

A photograph of a person in a field of water, likely a rice paddy. The person is wearing a dark, patterned shirt and is bent over, working in the water. The background shows a vast, flat landscape with green fields and a cloudy sky. The text is overlaid in yellow.

PHC 6937: Water Biology

Diseases Associated With Water-Borne Vectors

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Learning Objectives

- Identify the major vectors of human diseases associated with water
- Describe major diseases transmitted by water-borne vectors
- Describe the life history of major water-borne vectors and the diseases they transmit

Outline of Lecture

- Definitions: Vector, intermediate host, definitive host, larval habitat
- Major water-borne vectors and diseases they transmit
 - Mosquitoes – Parasitic and viral diseases
 - Black flies – Parasites
 - Snails – Schistosomiasis, swimmers itch??
- Life cycle and distribution of water-borne vectors
- Disease manifestations in human

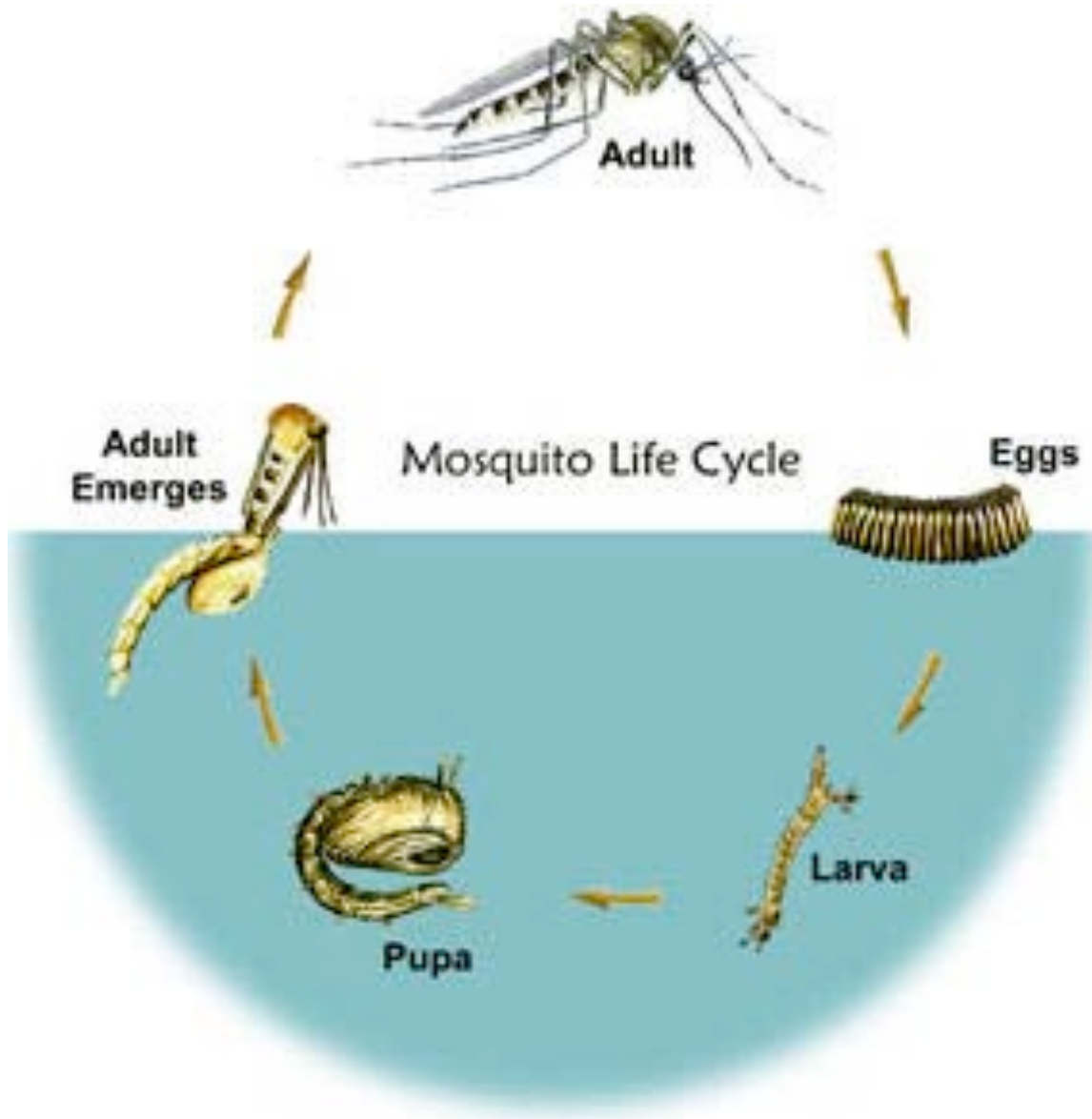
Definitions

- Vector – Any animal that carries and transmits a disease to another animal, usually an arthropod such as mosquitoes that carry malaria and yellow fever and transmit it to humans
- Intermediate host – an animal that hosts the parasite for a short transition period, during which developmental stage of the parasite is completed
- Definitive host – the animal in which the parasite reaches maturity and reproduces sexually
- Larval habitat – a breeding ground for a vector; implies a water body

Major Diseases of Water-Borne Vectors

- Mosquito-Borne Diseases
 - Malaria - *Anopheles*
 - Filariasis – *Culex quinquefasciatus*
 - Yellow fever – *Aedes aegypti*
 - Dengue – *Aedes aegypti*
 - West Nile virus – *Aedes sp, Culex*
 - Rift Valley fever – *Anopheles, Aedes, Culex*
- Black flies - Oncocerciasis
- Snails - Schistosomiasis, Swimmers Itch

The life cycle of a mosquito




- Mosquito species differ in the types of water bodies they use to breed
- *Culex sp* – dirty polluted waters: cess pools, latrines etc
- *Anopheles sp* – fresh water: rain pools, spring water
- *Aedes sp* - fresh water : rain pools on plants, tires, tins and cans

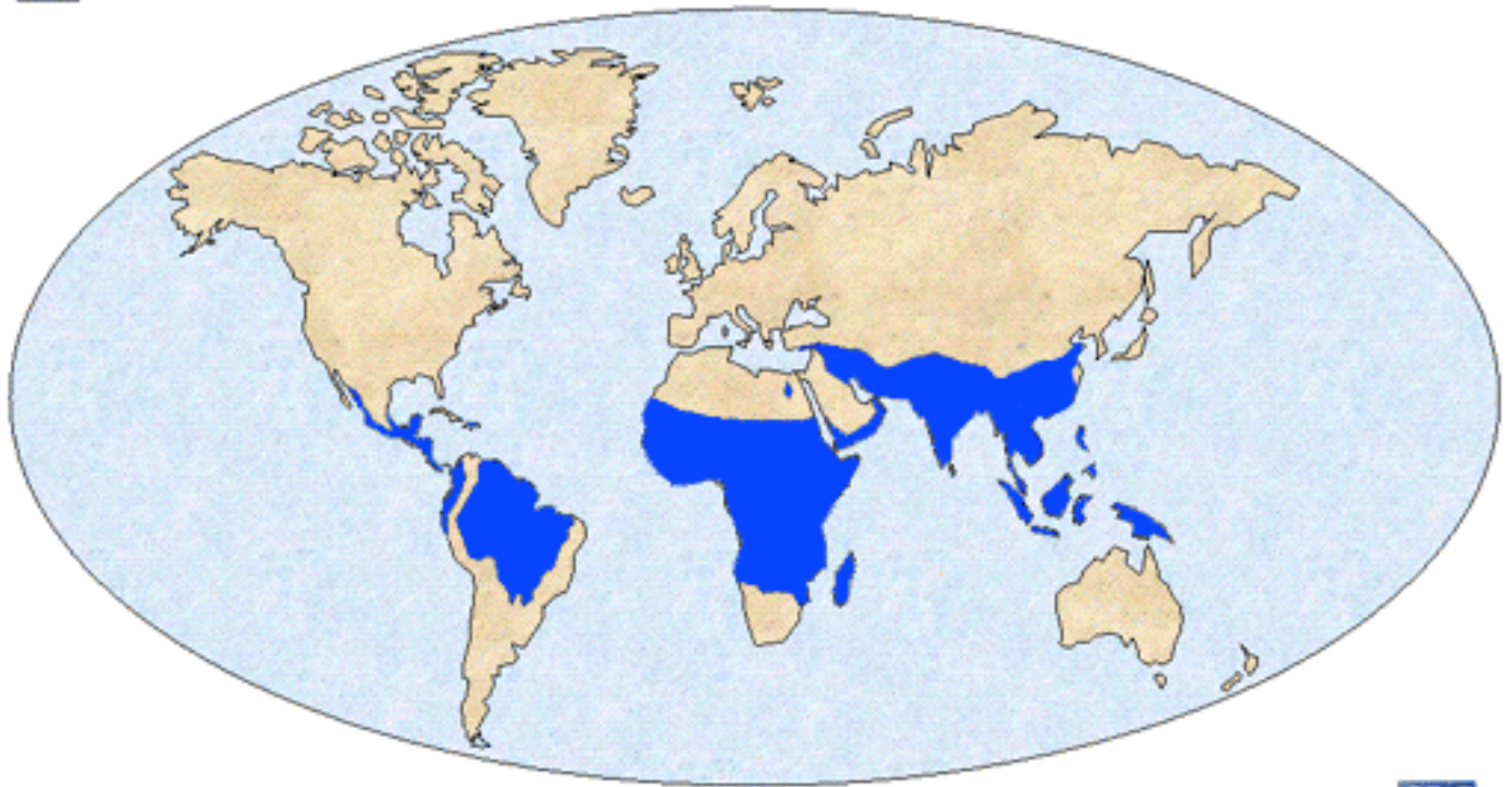
Malaria and Anopheles



Malaria

- Most devastating disease in the world. Mainly in tropics, 80% of cases in sub-Saharan Africa
- About 1million people die every year – mostly kids (reason?) numbers are steadily declining because of renewed efforts to control it, infusion of new funding, Bill Gates, PMI, GFMTA
- Malaria has been eliminated in many areas of the world including US but threat still exists

 **Distribution of Malaria**



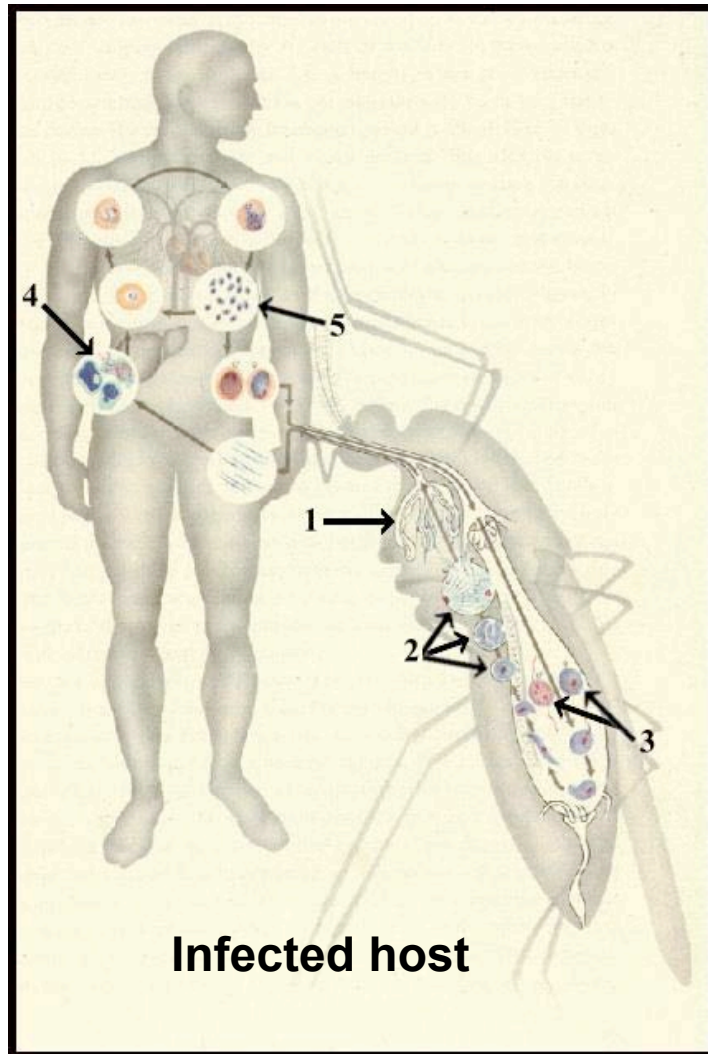


Vectors of Malaria

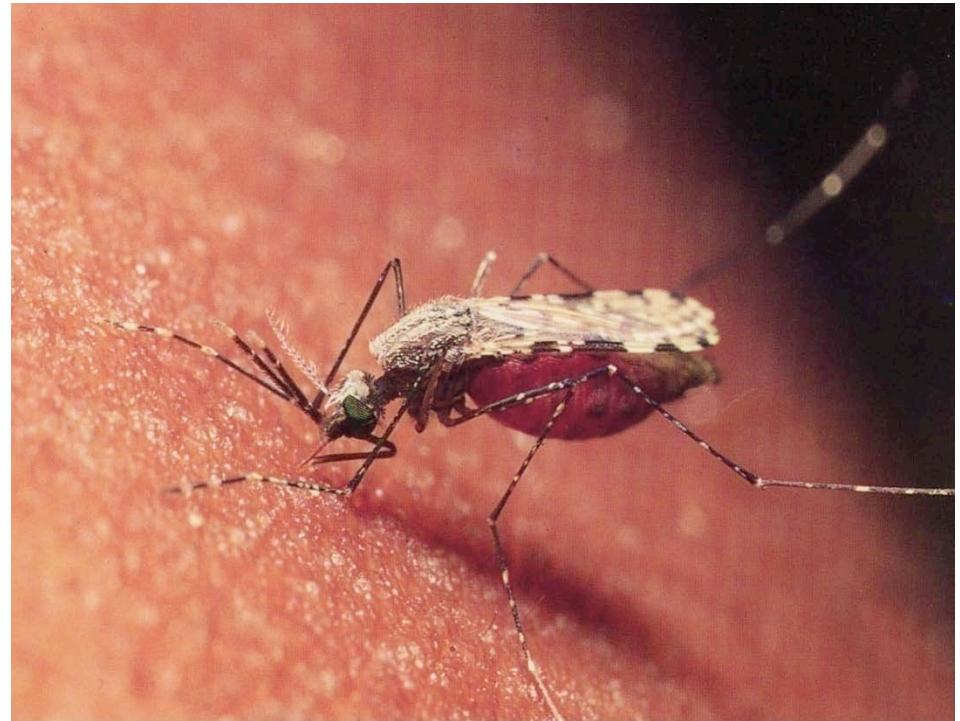
- There are over 400 species of *Anopheles* mosquitoes but only about 40 are human malaria transmitters
- The different species have different ecological requirements for breeding
- Most breed in fresh water ecosystems but here are brackish water species



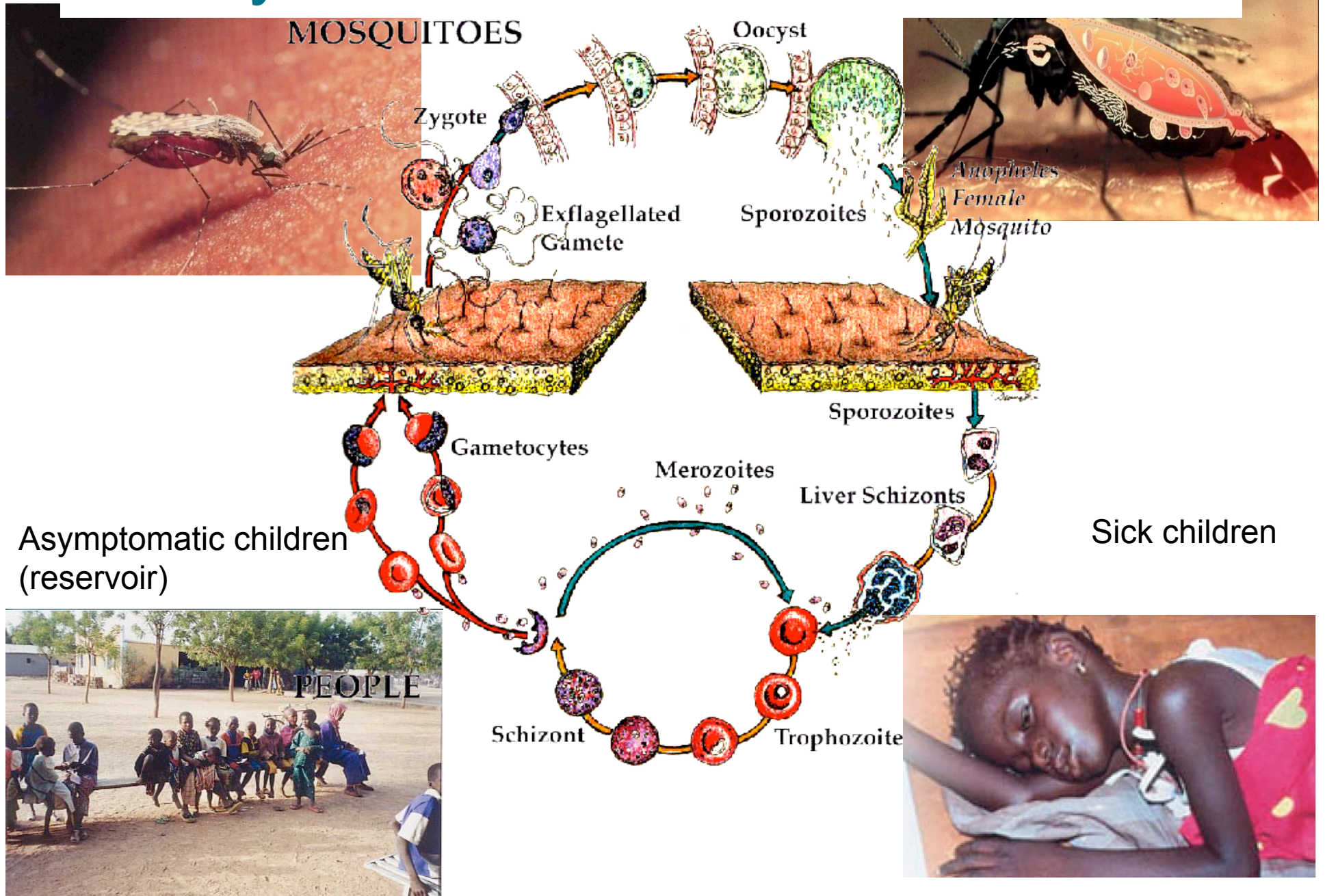
How mosquitoes acquire malaria infections



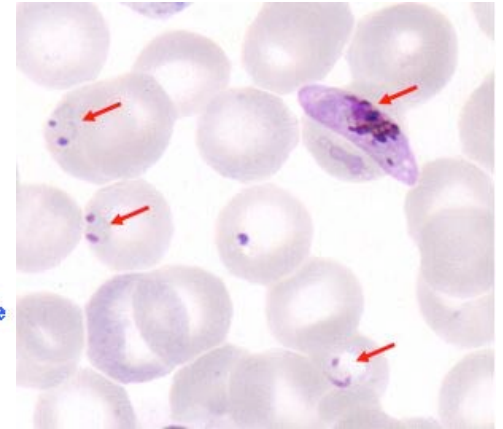
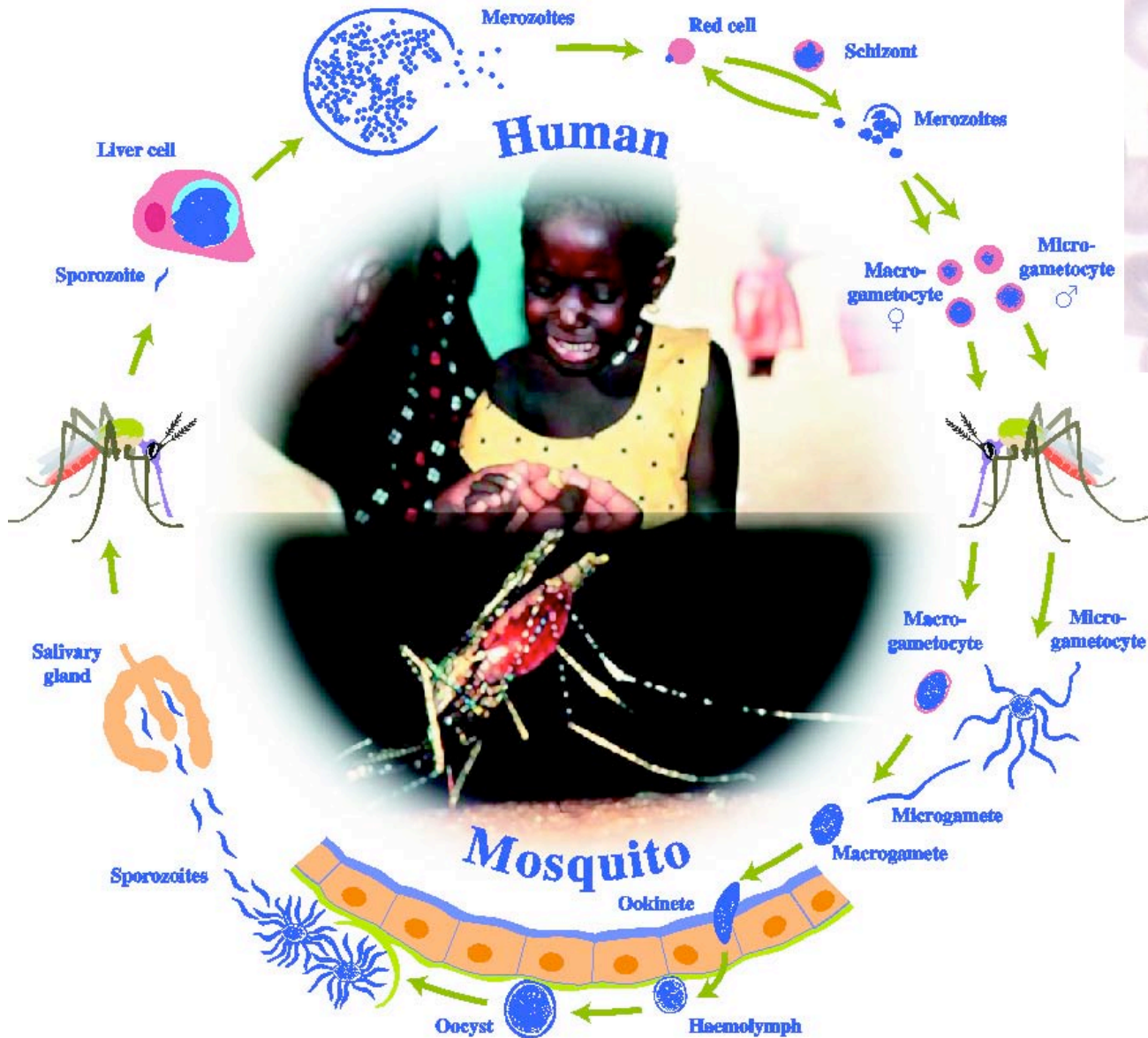
Hungry female Anopheles mosquito



Life cycle of malaria transmission



Life cycle of malaria transmission





Malaria vectors in S. America

- Major malaria vector in *An albimanus*
- It breeds in brackish waters or fresh water
- Mainly confined to coastal areas of S. America
- Several other species of Anopheles in S. America

Malaria vectors in Africa

- Major vector is *An. gambiae*
- Breeds in open sunlit pools of water forming after rainfall
- Prefers fresh water, distributed in much of sub-Saharan Africa
- Sibling species are brackish breeders – *An. merus*

Breeding sites of *An. gambiae* in Africa



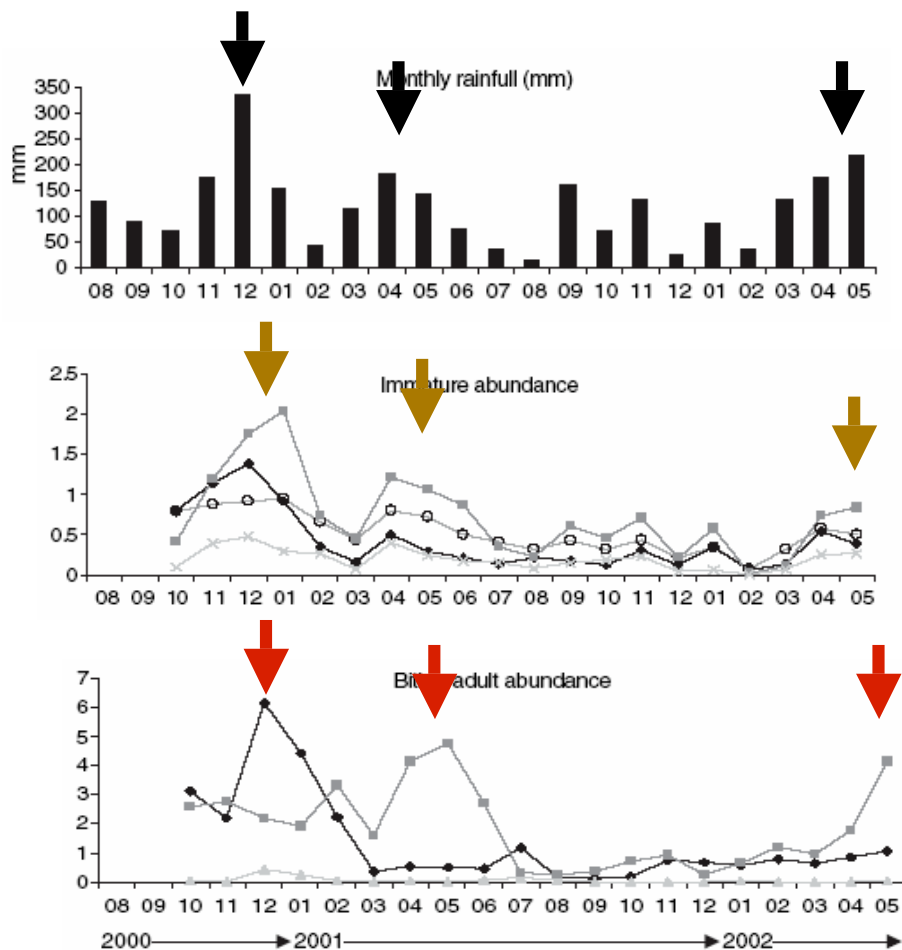


Malaria vectors in Asia

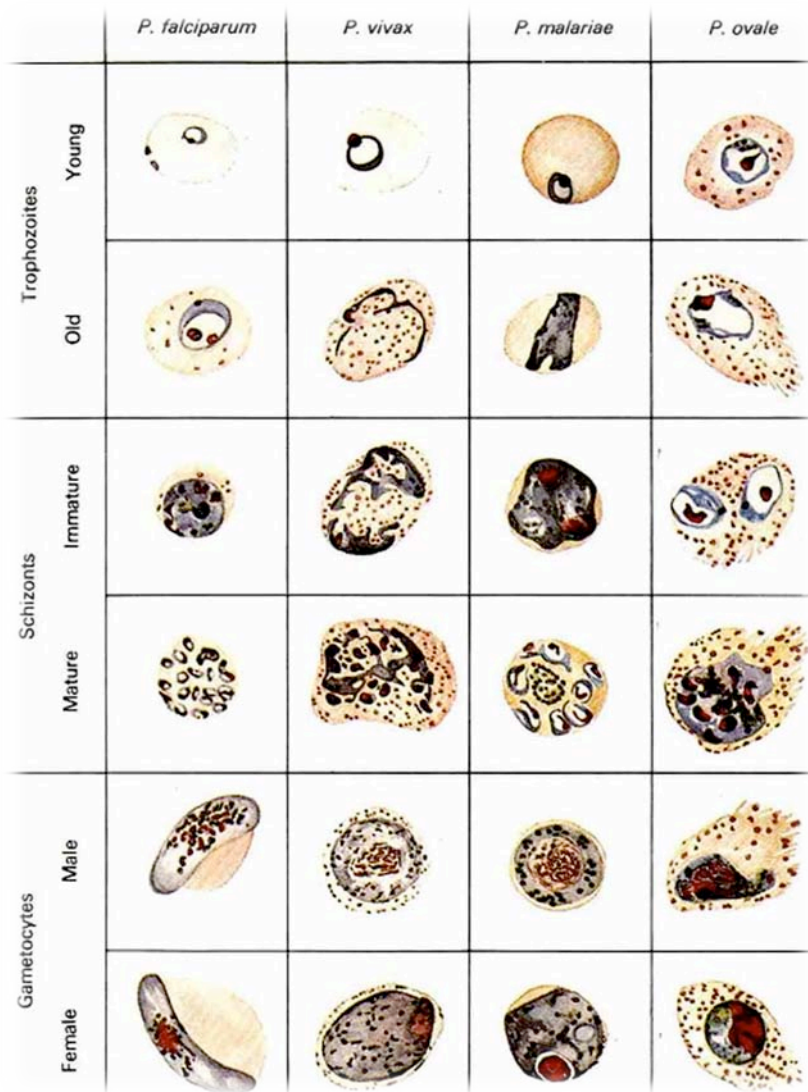
- The major vector in India is *An stephensi*
- Fresh water breeder
- In Indonesia: major vector is *An dirus*
- Other species breed in fast moving water

Larval mosquito distribution determines adult population distribution

Relationship between rainfall, immature abundance and adult abundance



Causative agent of malaria, *Plasmodium*



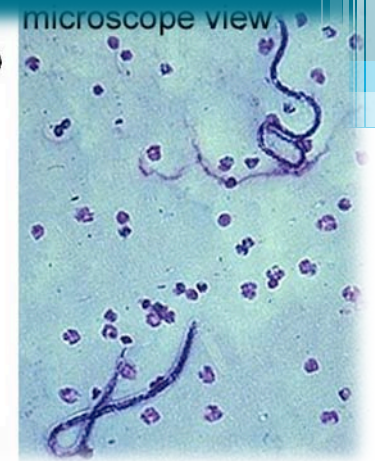
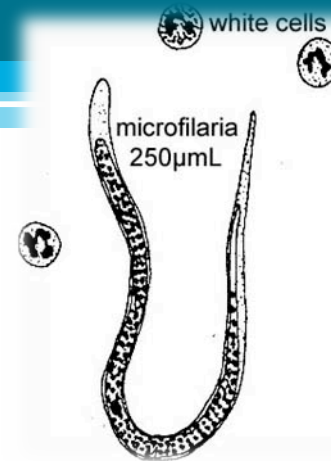
There are several species of malaria but the most common that infect man are 4. They can be distinguished by their characteristic morphology in infected RBC

- *P. falciparum* - most prevalent and dangerous form
- *P. vivax* – cause serious disease but no fatalities – prevalent in Asia, S America
- *P. ovale* – benign form
- *P. malariae* – benign form

Symptoms of malaria infection

- Cyclical occurrence of cold and sweating
- Febrile illness
- Paroxysms that coincide with the release of merozoites into the blood stream
- Vomiting, anemia, joint pains,
- Anemia
- Severe malaria (mainly due to *P falciparum*) can cause death

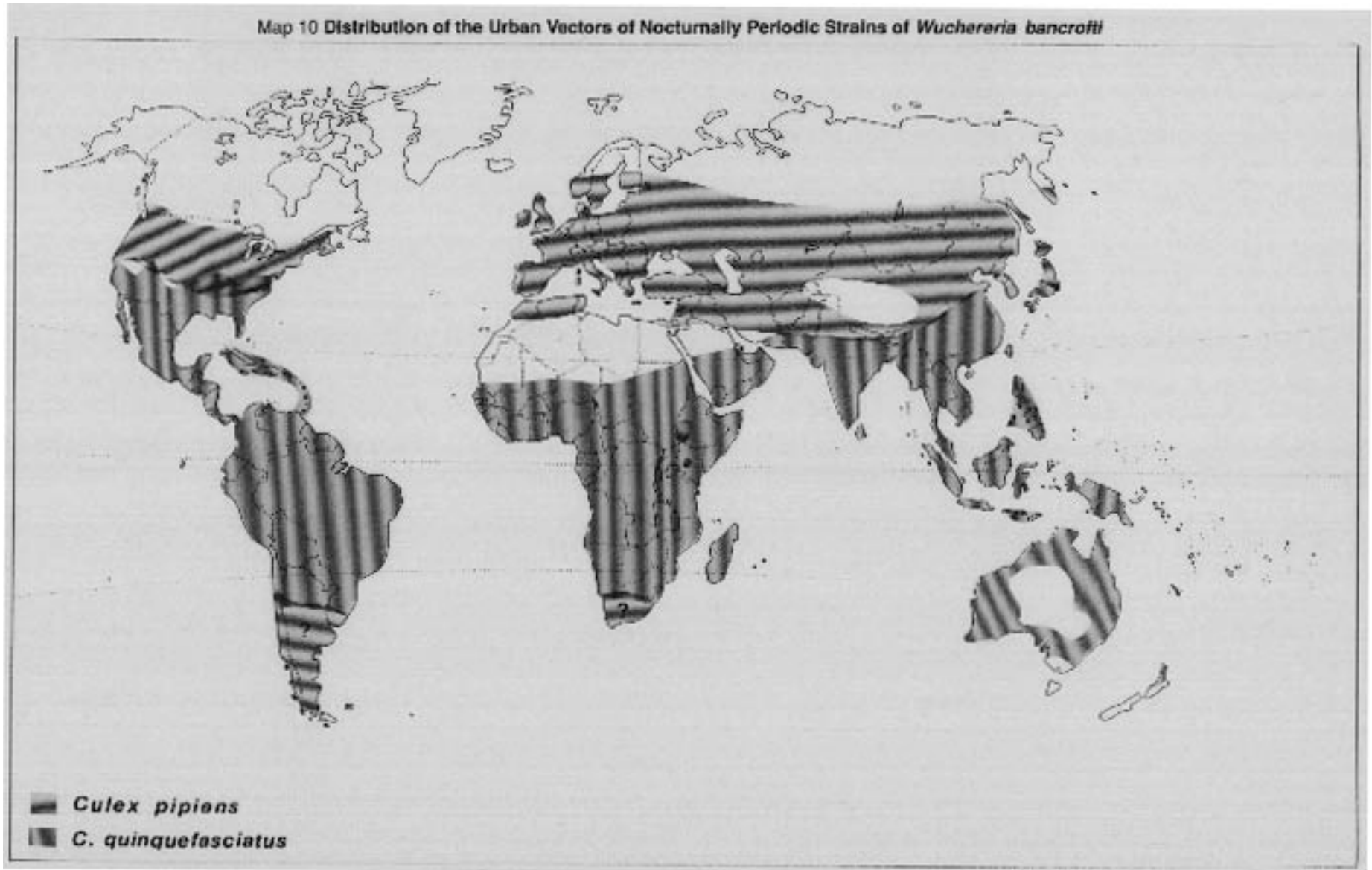
Filariasis



- It is caused by a filarial worm that is spread by mosquitoes of several genera
- Culex sp – Africa, S. America
- Anopheles sp – Africa
- Aedes sp – Asia
- Mansonia sp - Indonesia



Distribution and Ecology of LF vectors



Breeding sites of *Culex sp* vectors of Lymphatic filariasis

- Breeding in polluted waters that are rich in organic matter
- Cesspools and cesspits
- Latrines
- Contaminated water
- Rice paddies

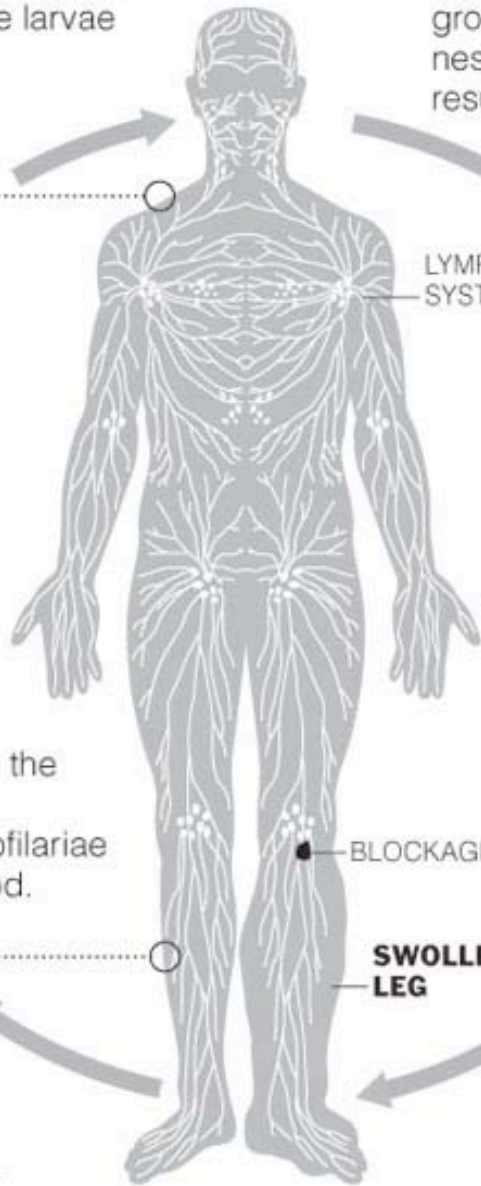


The Life Cycle of Lymphatic Filariasis

1 An infected mosquito deposits larvae on the skin while biting and the larvae enter the wound.



2 The larvae migrate to the lymphatic system, where they grow, mate and form nests. The nests cause blockages, resulting in swelling and fever.



LYMPHATIC SYSTEM

ADULT WORMS



5 Microfilariae develop into larvae over a period of a week.

3 Female worms produce microscopic worms called microfilariae, below, that swarm in the blood at night, when mosquitoes bite.

4 A mosquito bites the infected person, ingesting the microfilariae along with the blood.



BLOCKAGE

SWOLLEN LEG



Photo from C.D.C.

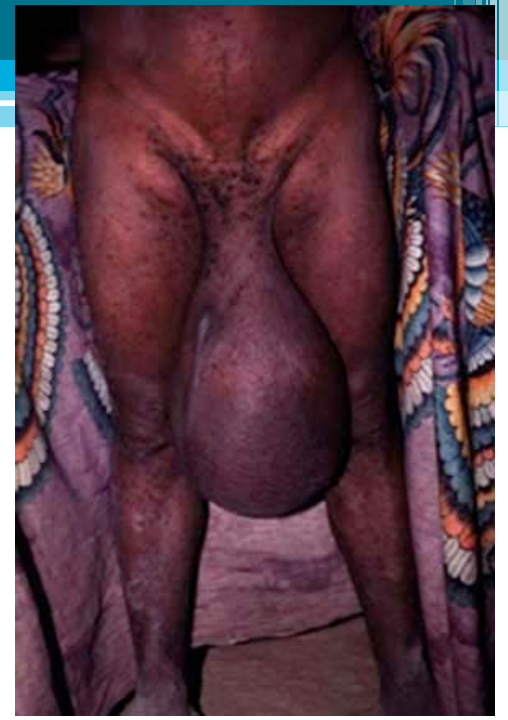
Al Granberg/The New York Times

Source: The Carter Center



Symptoms of LF

- Many cases are asymptomatic
- In few cases that show symptoms, they appear 5-18 months after a mosquito bite
- Symptoms appear as a result of lymphadema –
- Bodies immune response to the adult worm may cause symptoms
- Poor circulation of lymph results in bacterial infection





ARBOVIRAL DISEASES

Arboviruses

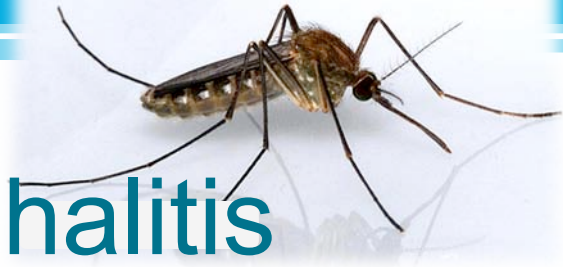
- These are viral diseases transmitted by arthropods
- Only mosquito borne viruses concern us, and include
 - Eastern Equine Encephalitis
 - West Nile Virus
 - Western Equine Encephalitis
 - Japanese Encephalitis
 - Dengue Hemorrhagic fever
 - Yellow fever
 - Chikungunya
 - Rift Valley Virus

Worldwide Distribution of Major Arboviral Encephalitides



EEE: Eastern equine encephalitis
JE: Japanese encephalitis
LAC: LaCrosse encephalitis
MVE: Murray Valley encephalitis
POW: Powassan encephalitis

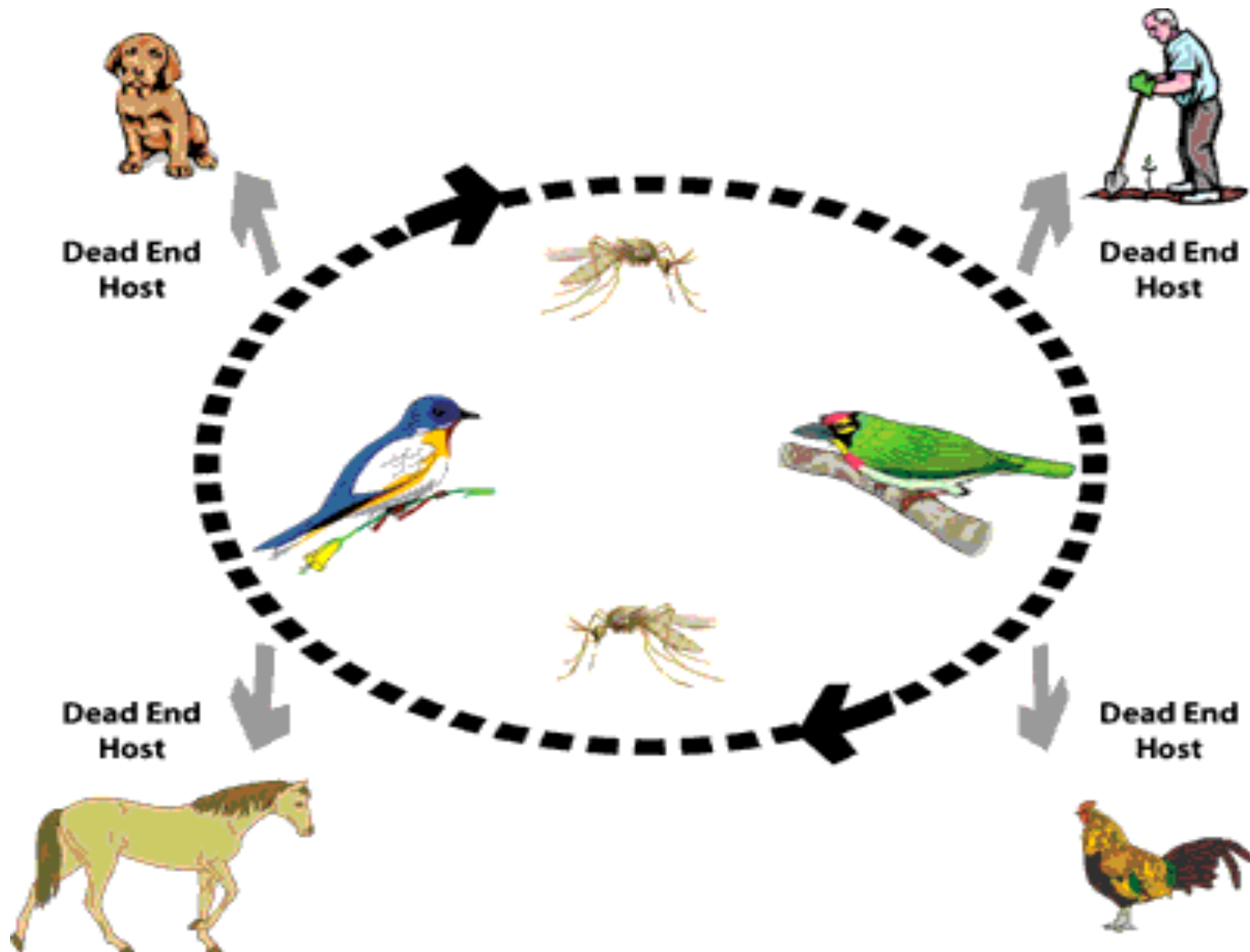
SLE: St. Louis encephalitis
TBE: Tick-borne encephalitis
WEE: Western equine encephalitis
WN: West Nile encephalitis
VEE: Venezuelan equine encephalitis



Eastern Equine Encephalitis

- EEE virus (EEEV) occurs in the eastern half of the United States
- Causes disease in humans, horses, and some bird species
- EEE is the most serious in US because of high mortality rate
- Transmitted by mosquito species *Aedes*, *Coquillettidia*, or *Culex* species that bridge sylvatic cycle with humans.

Transmission Cycle of EEE and WNV



Eastern Equine Encephalitis (EEE)

- Average of 5 human cases per year
- EEEV transmission common in and around freshwater swamps (Atlantic, Gulf Coast states and the Great Lakes region)
- Most cases are Florida, Georgia, Massachusetts, and New Jersey.
-
- Human cases relatively infrequent because the primary transmission cycle around swampy areas where limited human populations

Symptoms of EEE infection

- Many persons infected with EEEV have no apparent illness.
- Mild flu-like illness
- Inflammation of the brain, coma and death
- 30% mortality rate making it most deadly mosquito-borne diseases in the US
- Survivors of EEE have mild to severe permanent neurologic damage
- No specific treatment for EEE - hospitalization and supportive



West Nile Virus (WNV)

- WNV transmitted by *Culex* sp
- Bird reservoirs will sustain an infectious viremia for 1 to 4 days after exposure

Clinical Symptoms of WNV

- Fever, Headache, Fatigue
- Skin rash on the trunk of the body (occasionally)
- Swollen lymph glands (occasionally)
- Eye pain (occasionally)
- Febrile headache to aseptic meningitis to encephalitis with CNS involvement
- West Nile meningitis usually involves fever, headache, and stiff neck



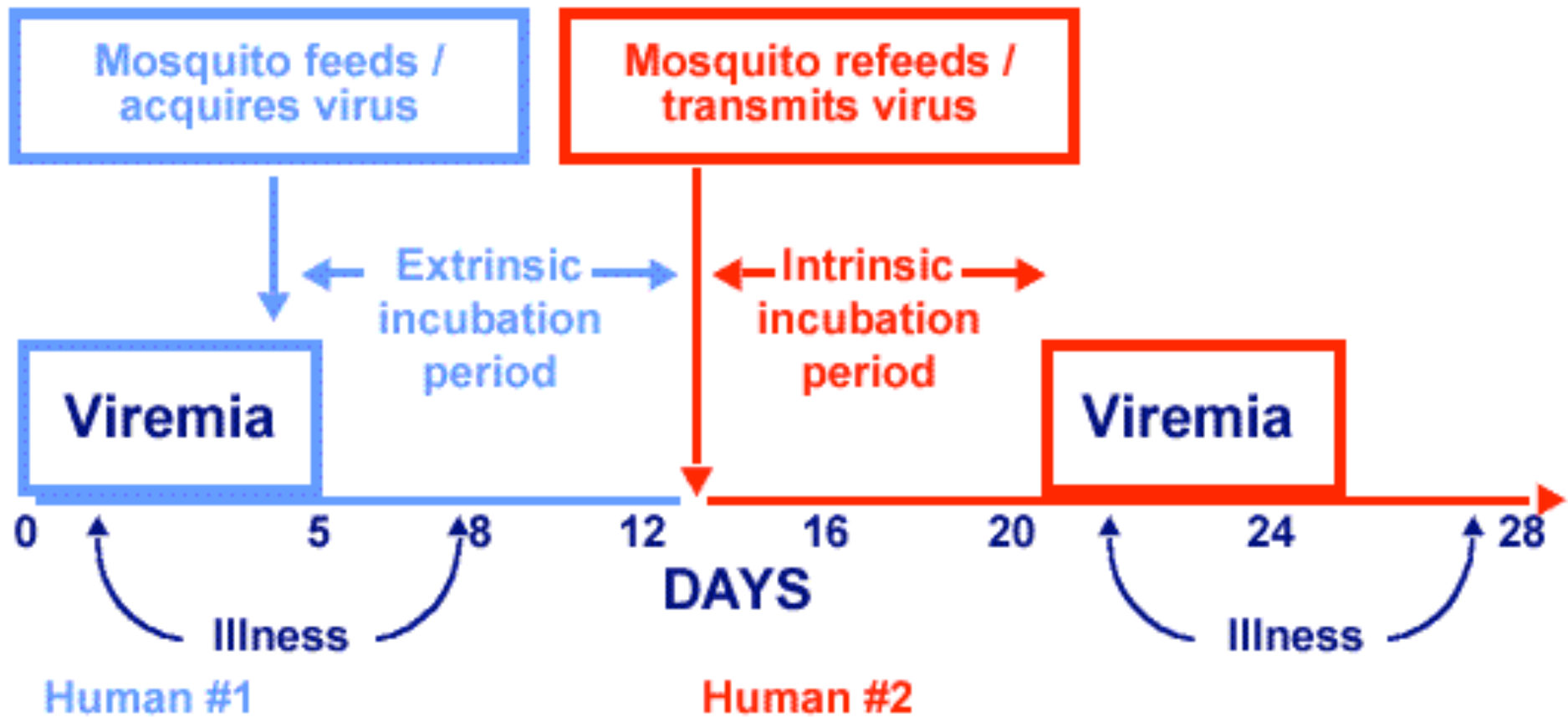
Dengue Fever

- Dengue transmitted by infected female mosquito
- Primarily a daytime feeder
- Lives around human habitation
- Lays eggs and produces larvae preferentially in artificial containers

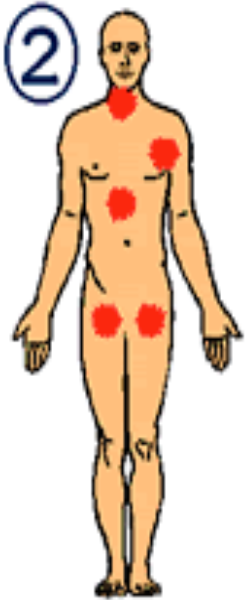
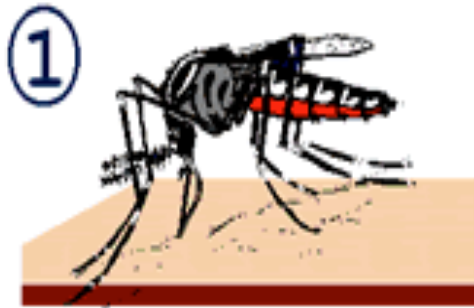
Aedes species: Yellow Fever and Dengue Fever vectors are container breeding mosquitoes



Transmission of Dengue Virus by *Aedes aegypti*



Replication and Transmission of Dengue Virus



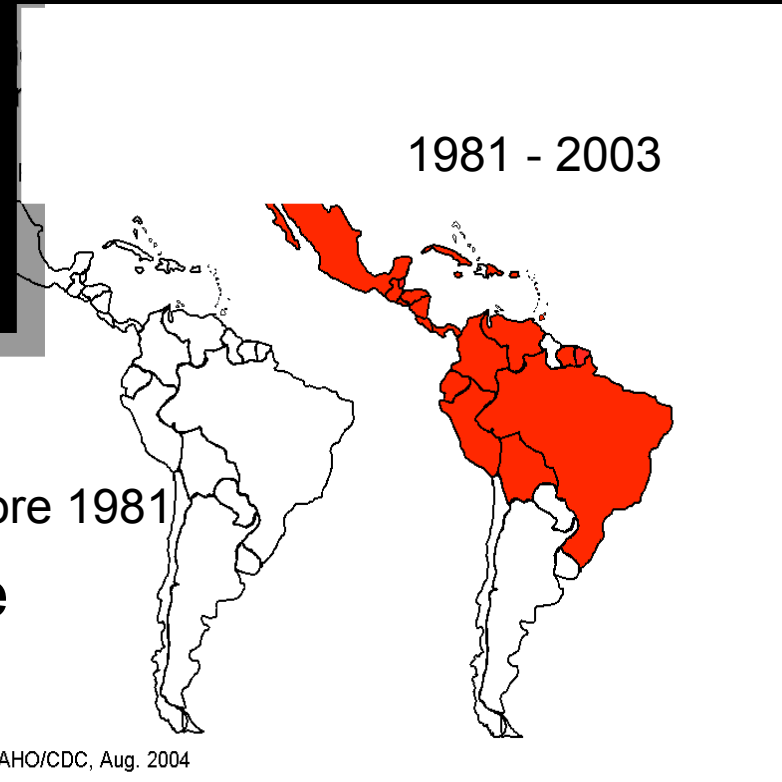
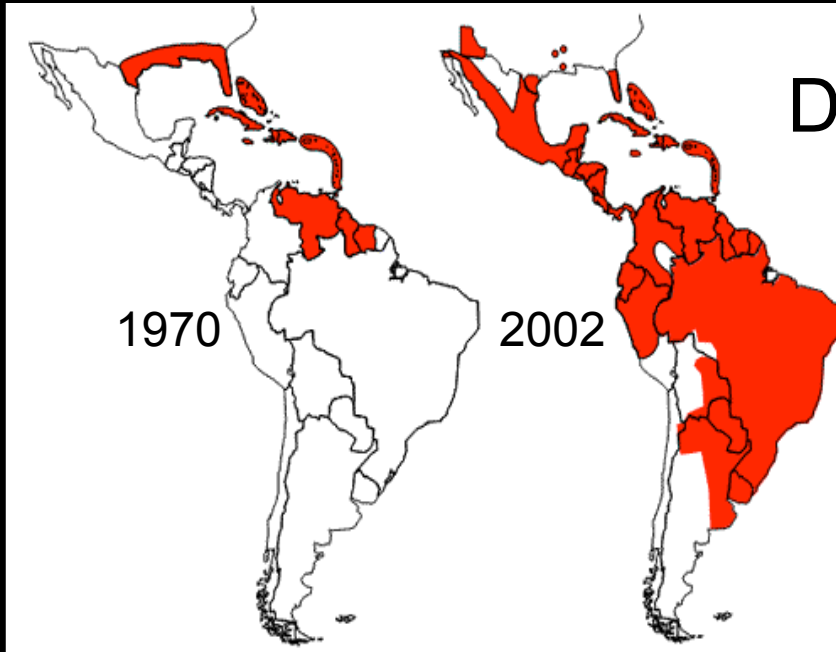
1. Virus transmitted to human in mosquito saliva

2. Virus replicates in target organ

3. Virus infects white blood cells and lymphatic tissues

4. Virus released and circulates in blood

Distribution of *Aedes aegypti*



Source: WHO/PAHO/CDC, Aug. 2004

Laboratory Confirmation of Dengue

The distribution of the DEN virus serotypes in the Central and southern America

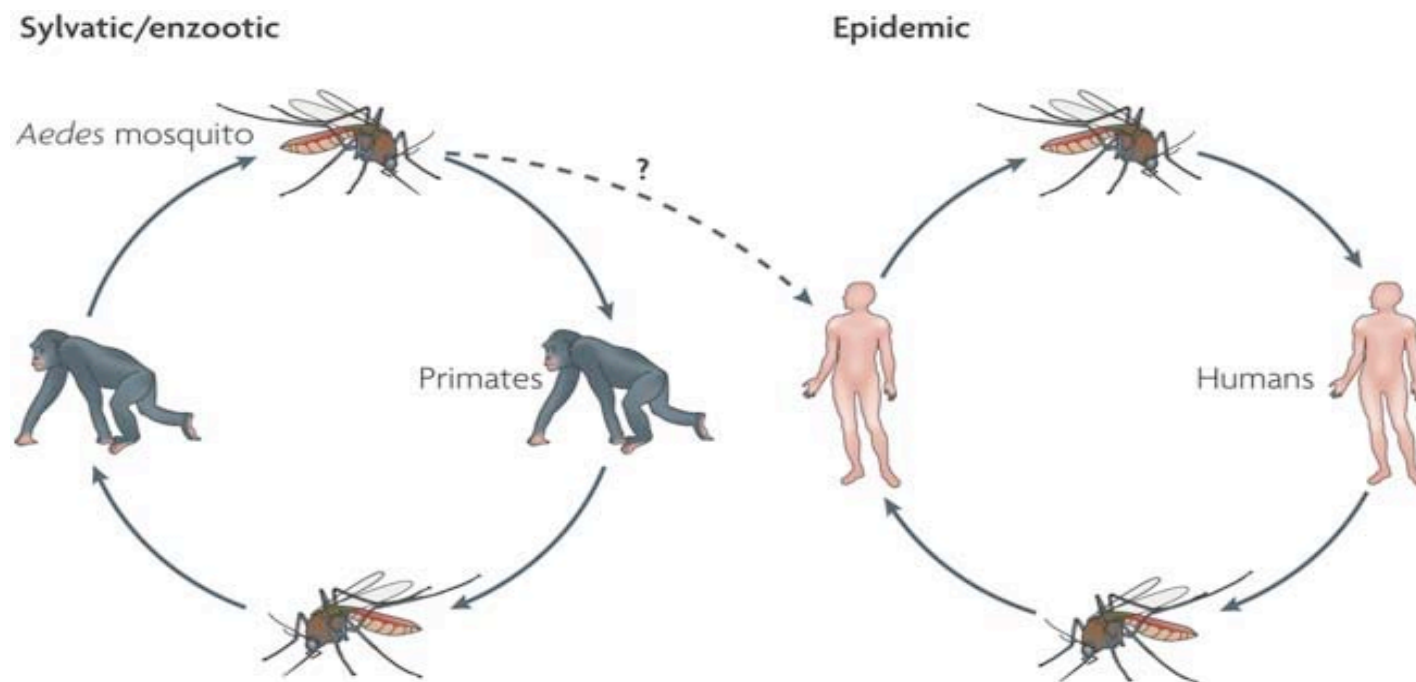


Symptoms of Dengue Virus Infection

- Sudden onset of fever
- Severe headache
- Myalgias
- Arthralgias
- Leukopenis
- Hemorrhagic manifestations
- Shock and hemorrhage leading to death

Yellow fever (YF)

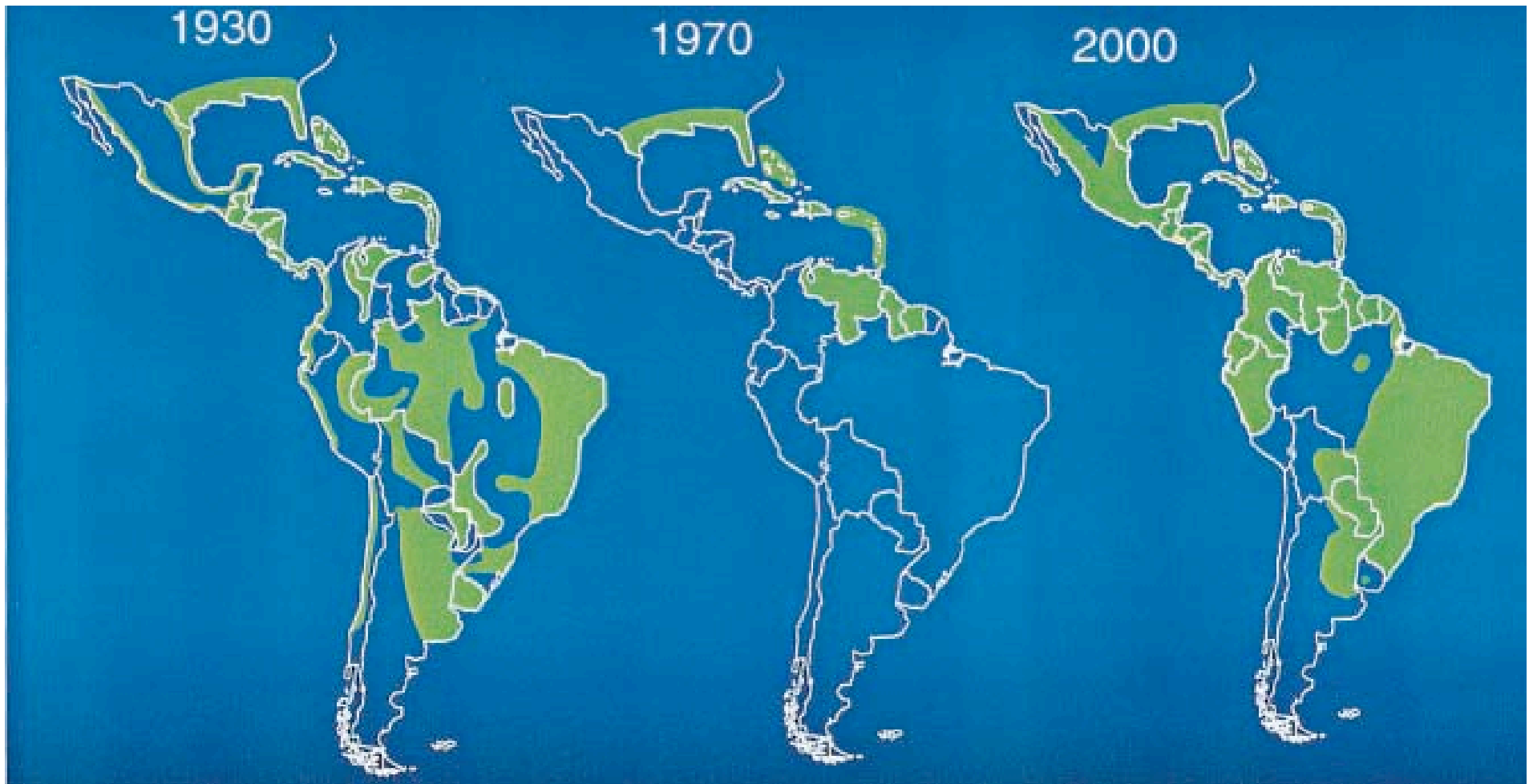
- YF is transmitted by *Aedes aegypti* and *Ae. albopictus*
- YF is transmitted in "jungle cycles" between non-human primates and mosquitoes



Approximate Global Distribution of **Yellow Fever**, by State/Province, 2007



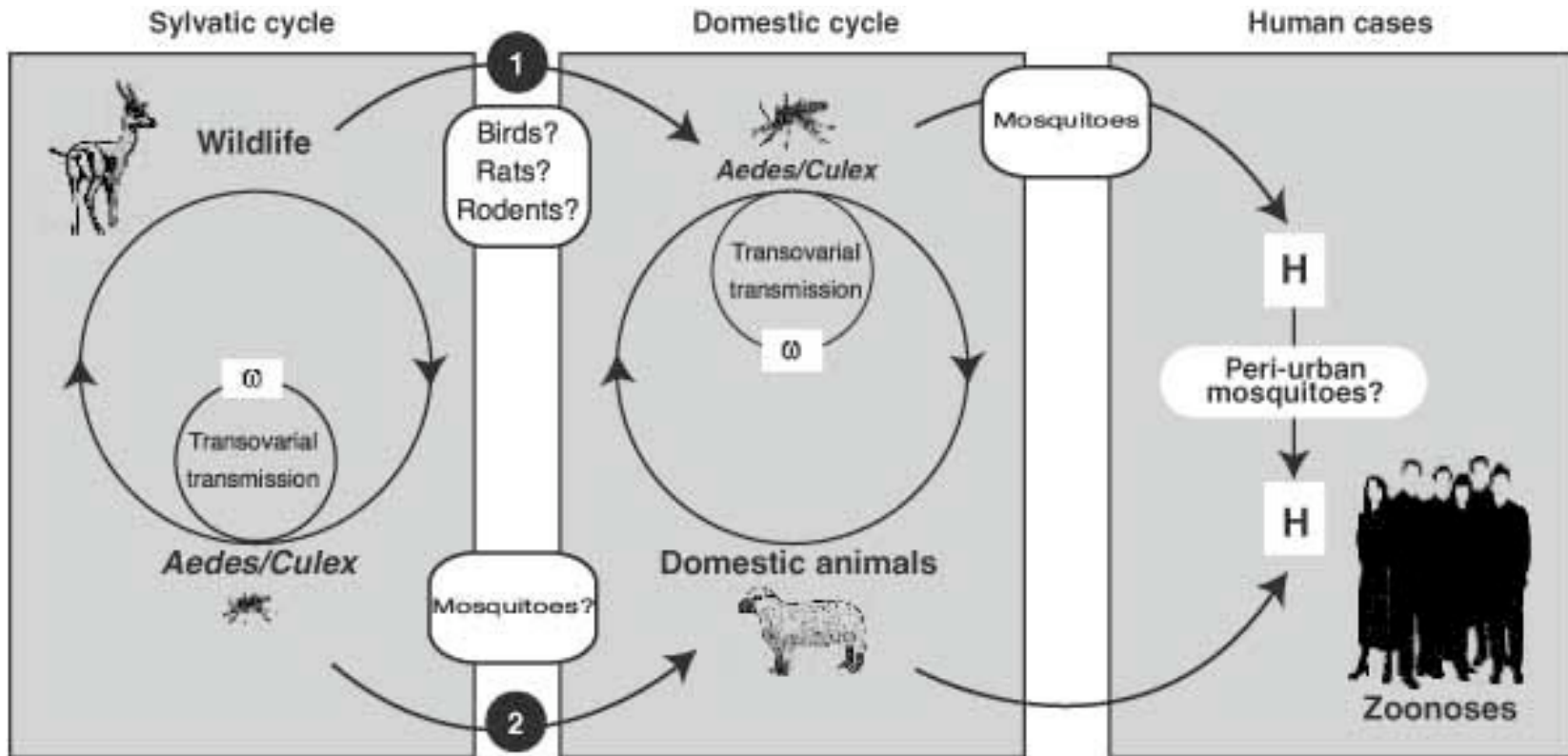
The distribution of the *Aedes aegypti* in the Central and southern America



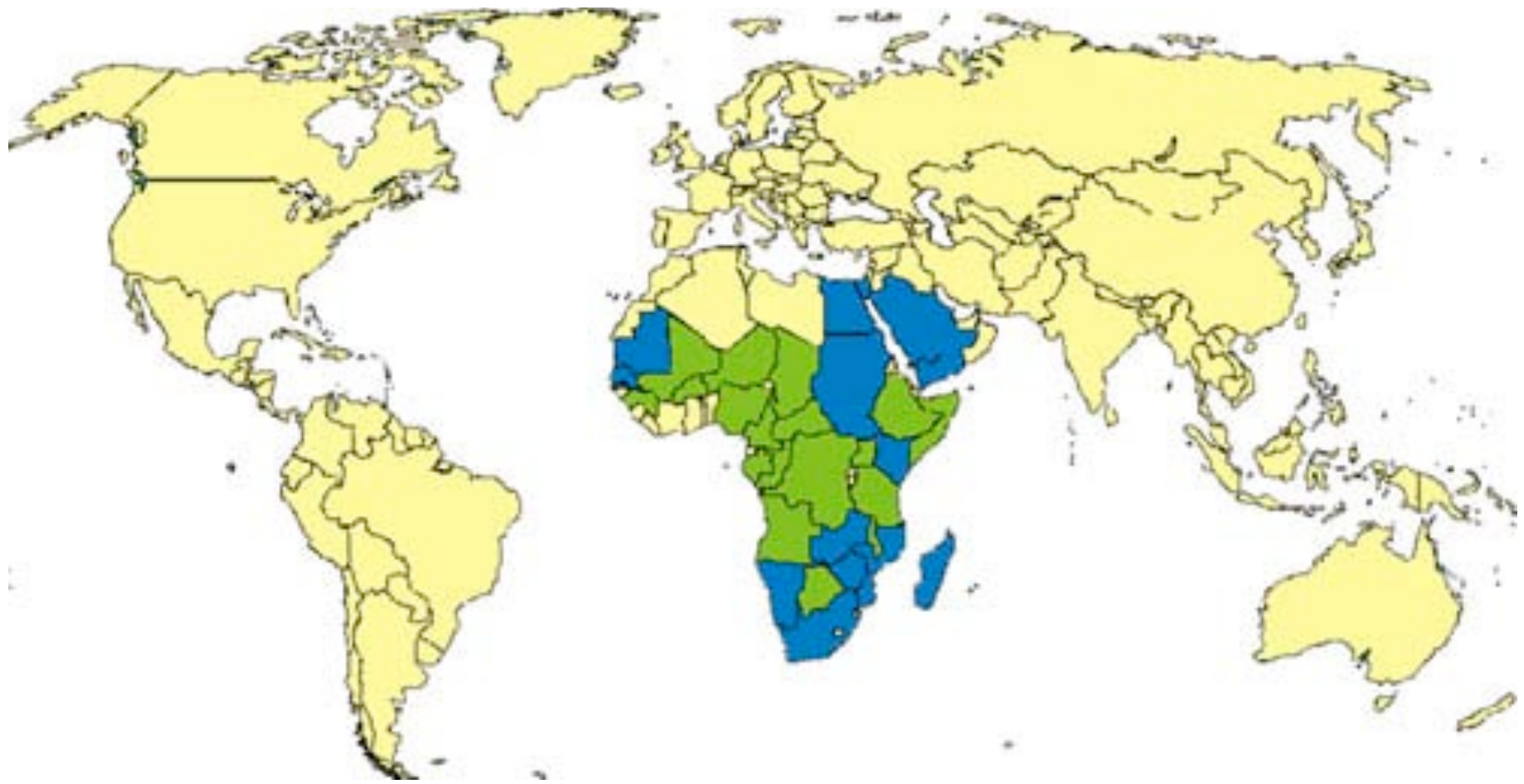
Symptoms of YF infection

- Fever and chills, severe headache, back pain, general muscle aches, nausea, fatigue, and weakness
- Hemorrhagic symptoms result after hepatic involvement
black vomit
- Other hemorrhagic symptoms include nose bleed, gum bleeding, petechial and purpuric hemorrhages (bruising)
- Deepening jaundice and proteinuria frequently occur in severe cases.

Rift Valley Fever Transmission Cycle



Distribution of Rift Valley Fever



Endemic /Major Outbreaks



Some cases present

Symptoms of Rift Valley Fever

- Patients with yellow fever may be viremic (have virus in their blood) for 3 to 6 days before demonstrating symptoms.
- Initial symptoms include fever and chills, severe headache, back pain, general muscle aches, nausea, fatigue, and weakness.
- The toxic phase develops as the fever returns, with clinical symptoms including high fever, headache, back pain, nausea, vomiting, abdominal pain, and fatigue.
- Hemorrhagic symptoms, including black vomit, nose bleed, gum bleeding, and petechial and purpuric hemorrhages (bruising).
- Deepening jaundice and proteinuria frequently occur in severe cases.

RIVER BLINDNESS and BLACK FLIES

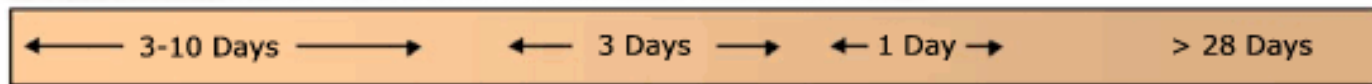


River Blindness or Onchocerciasis

- The vectors are Black flies or *Simulium* sp
- There are several species
- Breeding primarily on fast moving water bodies



Breeding and Life cycle of Black flies



Early Larva



Mid Larva



Late Larva

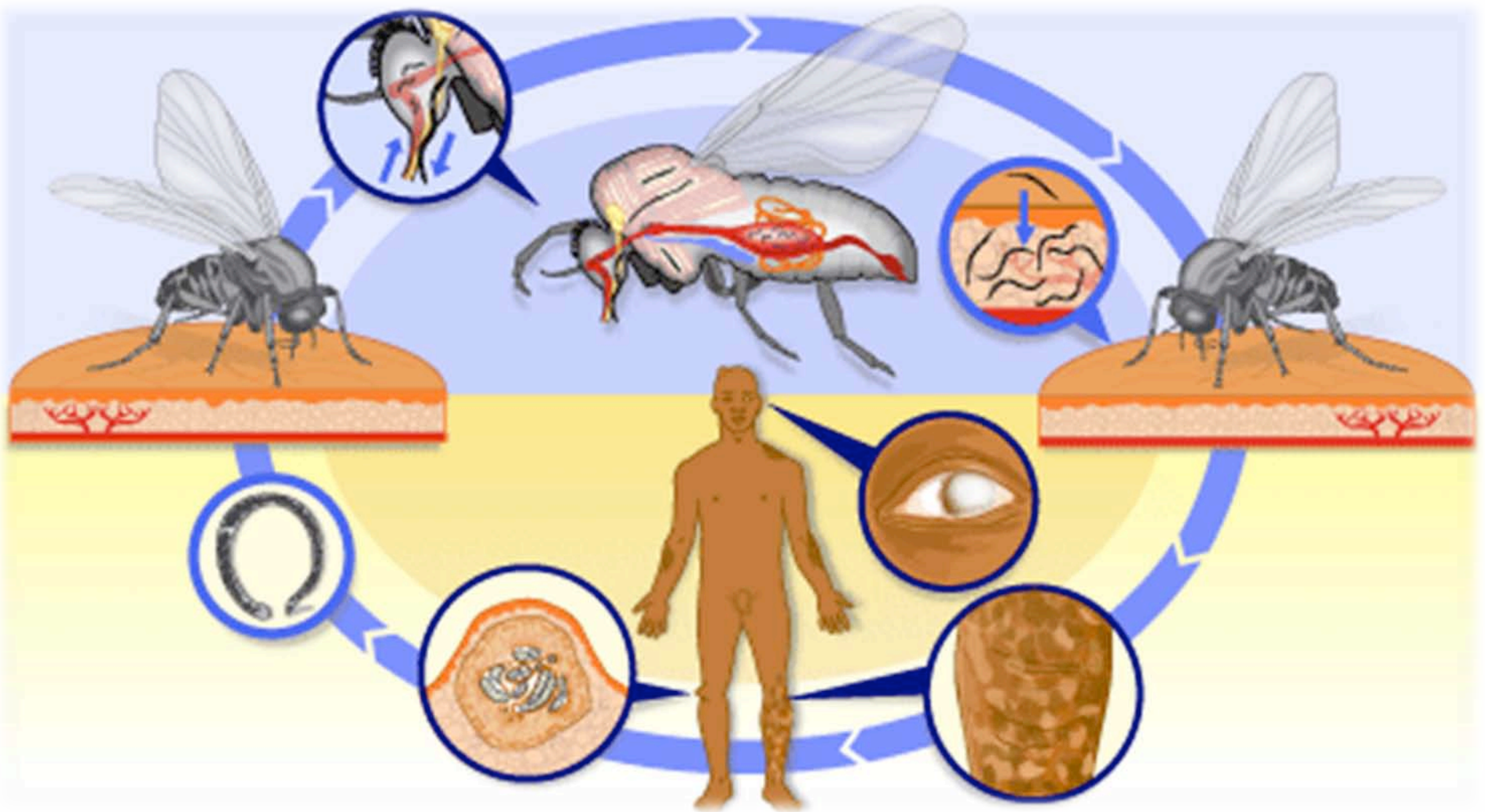


Pupa



Adult

Transmission Cycle of River Blindness



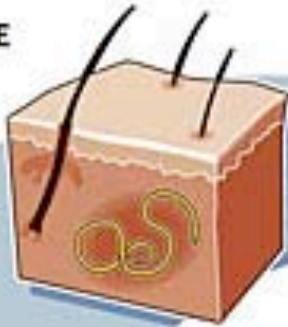
RIVER BLINDNESS

Onchocerciasis, also known as river blindness, is a parasitic disease caused by tiny worms or "microfilariae" and transmitted by flies. The disease affects an estimated 18 million people worldwide.

THE DISEASE CYCLE

2 Infection

The larvae enter the host's skin tissue, where they migrate and form nodules, and slowly mature into adult worms



1 Parasitized

The insect takes a blood meal from a human. A pool of blood is pumped up into the fly, saliva passes into the pool, and infective *Onchocerca* larvae pass from the fly into the host's skin.



3 Proliferation

New worms form new nodules or find existing nodules and cluster together. Smaller male worms migrate between nodules to mate.



4 Reproduction

After mating, eggs form inside the female worm and develop into microfilariae. A female may produce 1,000 microfilariae per day.



5 Transport

When the infected host is bitten by another fly, microfilariae are transferred from the host to the fly.



Carter Center-Assisted Onchocerciasis Control Programs



Highlighted areas in Africa represent areas where The Carter Center is actively working. The highlighted areas in Latin America represent the 13 remaining foci.

DISEASE SYMPTOMS

Eye lesions

If microfilariae migrate to the eye, they can cause severe lesions and in some cases blindness.



Microfilariae in the eye are actually about the size of the period at the end of this sentence.

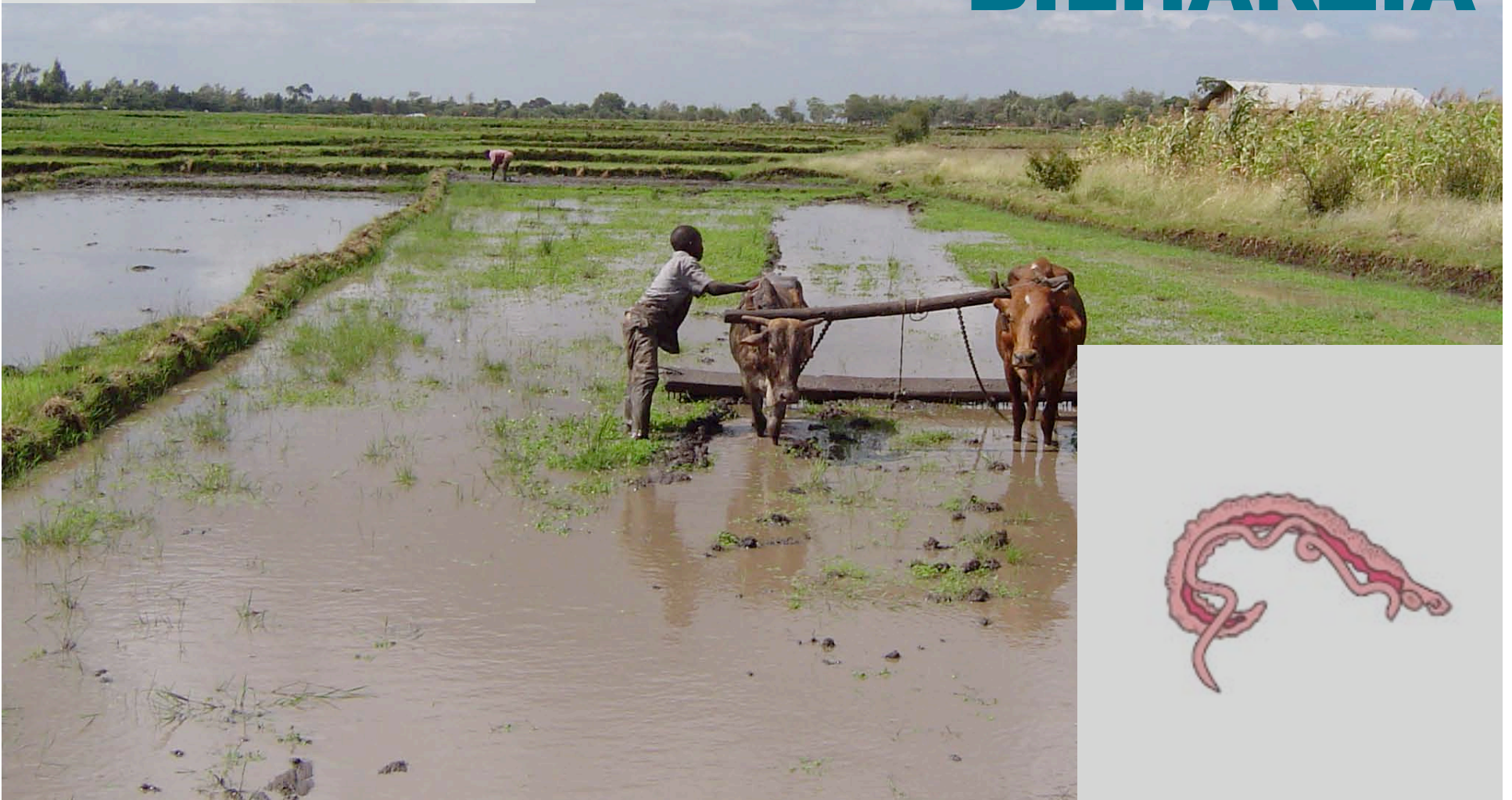
Skin lesions

Many thousands of microfilariae migrate in the upper layers of the skin. When the microfilariae die, they cause skin rashes, lesions, intense itching and skin depigmentation.





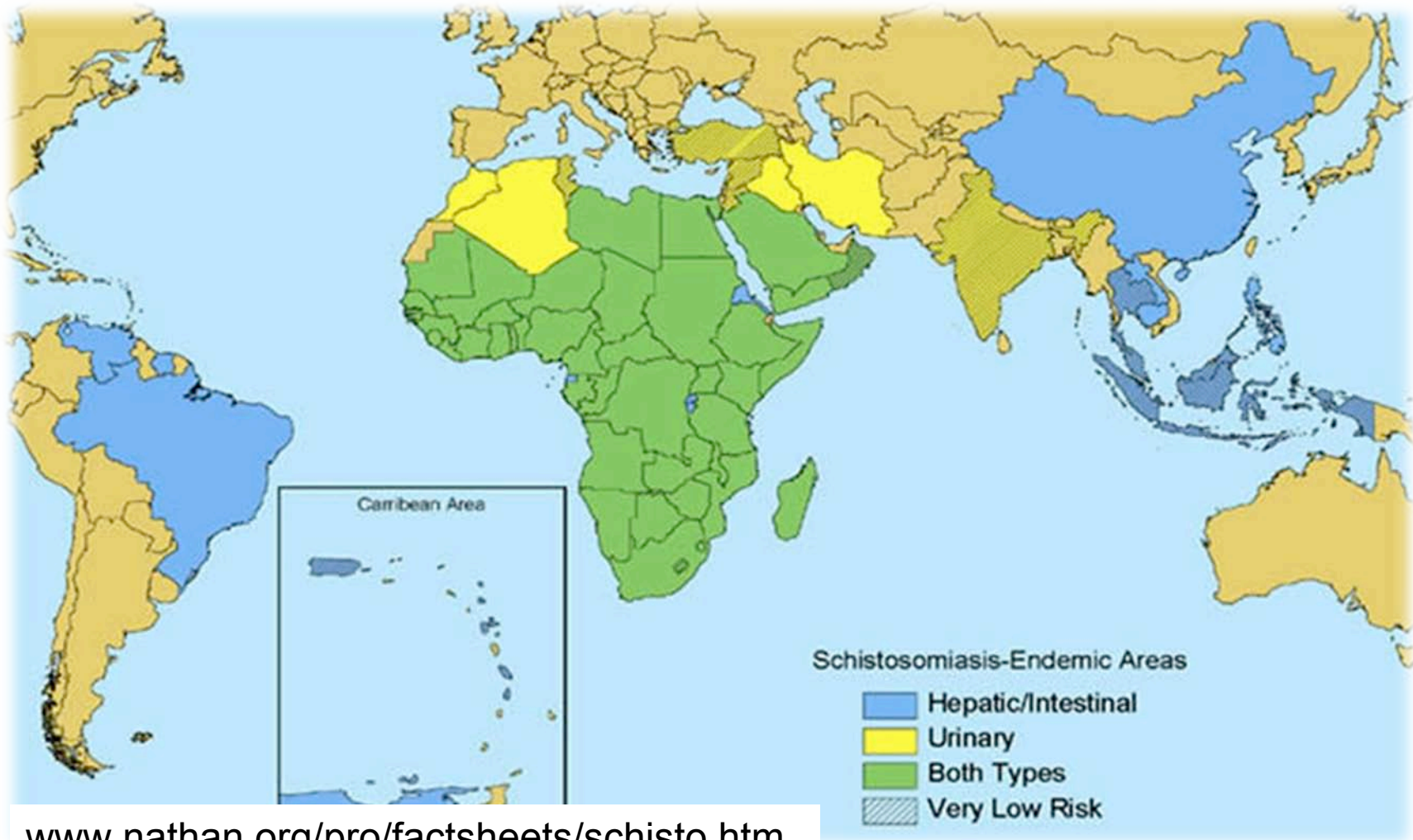
SNAILS and BILHARZIA



Facts about Schistosomiasis (Bilharzia)

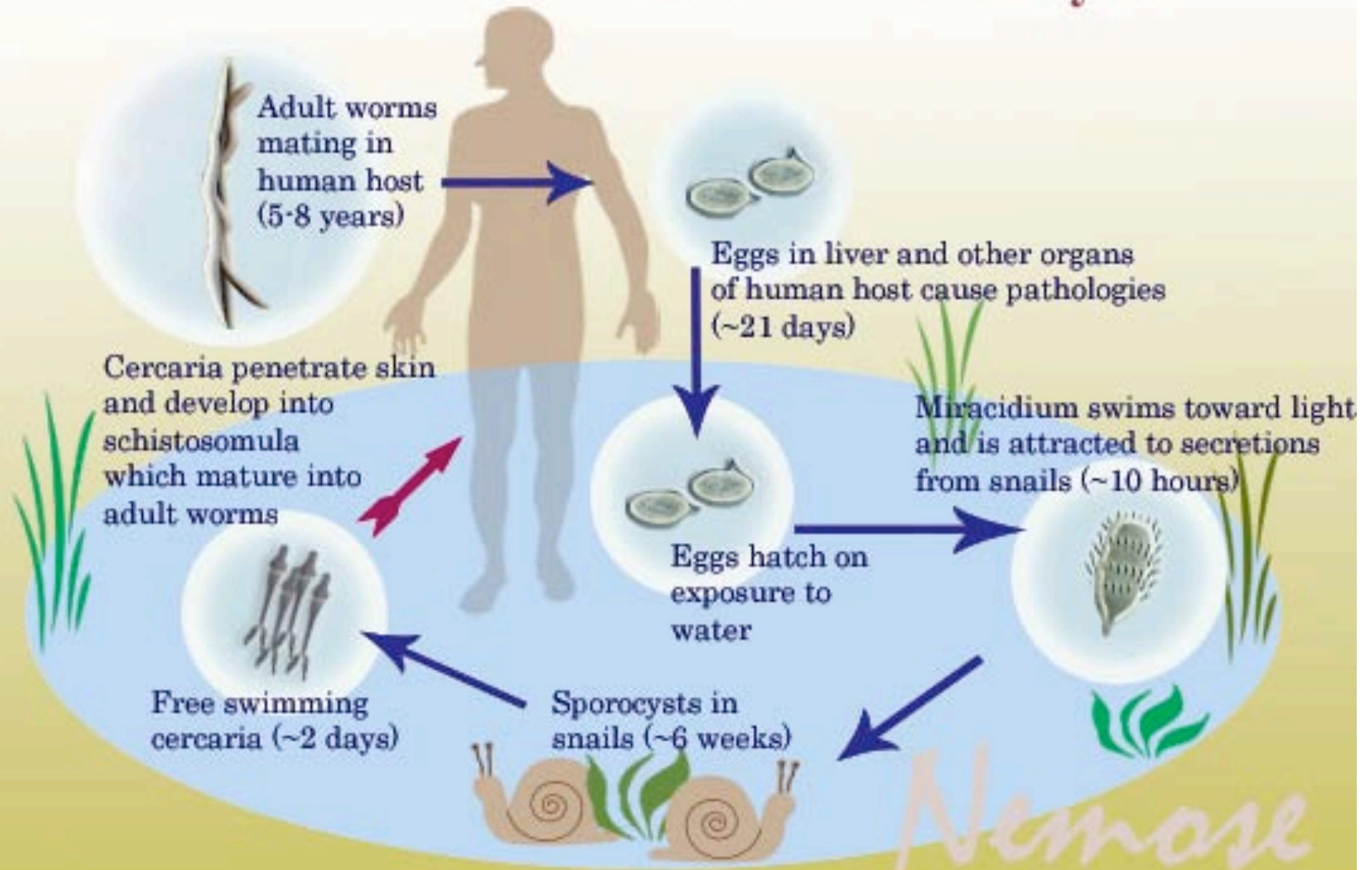
- Bilharzia or Schistosomiasis is a parasitic infection of the blood vessels caused by a trematode
- *Schistosoma sp* is *digenic* trematode - it has a lifecycle that includes two hosts - definitive (human) and intermediate (snail)
- Several species of Schistosome parasites. The important ones in human health include *S. mansoni*, *S. hematobium*, *S. japonicum*
- Affects about 200 million people world wide and 650 million people are at risk

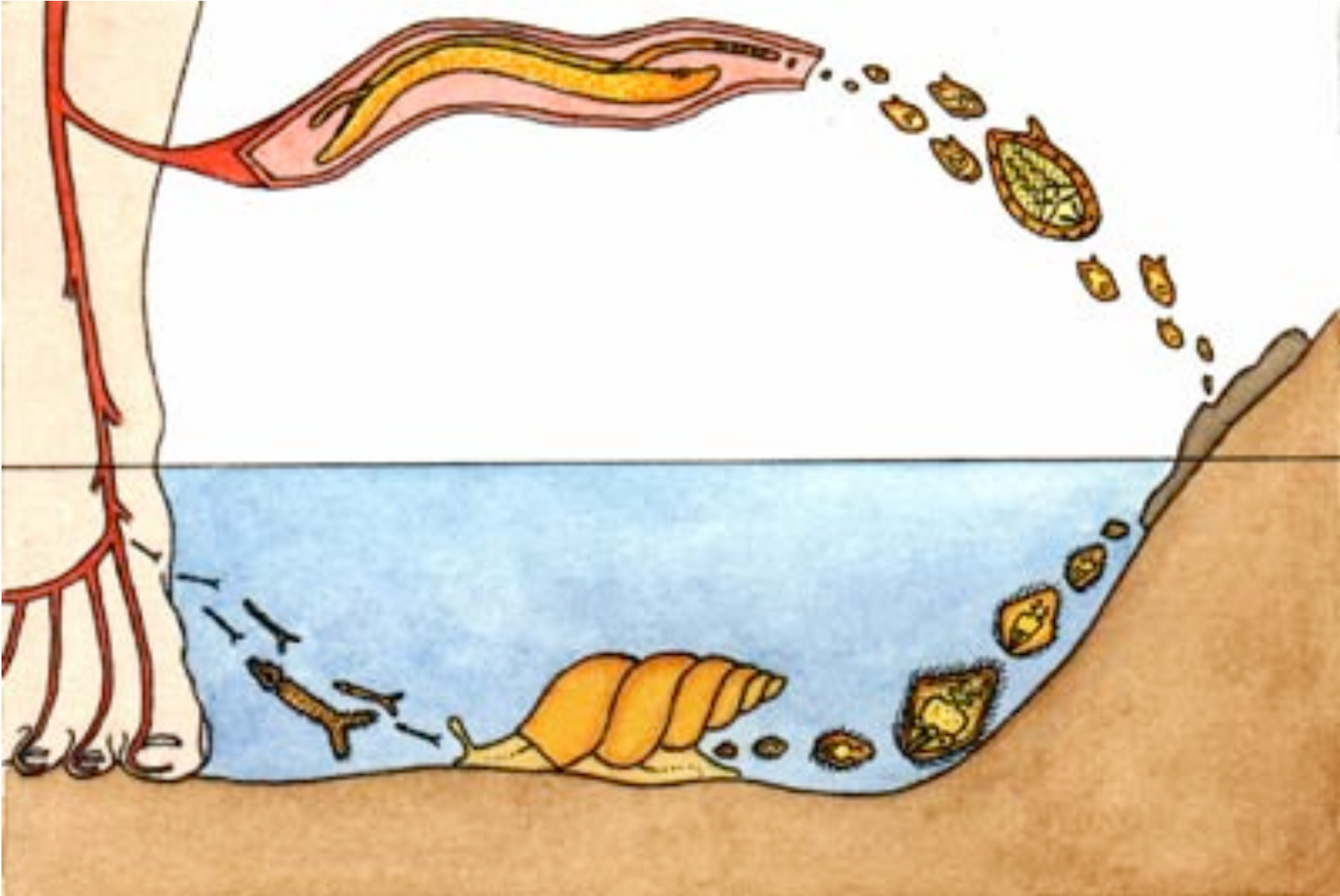
World Distribution of Schistosomiasis



Disease is prevalent in tropical countries in S. America, Africa, Asia and South East

Schistosoma life cycle



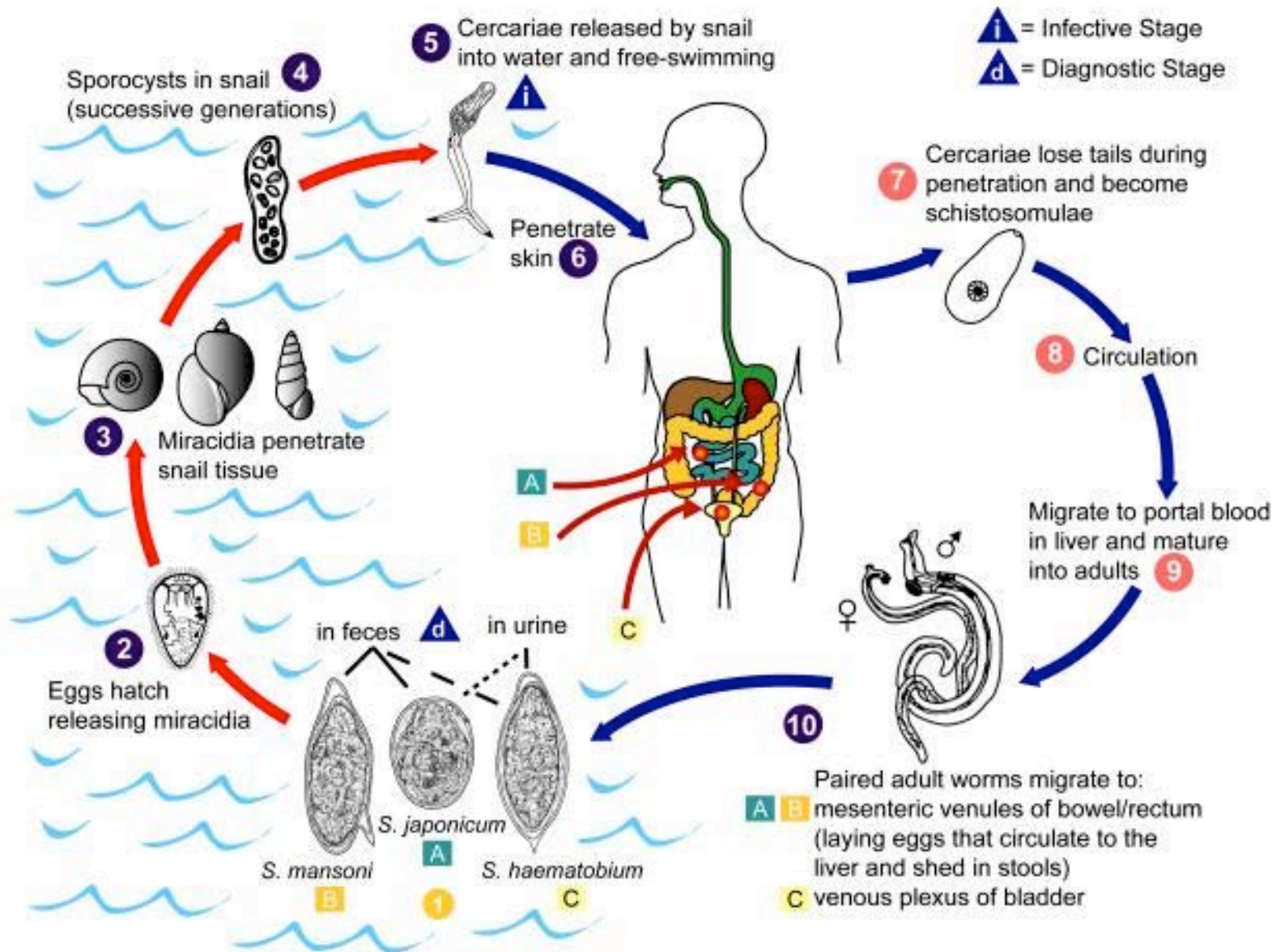


Ecological conditions suitable for Bilharzia transmission

- Irrigated agriculture
- Slow moving water systems
- Water holes
- Poor sanitary conditions (lack of safe disposal of human excreta)



Schistosomiasis



Intermediate hosts of Schistosomes

- *S. mansoni*
Biomphalaria sp



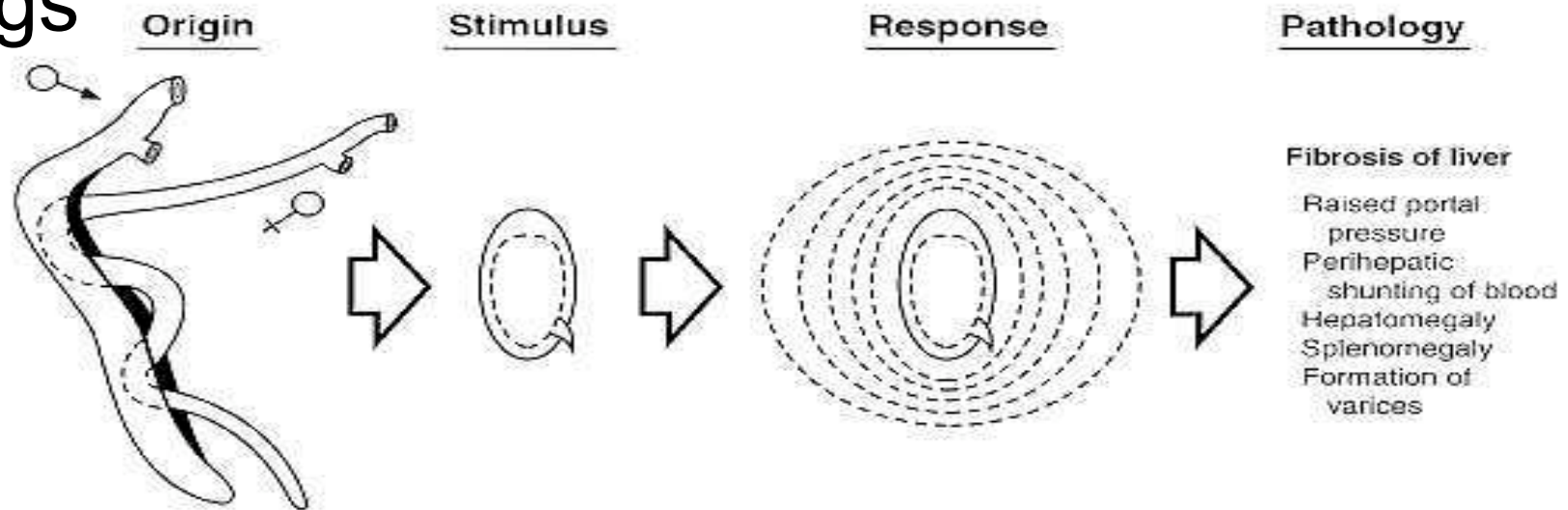
- *S. japonicum*
Oncomelania hupensis



- *S. hematobium*
Bulinus globosus



Symptoms caused by the body's reaction to the eggs



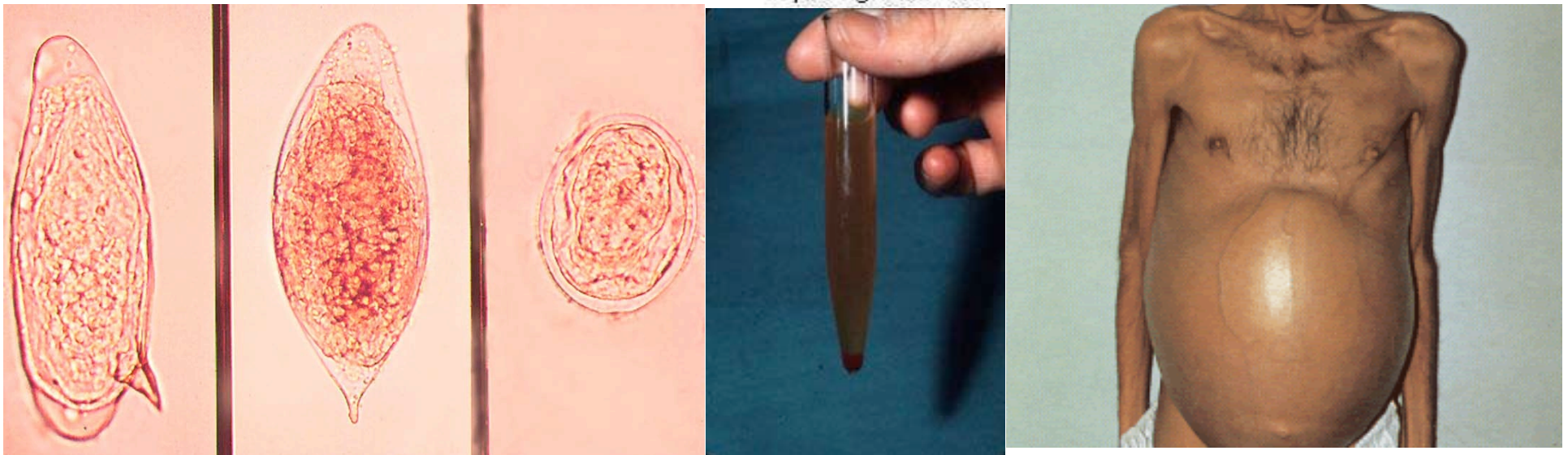
Adult schistosomes in blood vessels around small intestine

Eggs laid by female are carried in blood vessels and trapped in liver

Hypersensitivity to antigens of larva inside egg cause formation of granuloma. Liver sinusoids become blocked, impeding blood flow

Fibrosis of liver

- Raised portal pressure
- Perihepatic shunting of blood
- Hepatomegaly
- Splenomegaly
- Formation of varices





Symptoms of Schistosomiasis

- Rash or itchy skin at site of cercarial penetration
- Fever, chills, cough, and muscle aches occur within 1-2 months. Sometimes no symptoms are seen early infection
- Adult lodges in blood vessel, lay eggs which travel to the liver or pass into the intestine (mansoni) or bladder (hematobium), causing inflammation or scarring
- Repeatedly infected children develop anemia, malnutrition. Chronic infection leads to damage the liver, intestines, lungs, and bladder.
- Rarely, eggs are found in the brain or spinal cord and can cause seizures, paralysis, or spinal cord inflammation