

Swiss TPH



Swiss Tropical and Public Health Institute
Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse

Biostatistics and Computational Sciences

Introduction to mathematical epidemiology

1. Biomedical context

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Epidemiology

The study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to control of health problems

Mathematical Epidemiology

Chronic diseases

e.g. heart disease, diabetes, obesity

Frequently linear systems, often complex causal relationships

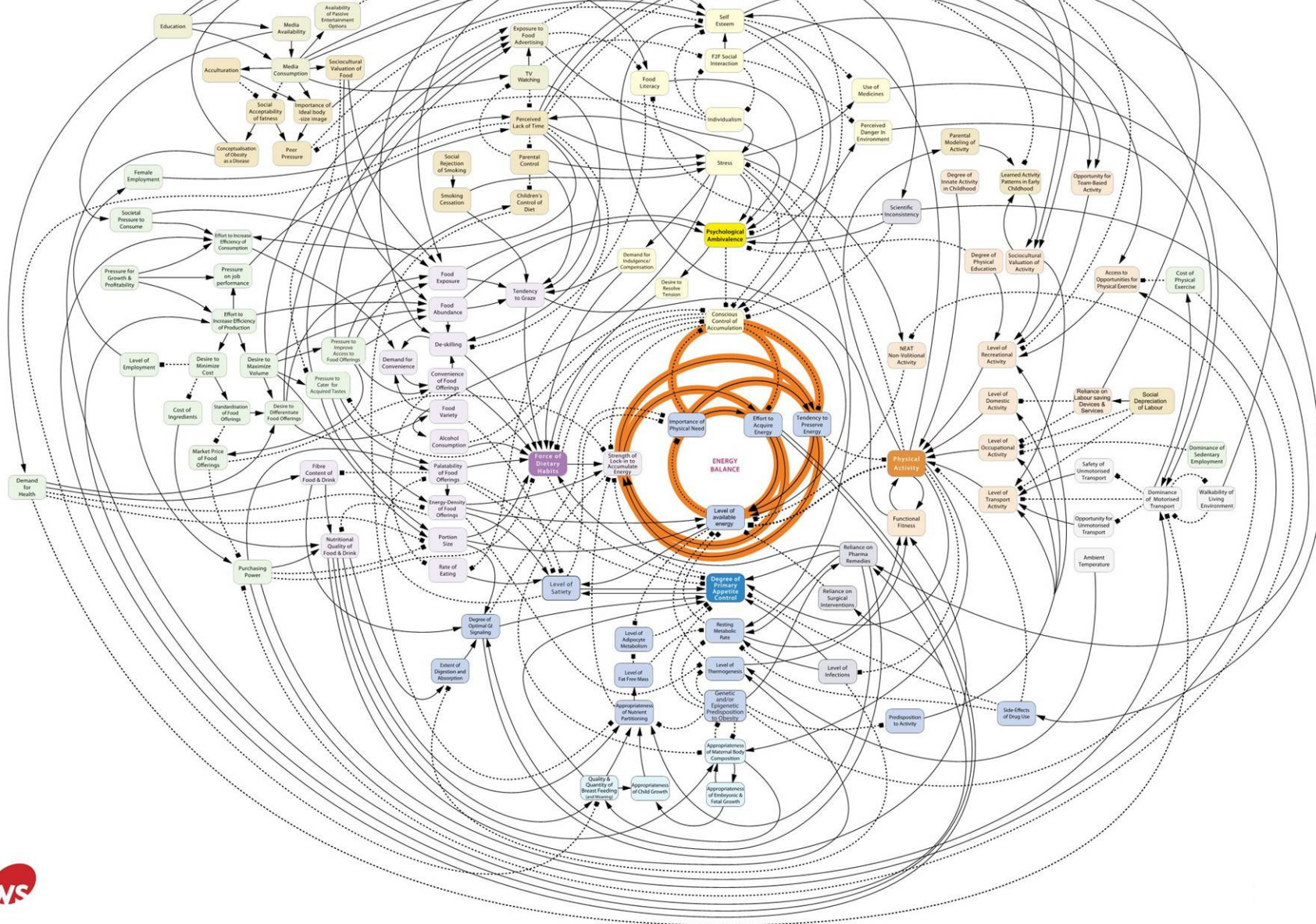
Infectious disease

e.g. pneumonia, malaria, infectious diarrhoea

Generally non-linear systems

Chronic disease epidemiology







Systems in public health

Most health problems occur within complex webs of causality

1. Determinants of exposure are complex
2. Implementation of preventive interventions or treatment is rarely perfect
3. Human genetics and behaviour are highly variable

Some roles of mathematical modeling

1. Understanding the drivers of the system
2. Identifying data gaps and uncertainties
3. Evaluating the potential of different interventions
4. Quantitative prediction of outcomes?

Some disciplines and topics in public health and epidemiology

Medicine

1. Pathophysiology
2. Diagnostics
3. Therapeutics

Computational sciences

1. Statistics
2. Information science
3. Mathematics of dynamic systems
4. Demography

Social Science/Psychology

1. Perspectives of different stakeholders
2. Communication

Biology

1. Pathogen biology
2. Human biology

Intervention technologies

1. Pharmacology
2. Environmental modification
3. Biological control
4. Physical methods

Environmental Sciences

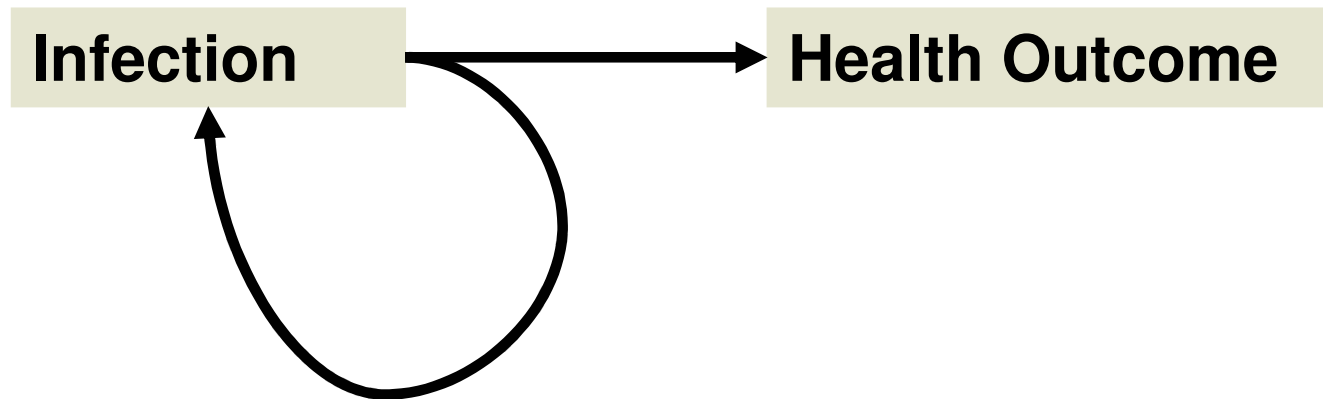
1. Environmental risk factors

Politics and economics

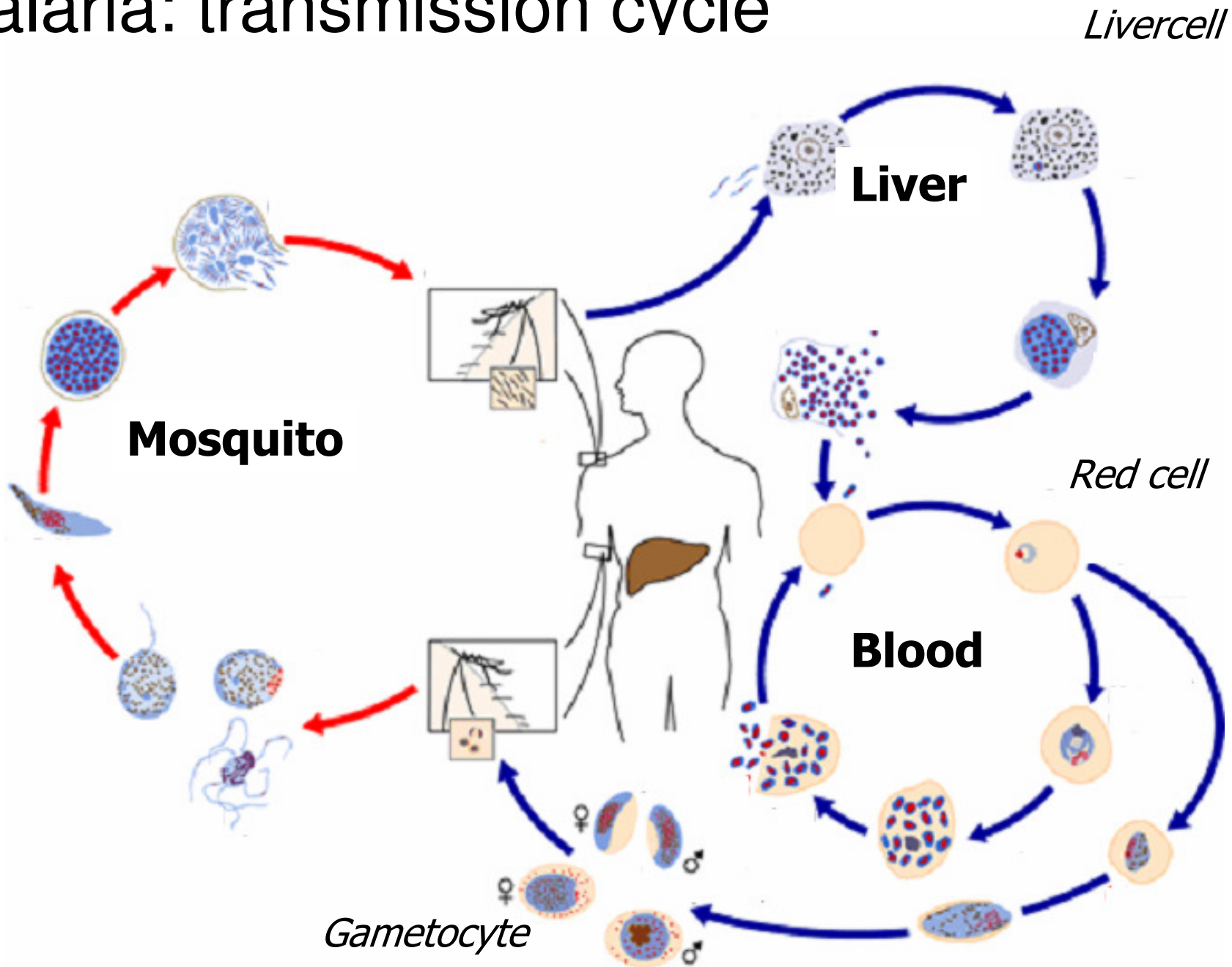
1. Organisation of the health system
2. Incentives and costs
3. Health and safety legislation
4. Human resource availability

Etc.

Infectious disease epidemiology



Malaria: transmission cycle

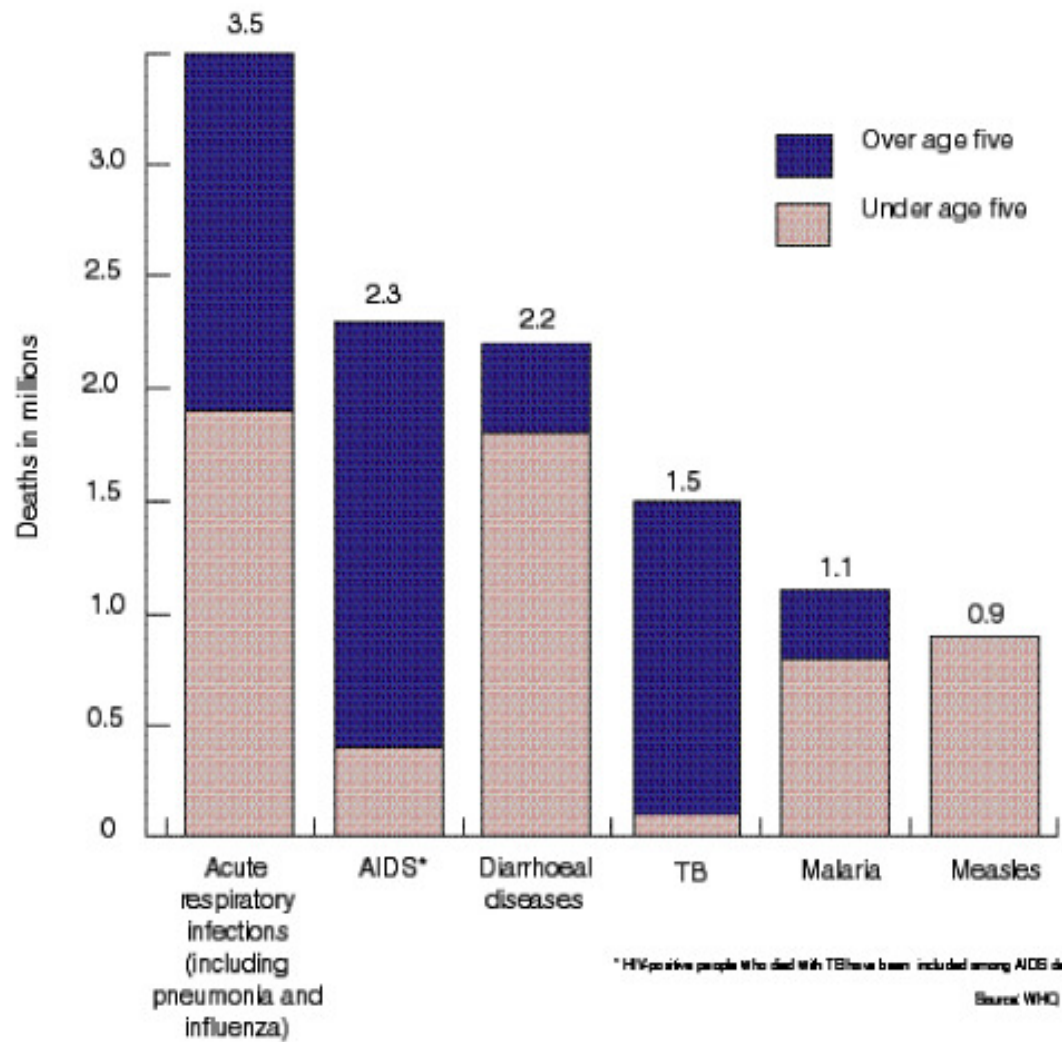


Todesursachen (2002)

	Europa	Afrika
Population	890 000 000	670 000 000
Anzahl der Todesfälle	9 500 000	10 800 000
Todesfälle durch Infektionen	200 000 2%	5 800 000 54%

Leading infectious killers

Millions of deaths, worldwide, all ages, 1998



Infektion ist nicht gleich Krankheit

Poliomyelitis in Kindern

0.1-1% der Infektionen führen zu klinischer Erkrankung

Spektrum der Virulenz

Röteln

50% der Infektionen sind klinisch relevant

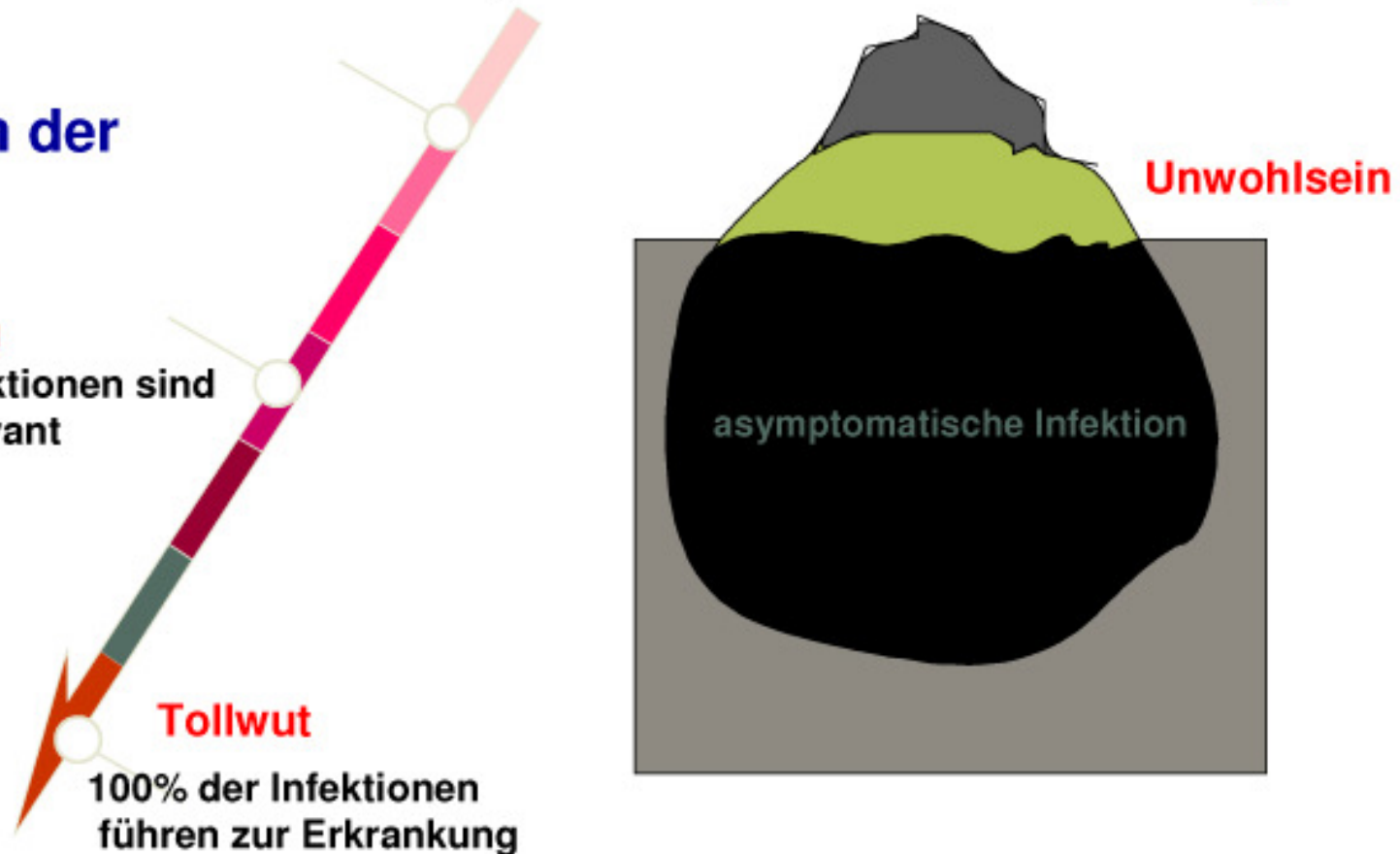
Tollwut

100% der Infektionen führen zur Erkrankung

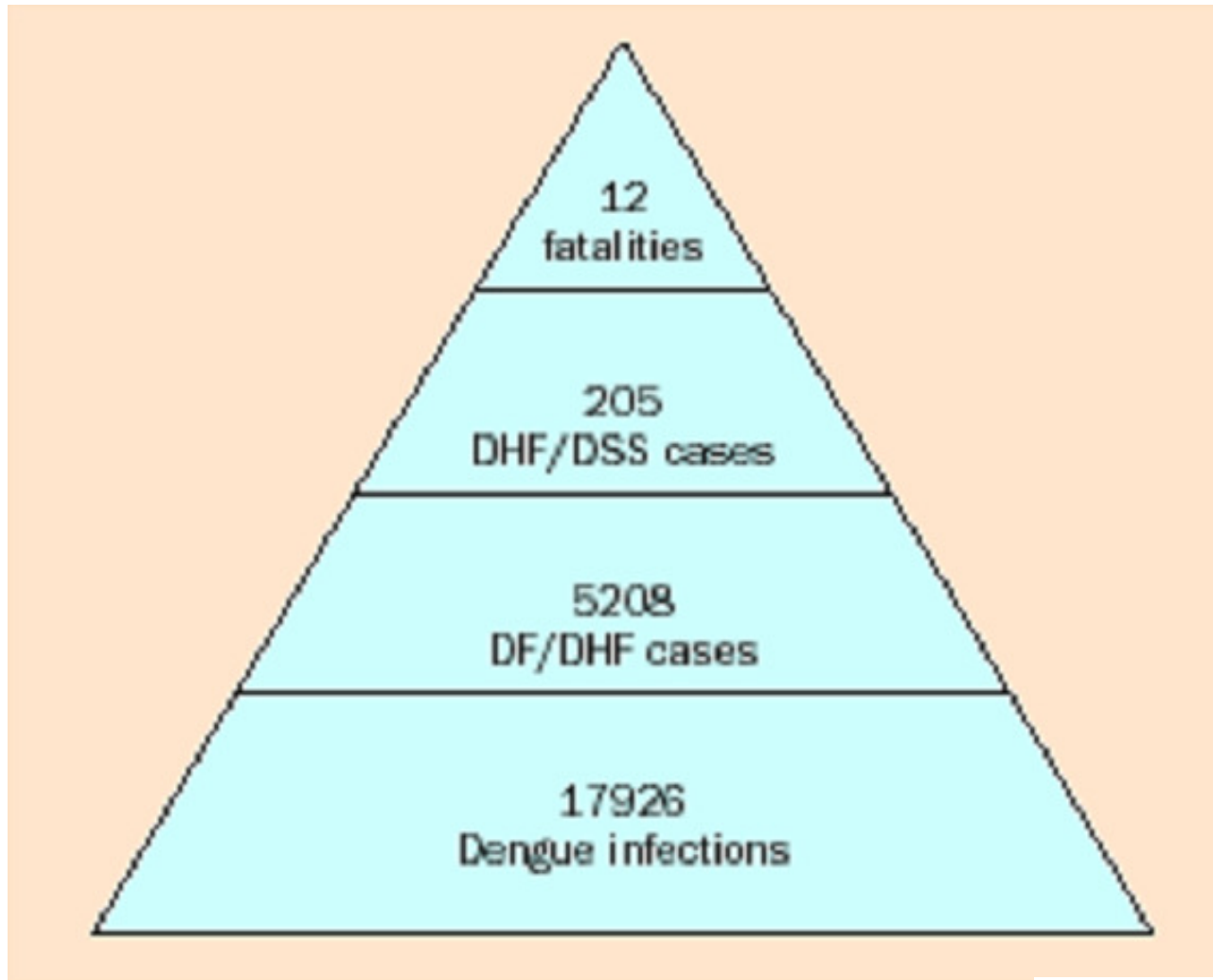
Klinische Erkrankung

Unwohlsein

asymptomatische Infektion



Dengue Outbreak in Cuba 1981 : health effects



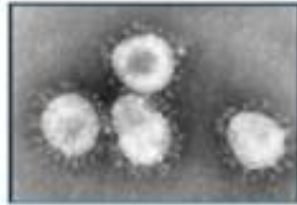
DF- dengue fever

DHF- dengue haemorrhagic fever

DSS- dengue shock syndrome

Types of pathogens

- Viruses



- Bacterial



- Fungi



- Protozoa

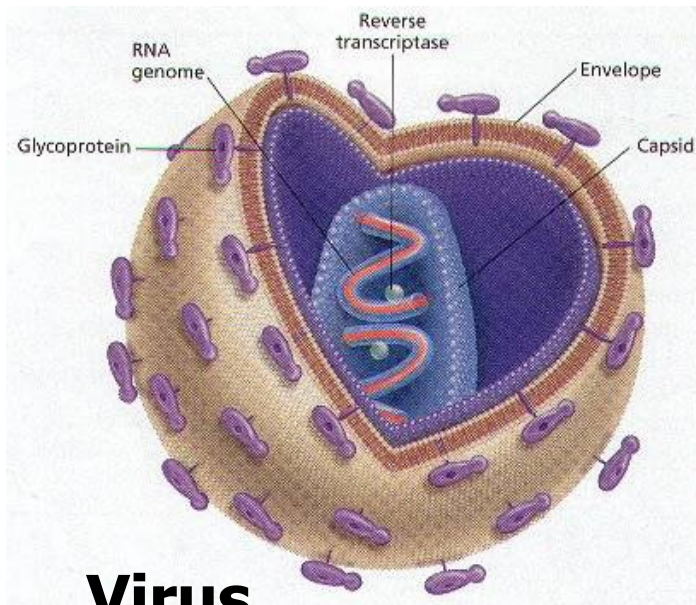


- Helminths





100 nm

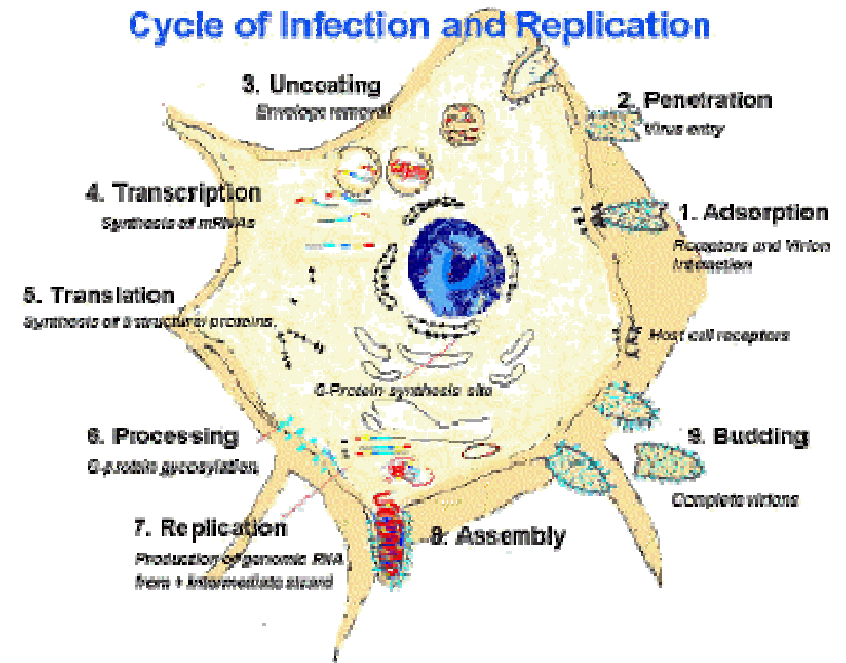


Virus

Capsid, protein spikes,
genetic material (DNA, RNA)



100 μ m

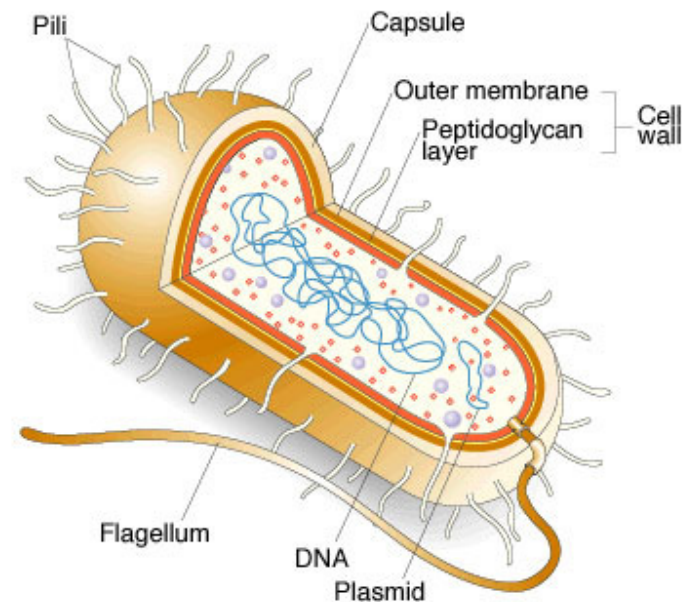


Host cell

Bacterium –

Capsule (sticky, biofilm), Pili (attach), DNA, flagellum (moving); prokaryote

Most bacteria beneficial (intestinal flora, degradation nutrients), spore forming, some pathogens



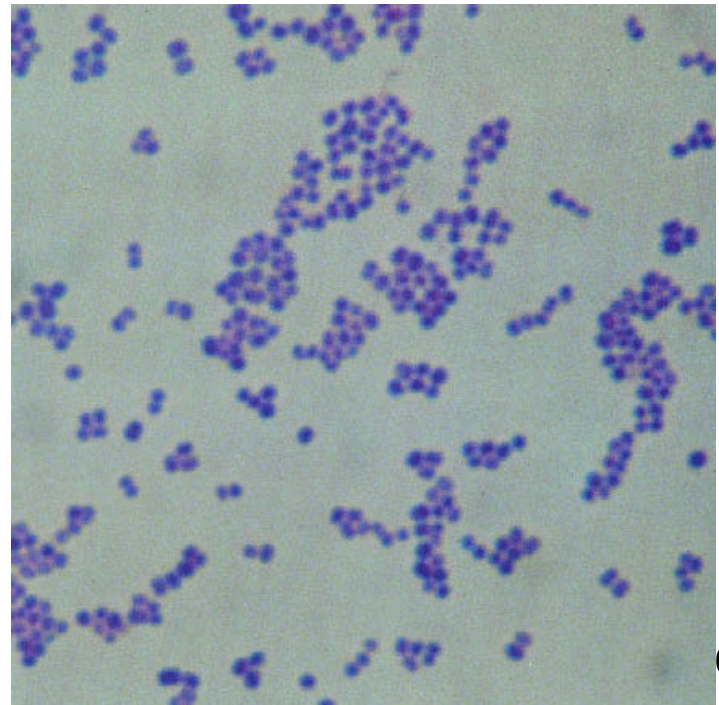
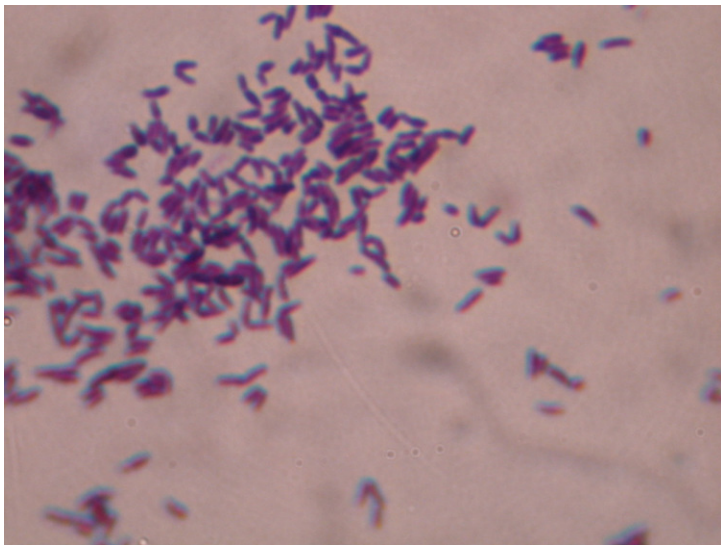
← 2 μm →



Micrococcus

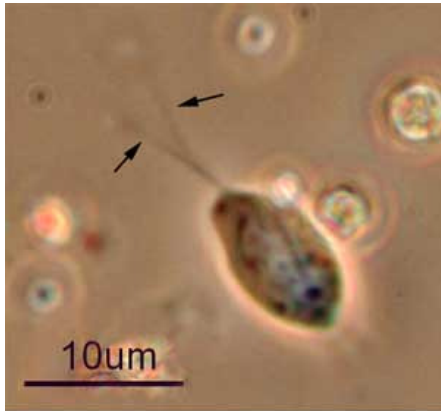
Corynebacterium sp.

Staphylococcus aureus



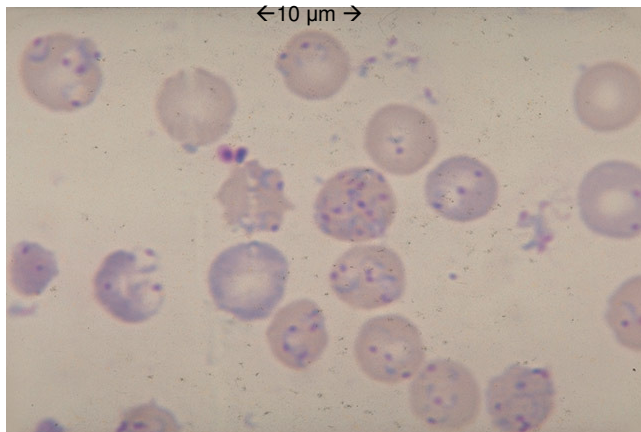
Parasite:

Protozoa (one cell), Helminths (worms), Ectoparasite (lice, fleas, lice...),



Giardia lamblia

Schistosomiasis



Malaria (Plasmodium sp.)



Hookworm



Types of pathogens

- Directly transmitted



Dust

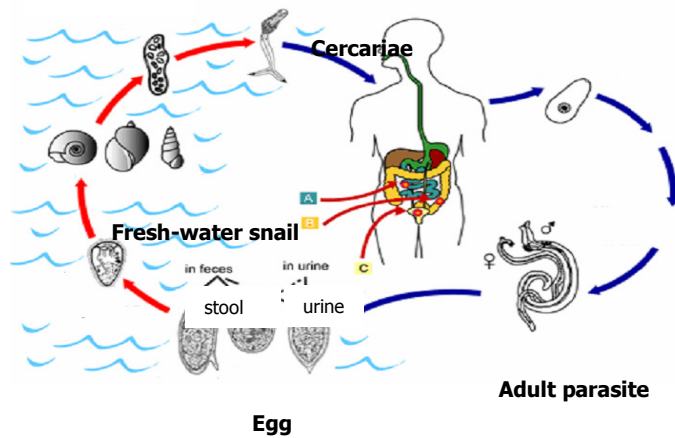


Contaminated water

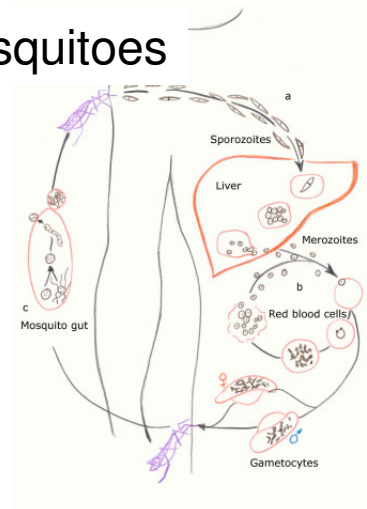
Respiratory droplets

- Vector-borne

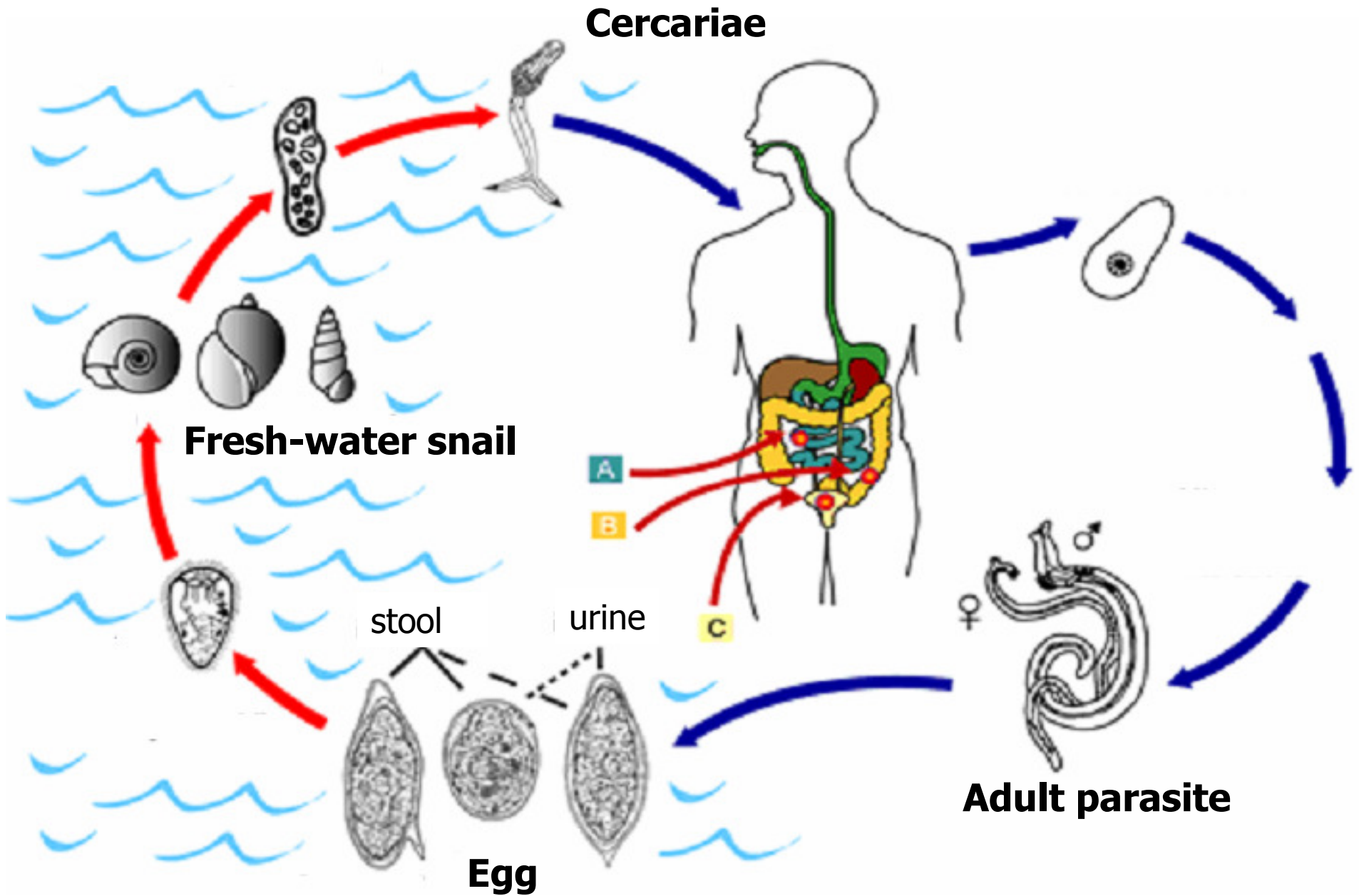
Snails



Mosquitoes

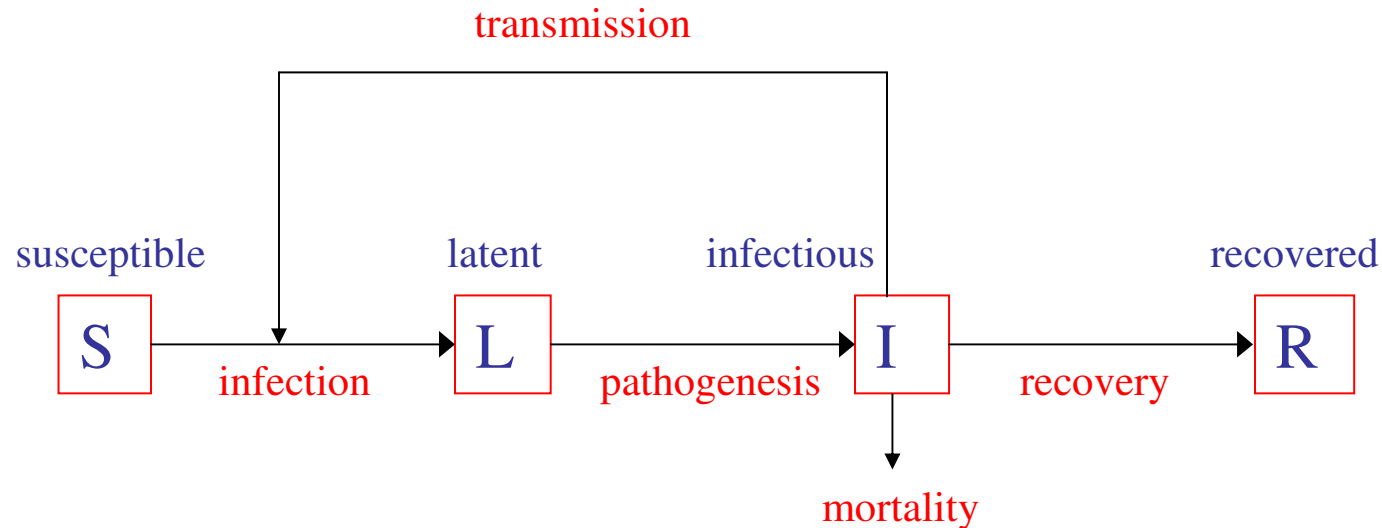


Schistosomiasis - Life Cycle



Approaches in modeling infectious diseases

- ODEs / Compartment models e.g.



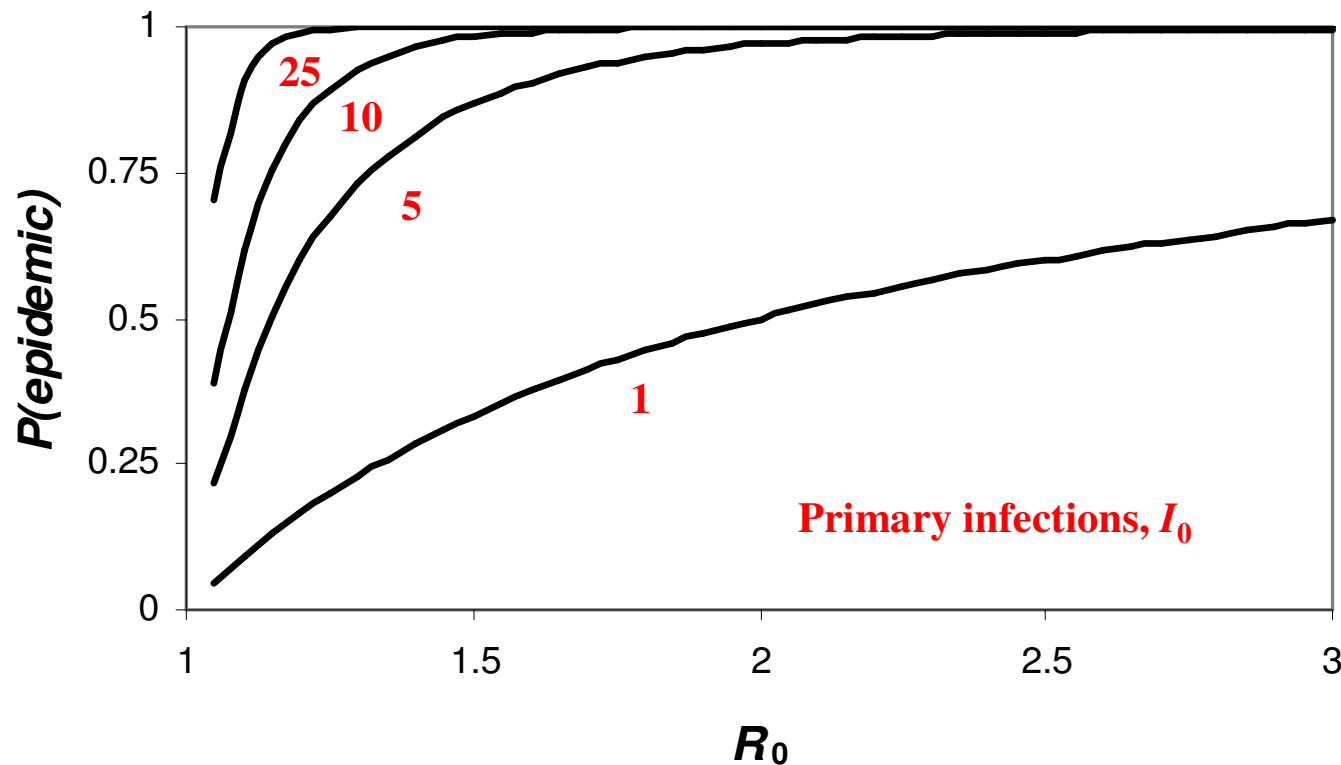
$$\frac{dS}{dt} = -\beta(N)SI; \frac{dL}{dt} = \beta(N)SI - \sigma L; \frac{dI}{dt} = \sigma L - \mu I - \nu I; \frac{dR}{dt} = \nu I$$

where β is the per capita transmission rate, $1/\sigma$ is the mean latent period, μ is the per capita mortality rate due to infection, ν is the rate of recovery from infection, $N = S+L+I+R =$ total population size

Approaches in modeling infectious diseases

- Stochastic processes e.g.
 - Probability of an epidemic

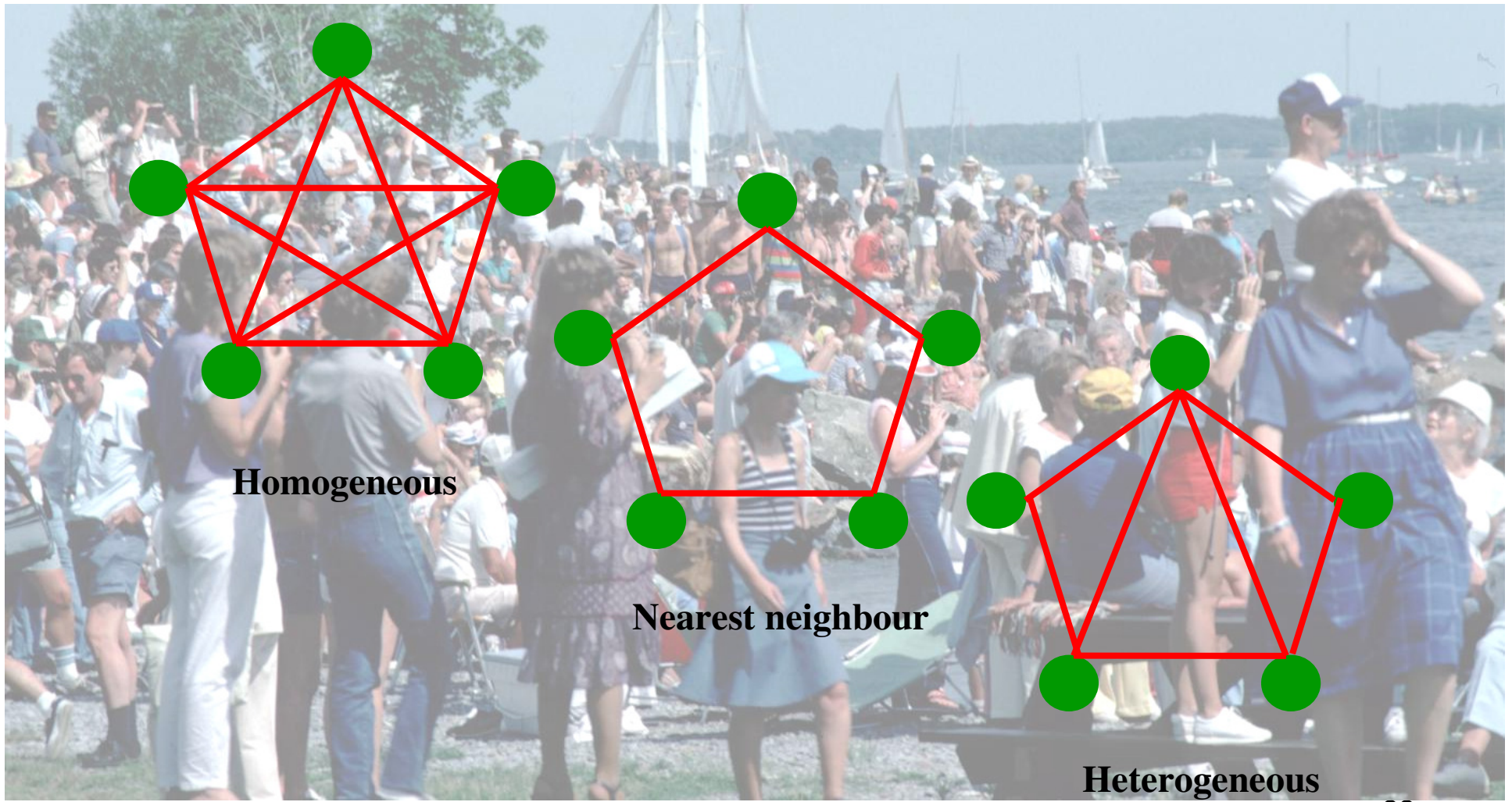
$$P(\text{epidemic}) = 1 - \left(\frac{1}{R_0}\right)^{I_0}$$



May et al. (2001) *Phil Trans R Soc Lond - Ser B*

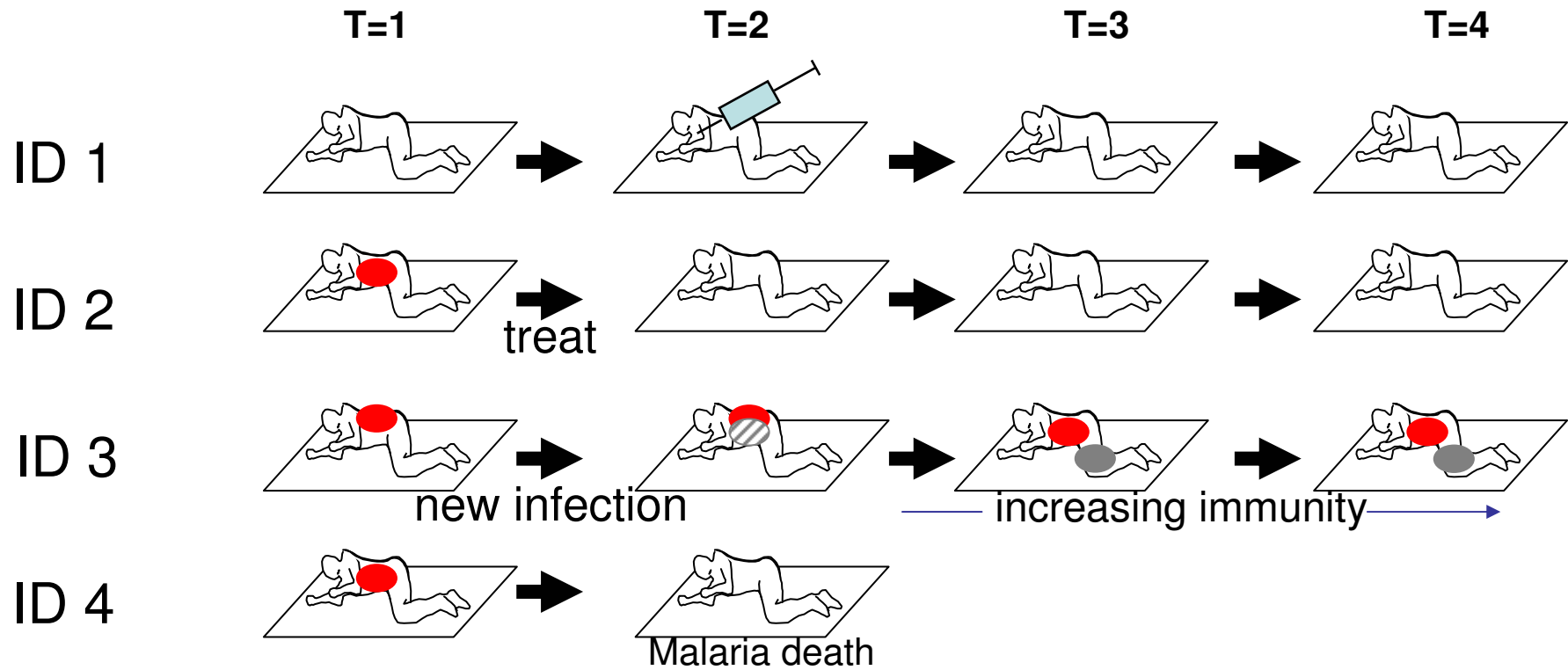
Approaches in modeling infectious diseases

- Contact network models



Approaches in modeling infectious diseases

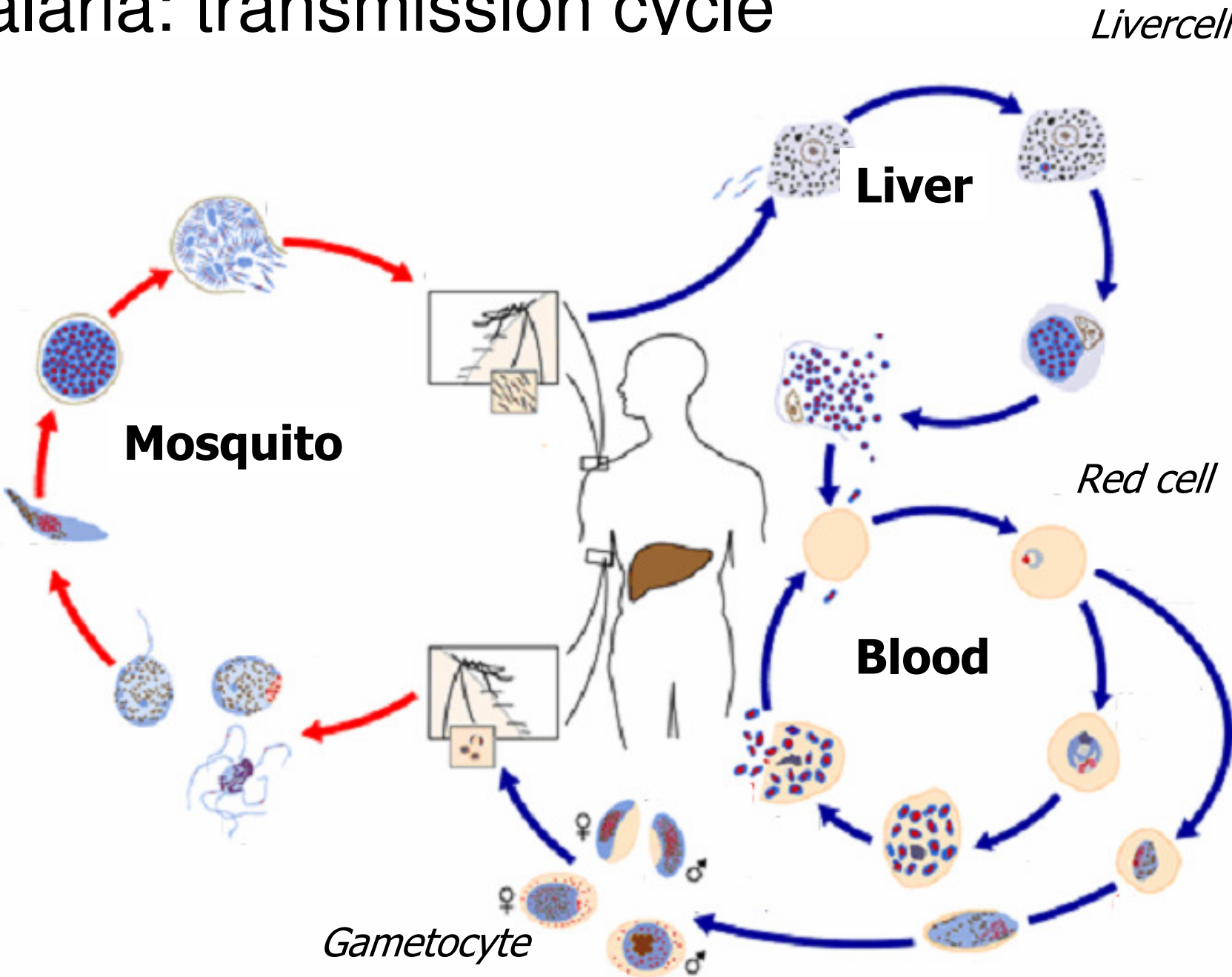
- Microsimulation



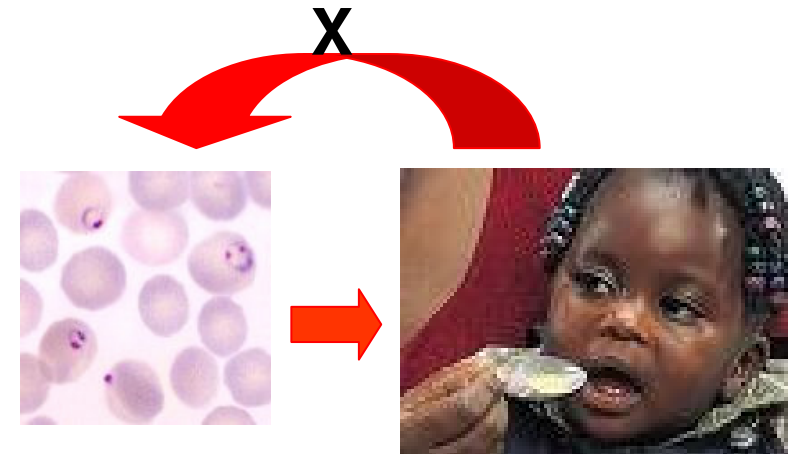
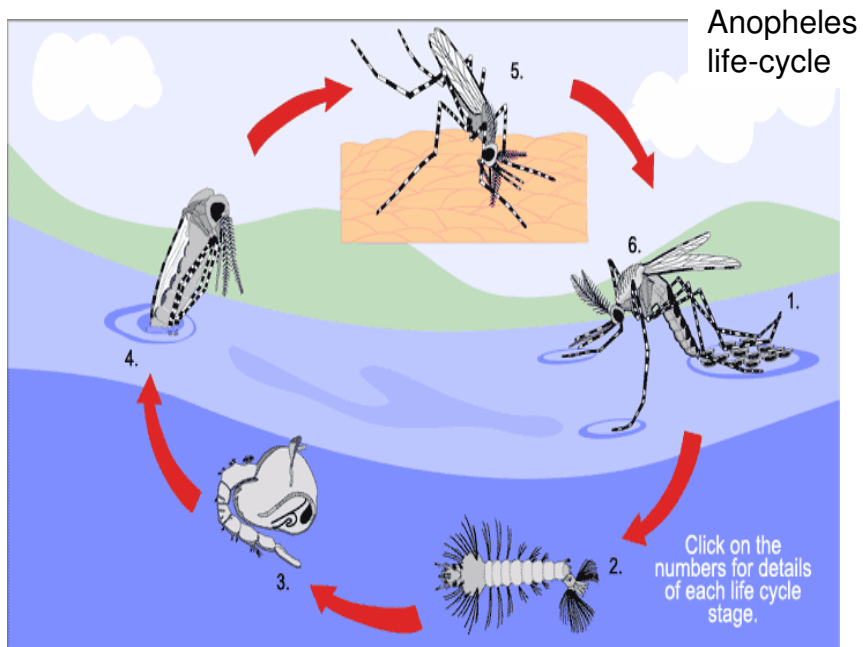
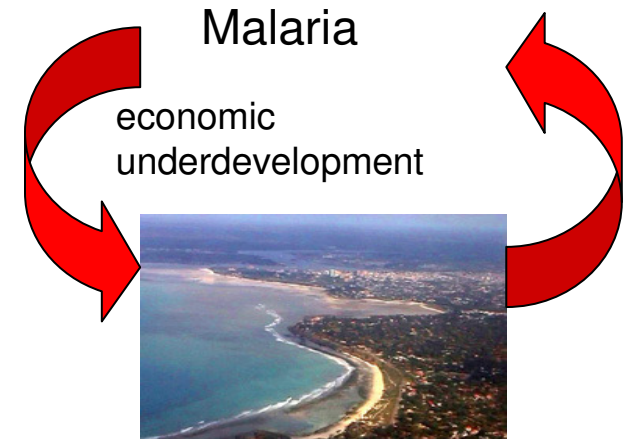
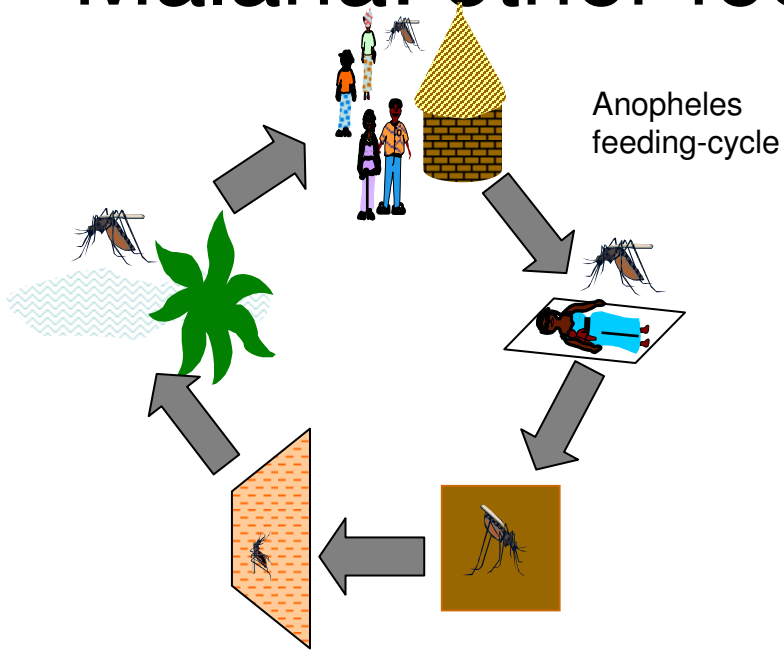
Example: Malaria

- Parasite: number **1 killer**
- 4 parasites: *Plasmodium falciparum* most deadly
- Disease: from symptomless to **acute disease** & death (semi-immunity possible)
- **Treatment** exists but: expensive, diagnosis not easy, under medical supervision, costly, ... **no vaccine**
- **42%** of world population at risk
- Ca. 300 million cases/year; ca 0.8 **million** death/year
- Huge **economic burden** (hospital admission, disease periods, death, ...)
- Mosquito: *Anopheles sp.*, *large number of species*
- **Ecology** of *Anopheles sp.* varies: Urban / rural; Plains, forest, mountains, ...; Small – large water sites; Look closely at local condition

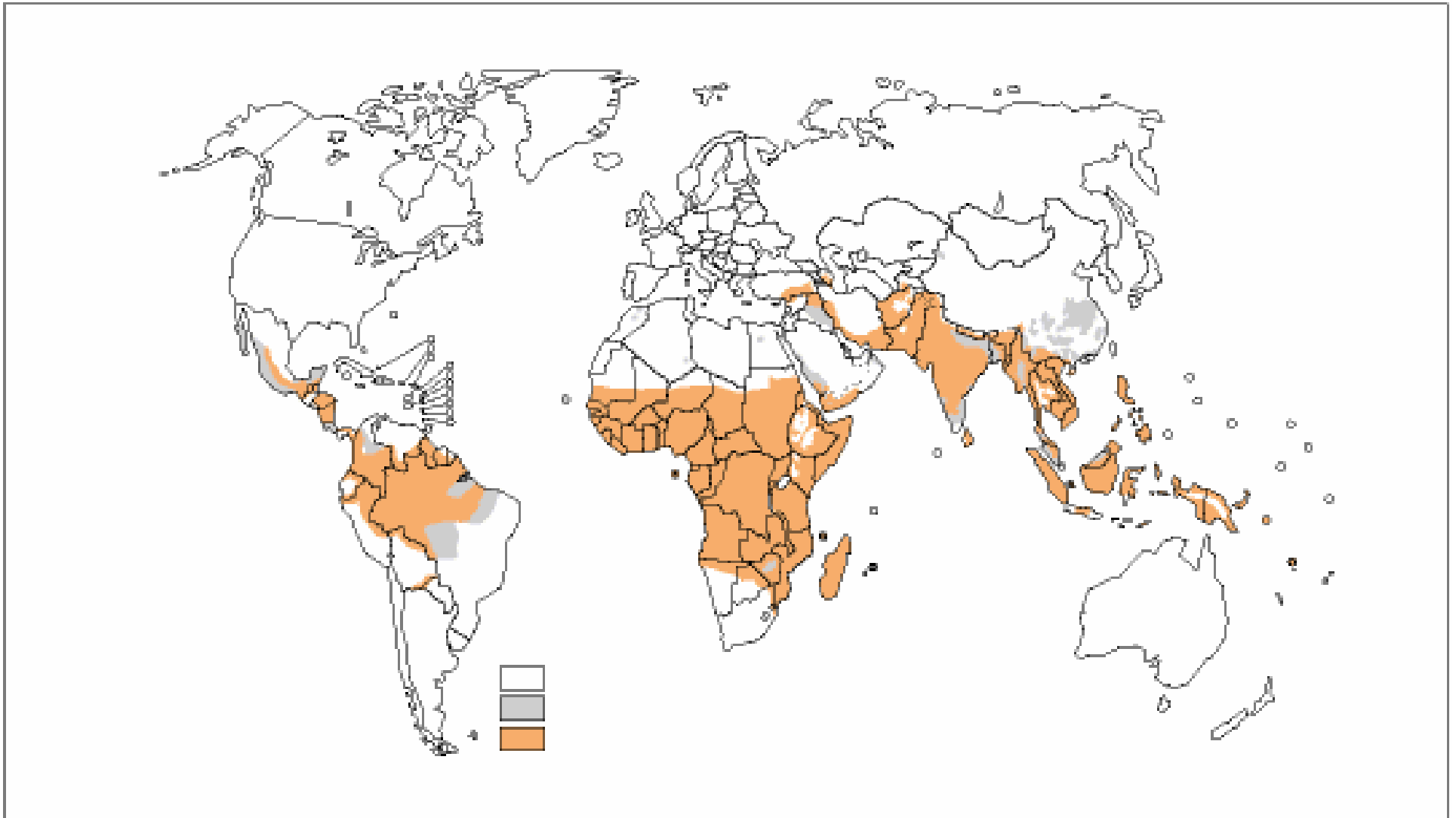
Malaria: transmission cycle



Malaria: other feedback loops



Effects of health systems



Malaria endemic countries (WHO, 2005)







Impregnated mosquito net

