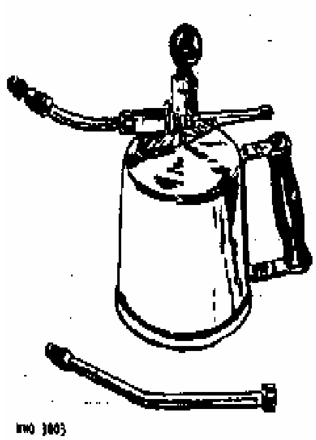

Fig. 6.1. Continous or Compression hand sprayer.

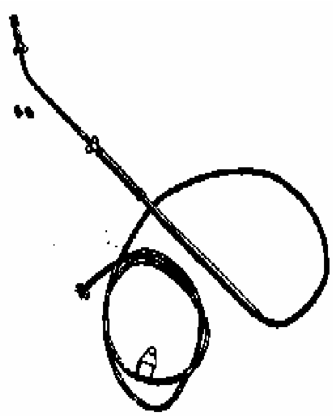

Fig. 6.2. Bucket sprayer with trombone pump.

(Source: Equipment for Vector Control: WHO-1964)

According to the method of operation, hand carried sprayers are divided in to intermittent sprayers and continuous or compression sprayers. The formers are those operated by a simple pump, which may be either a solid piston or a plunger type with a cup leather. And the latter type of sprayers operate on the same principle as the well known knapsack sprayer. The container is filled to approximately two-thirds of its capacity and the remaining air space is then compressed by means of a small built- in air pump of the plunger type. The container has to be sufficiently robust to withstand the pressure required to expel the liquid contents from the nozzle via a suitable trigger control valve.

2. Bucket sprayers:

The container for this type of srayer is a bucket or similar convenient receptacle, such as empty oil can or drum. The materials of construction are usually brass or plastic or a combination of the two. The pumps used are:-

i. Lance, trombone or slide pump:

In here, the pump is operated with hands, one hand steadying and directing the spray and the other operating the pump. These pumps are usually double-acting, i.e., pressure is applied to the liquid on both the forward and backward strokes. The pumps are nearly always continuous in action, but occasionally a single acting pump is employed, in which case the spray production is intermittent.

ii Stirrup pump:

These are of two type: the plunger or piston type pump that may be used in which there is a suction valve and strainer at the lower end. This is lowered in to the liquid in the bucket and held in place during operation by placing the foot on the flat stirrup provided.

The second version of this pump is fitted with a length of suction hose and strainer intake which enables it to be used with a much deeper container than is possible with the first type.

3. Knapsack or shoulder-slung sprayers:

There are different types of knapsack sprayers, but almost all have the same sprayer unit and one is differ from other only in the method of carrying the sprayer. Generally they are subdivided according to the method of operation.

i Lance, trombone or slide pump:

The same type of pump as described under bucket sprayers us used in conjunction with either a knapsack or a shoulder-slung container. The containers may be made of plastic materials, which may be either flexible or rigid, or from metal. The flexible plastic types are usually shoulder slung and are often used in conjunction with a pump of simple manufacture which may also be made of a plastic material. These type are inexpensive sprayers intended only to last for a limited period of use (one season).

ii Lever-operated plunger pump:

A conventional plunger pump is either mounted on the outside of the container or placed inside the container and immersed in the liquid content. The pump is operated by hand lever, which may either be so placed that in use it comes under the arm and is moved up and down by the hand, or it may pass over the shoulder and have a short chain or rod with a handle at the end which is pulled and released to operate the pump.

iii Lever operated diaphram pump:

The pump may be mounted externally on the container, in which case it is usually placed with in the protective skirt around the bottom of the container, or it may be mounted inside and immersed in the liquid contents.

The operating lever of this type is invariably of the under arm pattern, and it is uncommon to find provision for changing the lever from one side to the other. A small air vessel is again provided to even out the pump impulses and to maintain spraying pressure between the pump strokes.

4. Compression sprayers:

The essential feature of this type of sprayer is that the container is a pressure vessel. Normally, the container is filled with the liquid to be sprayed to about three quarters of the total capacity. The container is then closed and compressed air is forced in to the space above the liquid by means of a plunger type pump. It is this stored pressure which expels the spray liquid from the bottom of the container through a hose to the cut-off valve, lance, and nozzle. The capacity of the container varies from 1 - 6 gallon (4.5 - 27 litres).

5. Stretcher or pole-carried sprayers:

These sprayers are designed to be transported from place to place between two persons, either carried with the hands by the stretcher-type handles provided, or carried on the shoulders by poles placed through lungs or loops on the sprayer. The container is usually separate and is often provided locally or improvised. The pumps are usually of the plunger, solid-piston, or diaphragm type. These sprayers designed for operation from a fixed position with one or more hoses of lengths up to about 60 ft (18 meter). The pump has a hand lever which is usually double acting.

6. Barrow sprayers:

These type of sprayers are mounted in a light wheel barrow frame, with single or double wheels, so that they can be either pushed or pulled in to the vicinity of the area in which it is desired to spray. The container capacity ranges between 10 - 45 gal. (45 - 200 liters). The three pumps, the plunger, piston and diaphram type are used and operated by a hand lever.

13.7.2. *Power operated sprayers:*

Power operated sprayers are almost identical in design to the previously described manually operated sprayers, except that they all utilize power driven plunger, solid piston, diaphragm or rotary type pumps. When high pressures are required either the plunger or solid piston pump is used. Electric motor or internal combustion engines are used to power these type of equipments.

Power operated stretcher carried sprayer, power operated barrow sprayer and tractor sprayers are good examples.

1. *Tractor sprayers:*

Tractor sprayer are of two type, i.e. the mounted type, in which the sprayer is attached to the tractor and completely carried on the tractor both in and out of operation, and the trailed type of tractor sprayer, which is larger than the mounted type and designed to be drawn but not carried by a tractor.

2. *Vehicle sprayers:*

These type of sprayers are intended to be mounted on any suitable vehicle. The equipment is frequently provided with skids to facilitate loading. Some times the equipment is trailed behind the vehicle.

3. *Air craft sprayers:*

All equipment of the hydraulic type is included under this heading, the basic essentials being the container or containers, a pump, and a spray bar or boom to carry the nozzles. The container may be placed inside the air craft or may be carried externally as panniers on the fuselage, as is common practice on small rotary wing aircraft.

13.7.3. Choices of Applicator Selection:

The choices of applicator are usually carried out based on the size, durability, explode and spare part availability. The capacity of the tank is very important for choosing applicators. For easy operation the maximum recommended size of an application is 50 liter.

13.7.4 Safety Measure during Insecticide Handling:

Insecticides are toxic to both pests and humans. However, they need not be hazardous to humans and non-target animal species if suitable precautions are taken. Most insecticides will cause adverse effects if intentionally or accidentally ingested or if they are in contact with the skin for a long time. Insecticides particles may be inhaled with the air while they are being sprayed. An additional risk is the contamination of drinking water, food or soil. Care in handling insecticides, particularly in relation to spray man and people live in sprayed houses, should therefore, be routine practice and should form an integral part of any program involving the application of insecticides.

Special precautions must be taken during transport, storage and handling. Spray equipment should be regularly cleaned and maintained to prevent leaks. People who work with insecticides should receive proper training in their safe use. It is important to take in to consideration both the nature of the insecticide, including its formulation and the proposed method of application before use. The following factors may influence chemical hazards: type of formulation, type of ackaging, concentration of the insecticide, method of application, amount of surface or area to be treated dosage required, association of human or animal populations with treated surface or area, and the species or animals exposed, their age, sex and condition.

The planning of a vector control campaigns must include provision for the safe transport and secure storage of insecticide concentrates, which should not be stored in rooms in which people live or in food storage. They should be stored out of direct sunlight and protected from rain and flooding. Protection against theft, misuse and unaccessibility to children must be noted.

13.7.5 Precautions

1. Insecticides should be packed and labeled. The label should be in English and in the local language, and should indicate the contents, safety instructions and possible measures in the event of swallowing or contamination.

Fig. 6.5
Types of pesticide container (adapted from 2).

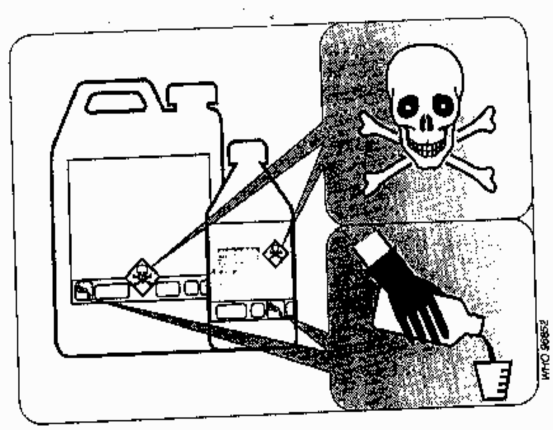

Fig. 6.6
look for warning symbol pictograms and colour coding on labels (adapted from 2).

(Source: Jan A. Rozendaal: WHO 1997)

2. Store insecticides in a place that can be locked and is not accessible to unauthorized people or children.

3. Left over insecticide suspension can be disposed of safely by pouring it in to a specially dug hole in the ground or a pit latrine. It should not be disposed of where it may enter water used for drinking or washing, fish ponds or river.

4. Do not eat, drink or smoke while using insecticides. Keep food in tightly closed boxes.

5. Spray workers should wear, overalls or shirts with long sleeves and trousers, a broad-brined hat, a turban or other headgear and sturdy shoes or boots. The mouth and nose should be covered with a simple device such as a disposable paper mask, a surgical-type disposable or washable mask, or any clean piece of cotton. Furthermore, training in the safe use of insecticides should be given to the workers. The training should include the techniques of spraying, safety precautions, protective equipment, recognition of the early signs and symptoms of poisoning, and first aid measures.

6. Clothing should be kept in a good state of repair and should be inspected regularly for tears or worn areas through which skin contamination might occur. Protective clothing and equipment should be washed daily with soap, separately from other clothing.

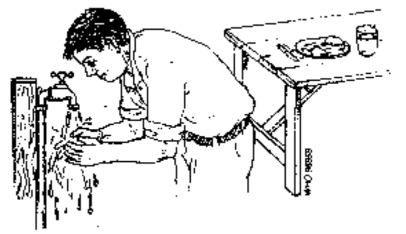

Fig. 10

Wash the hands and face before eating or drinking (adapted from 2).

Fig. 6.11

Wear gloves when handling concentrates.

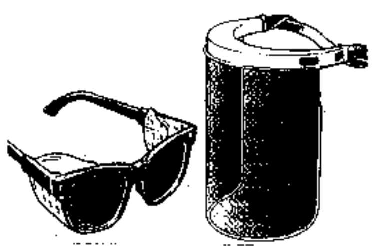

Fig. 6.12

Protective equipment for the eyes and face (adapted from 2).

(Source: Jan A. Rozendaal: WHO 1997)

Review Questions

1. List the different types of hand carried sprayers, Bucket sprayers and knapsack sprayers.

2. Write the difference and similarity between knapsack and compression sprayers.

3. List at least 4 safety measures (precautions) during insecticide handling.

GLOSSARY

1. **Aedegous**- genital organ of male insect
2. **Aerosol:** suspension of colloidal particles in gas.
3. **Appendages**: is any part of the body of insects or arthropods that is attached to the main structure. For instance, wing and legs are the appendages of insect thorax.
4. **Autogeny:** means spontaneous generation.
5. **Bilateral Symmetrical Body**: - is a body, which is divided in to two equal parts like that case of arthropods.
6. **Dichoptic :-** means a bit far apart.
7. **Complete** metamorphosis (holometabolous): type of metamorphosis by which an insect in its life cycle passes through egg, larva, pupa to reach to the adult stage.
8. **Holoptic:** nearer to each other.
9. **Dorsoventrally flattened insects**: - are insects that have a flat anatomical structure at the back and front side of their body.
10. **Epiphytic plants:** a non-parasitic plant that grows on another plant but gets its nourishment from the air.
11. **Incomplete Metamorphosis (hemimetabolous):** type of metamorphosis by which an insect pass through egg, and nymph only during its life cycle to reach to adult.

12. **Integument**: - is the enveloping membrane of insect body.
13. **Larvicides:** chemical agents that specifically used to kill the larvae of insects.
14. **Lymphadenopathy**: - is the enlargement of lymph nodes.
15. **Lymphatic filariasis**: is a disease caused by filarial worm which affects usually Lymph vessels at lower extremities.
16. **"Lyre" shape:** U-shape.
17. **Laterally flattened insects**: - are insects that have a flat anatomical structure at the right and left side of their body.
18. **Minimum lethal concentration**: - is the minimum concentration of a chemical that has a lethal effect on experimental animal.
19. **Myiasis**: - is an affection due to the invasion of the tissues or cavities of the body by the larvae of dipterous insects.
20. **New World:** the western hemisphere or countries or regions in the Western hemisphere**.**
21. **Non-residual Insecticide:** an insecticide that can't stay in the environment for long period of time after spraying.
22. **Old World:** the Eastern hemisphere; the World of Europe, Asia and Africa.
23. **Respiratory Trumpet**: is a breathing tube that is located on the cephalothorax of mosquito pupae that used to take in air from the atmosphere.
24. **Rodenticides**: - are chemical substances or agents that ormally kills rodents.
25. **Residual Intecticide:** an insecticide that can stay in the

environment for longer period after application or spray with out changing its chemical property.

26. **Reservoir:** a living or non-living things where disease causing microorganisms or agents normally live, multiply and transferred to organisms.

27. **Rodent:** any of several mammals, as rats, mice, rabbits, squirrels, etc characterized by constantly growing incisors adapted for gnawing or nibbling.

28. **Savanna habitat:** a habitat where there are grass land which characterized by scattered trees, specially in tropical or subtropical regions.

29. **Scutellum**: - a structure that located in between thorax and abdomen of some insects.

30. **Transovarian transmission:** transfer of disease causing agent from adult animal, particularly of insects to the egg and when the egg reach to adult stage, become infective.

31. **Twi-light:** is a light after the sun-set and before dark.

32. **Zoonosis**: is a disease, which can be transmitted from animals to humans.

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