PART B: Water-associates vector-borne diseases, with the emphasis on the vector

Water-based diseases

1. WATER BASED-DISEASES: Infections with parasites, for which aquatic and semi-aquatic snails function as intermediate hosts.

In this group Schistosomiasis is the only disease that will be discussed. It has a wide distribution and there are an estimated 200 million people infected in tropical areas.

There are two forms of the disease depending on the parasite species involved; one affects mainly the intestinal tract and the other affects the urinary system. Schistosoma parasites are trematode worms, or blood flukes, whose adult stage lives in specific veins in its principal host. They have to spend part of their lifecycle in certain species or species groups of snails.

The intestinal form is caused by Schistosoma mansoni, S. japonicum, or, of much more limited importance, by S. intercalatum. S. mansoni is found in Africa, parts of the Caribbean and in some northern and eastern parts of South America. Snails of the genus Biomphalaria are the intermediate hosts of S. mansoni. S. japonicum occurs in the Far East and is transmitted by amphibious snails of the genus Oncomelania.

S. haematobium, which invades the veins around the urinary tract, occurs in Africa and the Middle East and is transmitted by snails of the genus Bulinus.
All of the above mentioned snail species are found in fresh water, *Oncomelania* is unique in being semi-aquatic. It leaves the water and can be found in considerable numbers on moist ground. Each of the genera (*Biomphalaria*, *Oncomelania*, *Bulinus*) contains a number of species of snails (about 20 in each genus). *Schistosoma mekongi*, although a rare parasite, may eventually become of some significance in relation to water resource development in the Mekong Valley.
Table 3: THE PRINCIPAL GENERA OF SNAILS AND THE PRINCIPAL FORM OF SCHISTOSOMIASIS WHICH THEY TRANSMIT

<table>
<thead>
<tr>
<th>SNAIL GENUS</th>
<th>LIFECYCLE</th>
<th>PARASITE</th>
<th>TYPE OF DISEASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oncomelania</td>
<td>semi-aquatic</td>
<td>S. japonicum</td>
<td>intestinal</td>
</tr>
<tr>
<td>Biomphalaria</td>
<td>aquatic</td>
<td>S. mansoni</td>
<td>intestinal</td>
</tr>
<tr>
<td>Bulinus</td>
<td>aquatic</td>
<td>S. haematobium</td>
<td>urinary</td>
</tr>
</tbody>
</table>

Slide B4
1.1 The life cycle of a Schistosome parasite (S. mansoni as an example)

The way by which humans become infected with schistosome parasites (also called flukes) is one of nature's complex biological systems. Eggs containing the schistosome larvae are passed with the urine or faeces of an infected person into the water. Because of the change of the osmotic pressure in the water, the eggs rupture and the larva (called miracidium) hatches from the egg. The miracidium must enter an aquatic (or amphibious) snail within about 6 to 24 hours, or it will die. Once in the snail, the miracidium develops into another stage called a sporocyst. During a period of 4 to 8 weeks (in Oncomelania the time may exceed 8 weeks), fork-tailed cercariae develop within the sporocysts, and these eventually leave the snail host. After leaving the snail, the cercariae swim about freely in the water in search of a vertebrate host. Unless they are able to contact and enter a suitable vertebrate host within 24 to 48 hours, they die in the water.
For two species, *S. haematobium* and *S. mansoni*, the principle host mostly is human, while *S. japonicum* also infects domestic animals such as water buffaloes, dogs, cats, pigs and rodents. On penetrating the peripheral veins of the host, the cercariae develop into adult...
parasites. After mating, males and females live together as pairs; the bigger male worm holding the smaller female worm within a fold of its body.

*To interrupt the life cycle of Schistosoma parasites, the man-water contact has to be minimized, no faeces or urine should enter the water, or the number of snails has to be diminished.* Chemotherapy, which reduces or eliminates the parasite in man, is another approach to interruption of the life cycle.

1.2 Bionomics of snail intermediate hosts

**Physical factors**: Snails tolerate temperatures from 18° to 32°C and develop best at a temperature of 26°C. As a rule, *snails do not tolerate water velocities higher than 0.7 m/s*, nor turbulences and waves, and seldom are found in water depths greater than 1.5 m.

Some snail species are adapted to the drying-up of water bodies. Such snails may survive where water is present for only three months in the year. Species of *Oncomelania* are semi-aquatic and can survive in marshes. They are well adapted to irrigation systems, rice fields, and especially to drainage canals and ditches.

**Biological factors**: Snails have *few natural enemies*. They frequently attach to relatively dense vegetation, and to *plants giving protection from direct sunlight and water current*. Snails are omnivorous animals and prefer rotting plant material (unicellular green algae is preferred fodder). Aquatic weeds have an important role with respect to the oviposition by snails.

**Chemical factors**: Snails are very tolerant to dissolved matter in water including chlorides, minerals and salt. They may be found in waters of a wide range of pH values (5 to 10). However, water containing barium, nickel or zinc is toxic for snails.

**Water contamination**: *Moderately polluted water* with faecal and/or organic plant material is *most favourable* for the development of snails.

Figure 4: FAVOURABLE HABITAT REQUIREMENTS FOR AQUATIC SNAILS (also preferred by the amphibious species)
Water-related vector-borne diseases

2. VECTOR-BORNE DISEASES: Transmission by insects having aquatic immature stages

2.1 Mosquito-borne diseases

Mosquitoes have a cosmopolitan distribution. The number of species exceeds 3000. Mosquitoes have been classified into three subfamilies - ANOPHELINAE, CULICINAE and TOXORHYNCHITINAE. The latter subfamily does not include vectors of disease and is not discussed here.

Five of the major vector-borne diseases transmitted by the female mosquito while obtaining a blood meal, necessary for the development of their eggs, are presented below. Only malaria, brugian filariasis and Japanese encephalitis are of direct relevance in irrigation projects. The vectors of yellow fever and dengue fever breed in the man-made environment of human settlements. These diseases may therefore be indirectly related to irrigation development.

1. MALARIA: Although there are more than 400 known species of anopheline mosquitoes, only about 30 species can be considered important malaria vectors. Only the female mosquito obtains blood meals. Its ability to be an efficient vector is related to the frequency of man-vector contacts and the longevity of the species in question. Malaria is responsible for high morbidity and mortality rates in the tropical and subtropical areas of the world, especially in the young age groups. The debilitating effects and general impairment of well-being, resulting from the accumulated effects of repeated malaria infections are of great concern, because they hinder the economic and social progress of the regions where this disease is widespread.

2. FILARIASIS: Mosquito-borne filariasis in man includes a group of diseases caused by parasitic worms called filarial nematodes. The species of filarial worms involved are Wuchereria bancrofti, Brugia malayi and B. timori. Wuchereria bancrofti has an extensive geographical distribution and is found in many tropical countries. Several genera and species
of mosquitoes are vectors of filariasis. *Culex quinquefasciatus* is a mosquito found primarily in urban and suburban areas. *Anopheles, Mansonia* and *Aedes* species also can serve as vectors for filarial nematodes.
3. **JAPANESE ENCEPHALITIS** is an acute, often fatal disease caused by an arbovirus (arthropod-borne virus). Patients suffer from fever, may become comatose and die of encephalitis. Recovery often leaves neural impairment. The disease is widely associated with *Culex tritaeniorhynchus*, *Culex pseudovishnui* or *Culex gelidus* mosquitoes throughout South and South-East Asia, China and Korea. Its distribution is particularly associated with flooded ricefields where the mosquitoes thrive. Several vaccines are available.

4. **YELLOW FEVER** is an acute, often fatal disease caused by an arbovirus. The urban type of yellow fever is transmitted by *Aedes aegypti* mosquitoes whereas other genera and species of mosquitoes may be involved with jungle yellow fever. Mosquitoes of the genera *Haemagogus* and *Sabethes* are vectors of jungle yellow fever in the Americas but species of *Aedes* are vectors in Africa. Yellow fever has not been found in Asia. The development of effective vaccines and their mass application have reduced the occurrence of yellow fever, and it no longer has the global importance it had half a century ago. However, occasional cases and sporadic epidemics still occur in Africa and South America.

5. **DENGUE FEVER**, widespread in 60 tropical/subtropical countries, is an acute febrile disease with a low mortality rate, characterized by fever, intense muscular and joint pains, and prolonged incapacitation. The causative agent is a virus related to yellow fever. It is transmitted primarily by *Aedes aegypti*, a container breeding mosquito, that is closely associated with man and urban development. However, other *Aedes* species also may be involved. A more severe disease, dengue haemorrhagic fever, has produced high mortality among children in SE-Asia and 1981 reached the Caribbean region with outbreaks in Cuba (1981), Mexico (1985) and Puerto Rico (1986). No vaccine is available as yet.
2.1.2 The life Cycle Of a mosquito (adapted from WHO Offset publ. No. 66)

The immature and adult stages of mosquitoes are passed in two completely different environments. The immature stage, i.e., eggs, larvae and pupae, require an aquatic environment, and the adult mosquito requires a terrestrial one.

Figure 5: MAIN DISTINGUISHING FEATURES OF ANOPHELINES AND CULICINES (source WHO)
**Egg:** Anophelines lay their eggs separately on the surface of water, and each egg has lateral air floats (af) to keep it afloat. Culicines of the genus Culex and Coquilletidia lay several eggs cemented together as an egg raft on the water, whereas those of the genus Aedes are laid separately, often in dry hollows or containers which become flooded after rain. The eggs of many Aedes species are able to retain their viability without water for long periods.

**Larva:** Eggs of mosquitoes generally hatch after two or three days in contact with water. Some transient pool or floodwater species e.g., Aedes, may hatch within one-half hour of submersion in water. The larva of most species is about 1.5 mm long when newly hatched and about 10 mm long when fully grown. The larvae cast their skins four times, as they mature and finally become pupae. The larva of a mosquito has a head (h), thorax (th) and abdomen (ab) - the latter having eighth distinct segments. A mosquito larva breathes through a pair of orifices at the terminal end of the body called spiracles; those of the anopheline larvae are situated on the eight abdominal segment so that, in breathing, it rests in a horizontal position at the surface of the water.

In culicine larva, the spiracles are situated at the end of a tubular organ, called the siphon (s), which extends from the eighth abdominal segment. The culicine larva hangs down from the water surface by the tip of its siphon in order to breathe. An exception is the genus Mansonia, in which the siphon is highly modified for piercing and adhering to stems of aquatic plants from which air is drawn for breathing.

**Pupa:** The pupa is a non-feeding stage, lasting one or more days. This stage provides for the morphological and physiological changes required for transformation of the larva to the adult. The pupa is mobile and able to dive rapidly when disturbed. When quiescent, the pupa rests at the surface of the water. Breathing is carried out, at the surface of the water, by a pair of respiratory trumpets (tr) extending from the thoracic area.

**Adult:** After emergence (5 to 10 days after the eggs have been laid), the adult mosquito rests for a few minutes on the discarded pupal skin while its wings expand and harden for flight. The proboscis (pr) requires longer to harden and is too soft during the first day after emergence for the female to take a blood meal. The adults of both sexes feed on plant juices. Only the female feeds on blood, because egg development is dependent on a blood meal for almost all anophelines and most culicines. In a few species the first batch of eggs can be laid without a prior blood meal.

### 2.1.3 Mosquito Bionomics

Climatic factors play an important role in species distribution, behaviour, survival, and vectorial capacity. **Water is an essential component of the mosquito environment. The characteristics of the water habitat, whether it is running or standing, clean or polluted, sweet or brackish, shaded or sunlit, permanent or intermittent, is the predominant factor determining which species of mosquito breed in it.** The environments of the immature stages and the adult mosquito are interdependent, since the adult mosquito must have access to water for egg laying.

**Physical factors:** Rate of growth of the immature stages of the mosquito depends in part, on the temperature of the water. This range is lower for species living in temperate rather than in tropical zones and varies somewhat between different species living in the same geographical zone; thus temperature is one of the limiting factors for geographical distribution of a species. Within these optimal ranges, there is a direct relationship between temperature and growth. For example, mosquitoes breeding in the tropical zone, in water at 23° - 33°C, usually complete the aquatic stage of their lifecycle within two weeks. Moderately frequent rainfall often increases the opportunities for prolific breeding, but
repeated and heavy rainfall may cause severe flooding and a temporary flushing out of breeding places and reduction in the mosquito population (except the floodwater complex of mosquitoes). The extent to which the breeding place is shaded or exposed to the sun influences which species of mosquito inhabit a particular habitat. Hedges, planted to give shade over breeding places, or clearing of forests to allow the sun to penetrate have been successfully used for environmental control of some malaria vectors (Anopheles minimus and A. dirus).

**Biological factors:** Unless islands of vegetation are present to provide breeding sites, mosquito larvae are not found on open surfaces of large bodies of deep fresh water (e.g., lakes, ponds, rivers or reservoirs). However, *Anopheles often are breeding at the sheltered shallow edges of lakes, ponds, rivers, or reservoirs.* The immature stages of some species (A. gambiae) are found throughout the entire surface of shallow swamps and temporary rainwater pools. The aquatic environment of some species is *associated with particular plants.* For example, larvae of *Coquilletidia* (a vector of Brugian filariasis) are linked with the presence of water lettuce plants (*Pistia, Eichornia, Salvinia*) while *Aedes simpsoni* (a vector of sylvatic or jungle yellow fever in Africa) are frequently found breeding in leaf axils of banana plants. Other species such as *A. aegypti*, breed in great numbers in small artificial containers including old tins, tyres, water storage vessels, flower vases, ant traps, etc.

**Water contamination, chemical factors:** Some species (*A. funestus*) breed in clear fresh water with vegetation, whereas others are adapted to breeding in brackish water (*A. sundaicus*) or highly polluted water (*Culex quinquefasciatus*). *Anopheles gambiae*, the main vector of malaria in Africa, develops in different types of breeding sites (i.e., from footprints to ponds, etc.).

**Mosquitoes as a group breed in an almost infinite variety of sizes and types of water bodies. Most disease transmitting species, however, breed only in a restricted range of habitats, while few species breed readily in a wide range of habitats.**

Some biological insight into the habitats of the vector species in relation to water resources development can help to offset or reduce the disease problem.
Figure 6: GEOGRAPHICAL DISTRIBUTION OF MALARIA (Source: WHO)

Figure 7: GEOGRAPHICAL DISTRIBUTION OF WUCHERERIA BANCROFTI, BRUGIA MALAYI AND B. TIMORI (Source: WHO)
2.2. Blackflies (=SIMULIUM)

There are many Simulium species, of which the most important is S. damnosum, vector of ONCHOCERCIASIS or “river blindness”, which is caused by a parasitic worm. Onchocerciasis occurs mainly in tropical Africa, but there are foci of the disease in South and Central America, where other Simulium species are the vector. About 18 million people are infected; annually, some 340'000 start showing the pathogenic symptoms of the infection, eventually leading to total blindness.

Figure 8: GEOGRAPHICAL DISTRIBUTION OF ONCHOCERCIASIS (source WHO)

2.2.1 The life cycle of Simulium damnosum

The blackfly, like the mosquito, has the egg, larval and pupal stages in water, but unlike mosquitoes, the habitats are restricted to highly oxygenized fast flowing turbulent water, containing a readily available source of food. The female black fly lays several hundred eggs, and a blood meal is required before each batch of eggs can develop. Depending upon the temperature, development of the larvae takes from 1 week to 15 days.
The larval stages (called microfilariae) of the parasitic worm *Onchocerca volvulus*, the causal agent of onchocerciasis, is engested by the female blackfly during the blood meal and matures in the fly. At a subsequent meal the matured larvae may be transmitted to a second human host where it develops into an adult worm, mates and produces microfiliarae.

Figure 9: THE LIFECYCLE OF *SIMULIUM DAMNOSUM*
2.2.2 Bionomics of blackflies

The main resting places of adult black flies are not well known but females of *S. damnosum* are widespread especially during the rainy season. Their large flight range (upto 200 km when winds are favourable) makes control of adults difficult. Since the larvae are stationary and limited to the turbulent parts of a river they are the easiest to attack with insecticides which can be carried down stream by the water flow. The Onchocerciasis Control Programme in West Africa is based on this approach. Chemical control treatments have been effective upto distances of 50 km or more (when river discharges were large enough) below the point of larvicide application. The development of larval resistance to insecticides has diminished the effectiveness of chemical control in some areas. However, new biological control methods, such as the use of bacteria (*Bacillus thuringiensis*, serotype H14) where resistance to Temephos occurred, have been successful in Côte d'Ivoire.