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Pathogens and Dirty Water

Public Health Microbiology

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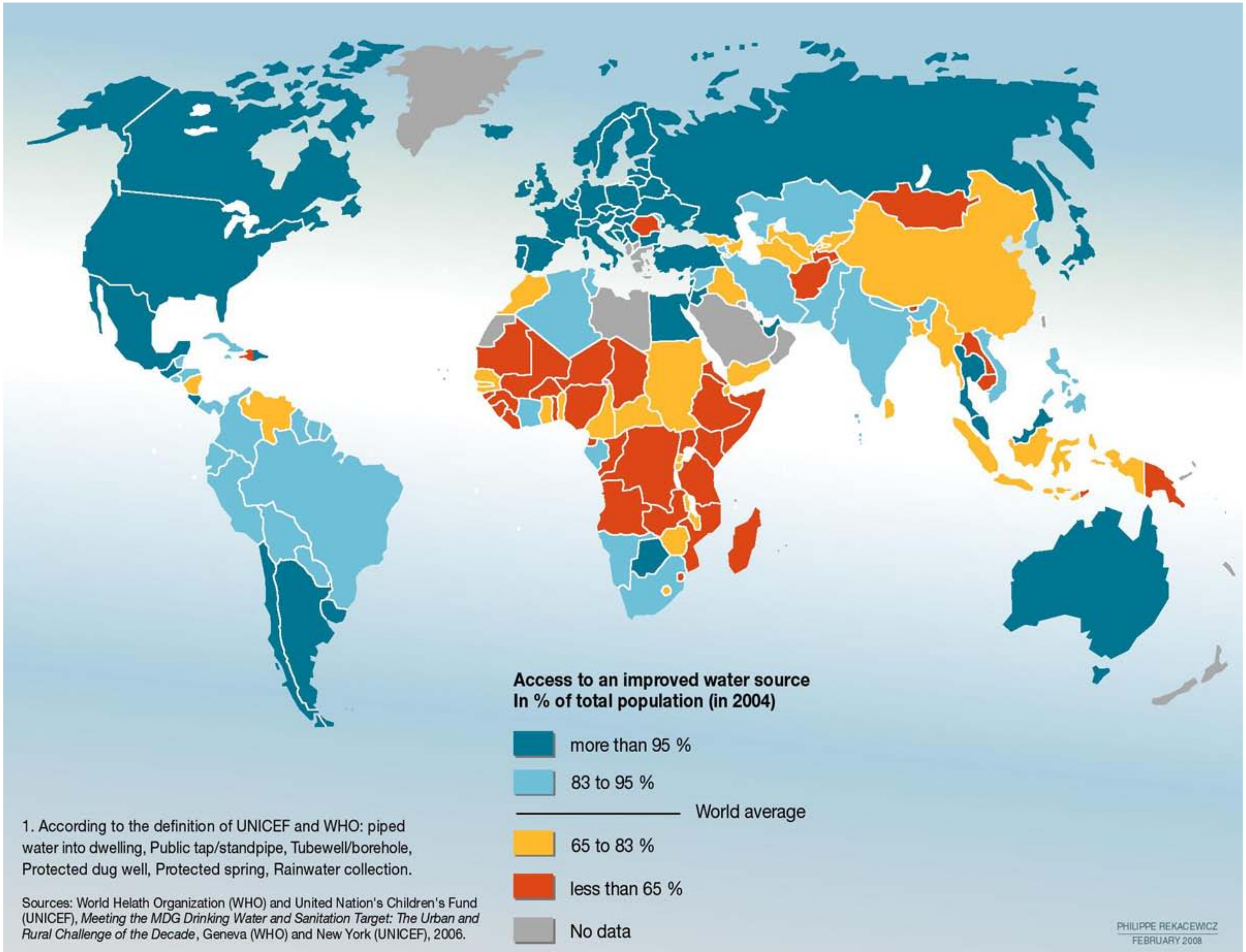
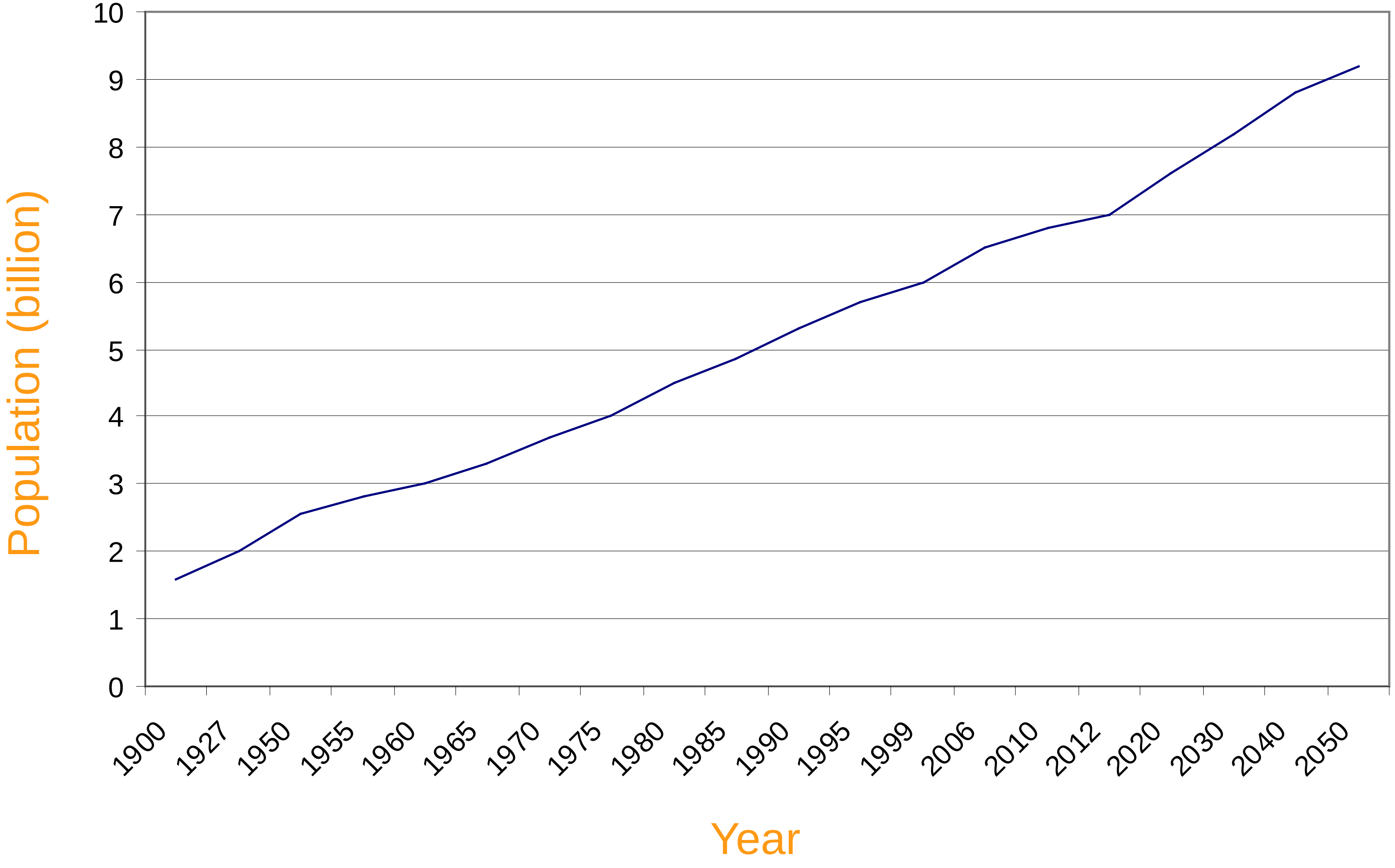
Water

- •1.1 billion people lack improved water supply
- •17% of the global population
- •2/3 live in Asia



World Population Growth



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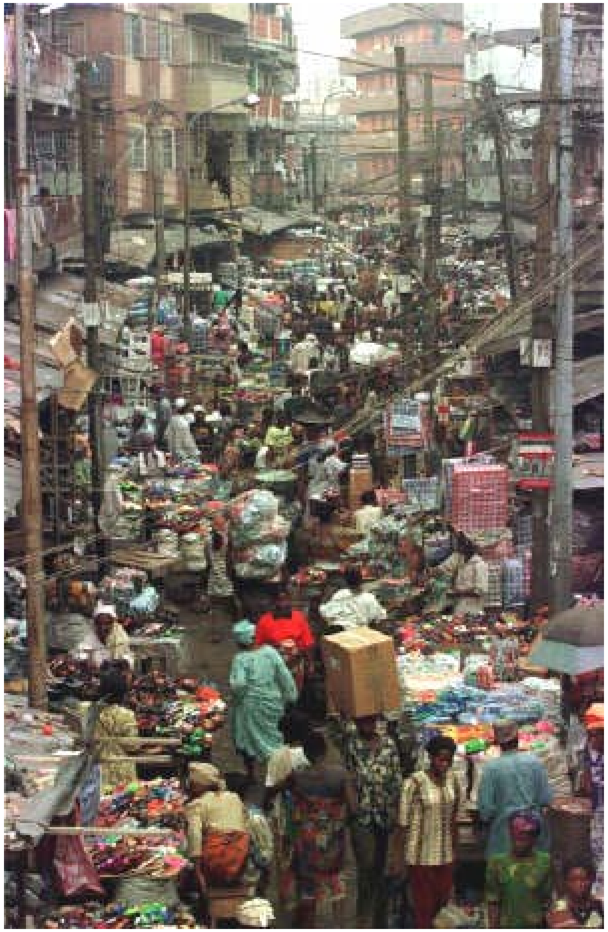
Population Growth and Demand for Resources

- Cities worldwide are growing at an incredible rate.
- The current **urban population** of 3.2 billion will increase to 3.8 billion in 2015 and to 4.5 billion in 2025.
- Megacities create tremendous demand for water and act as concentrated sources of pollution.



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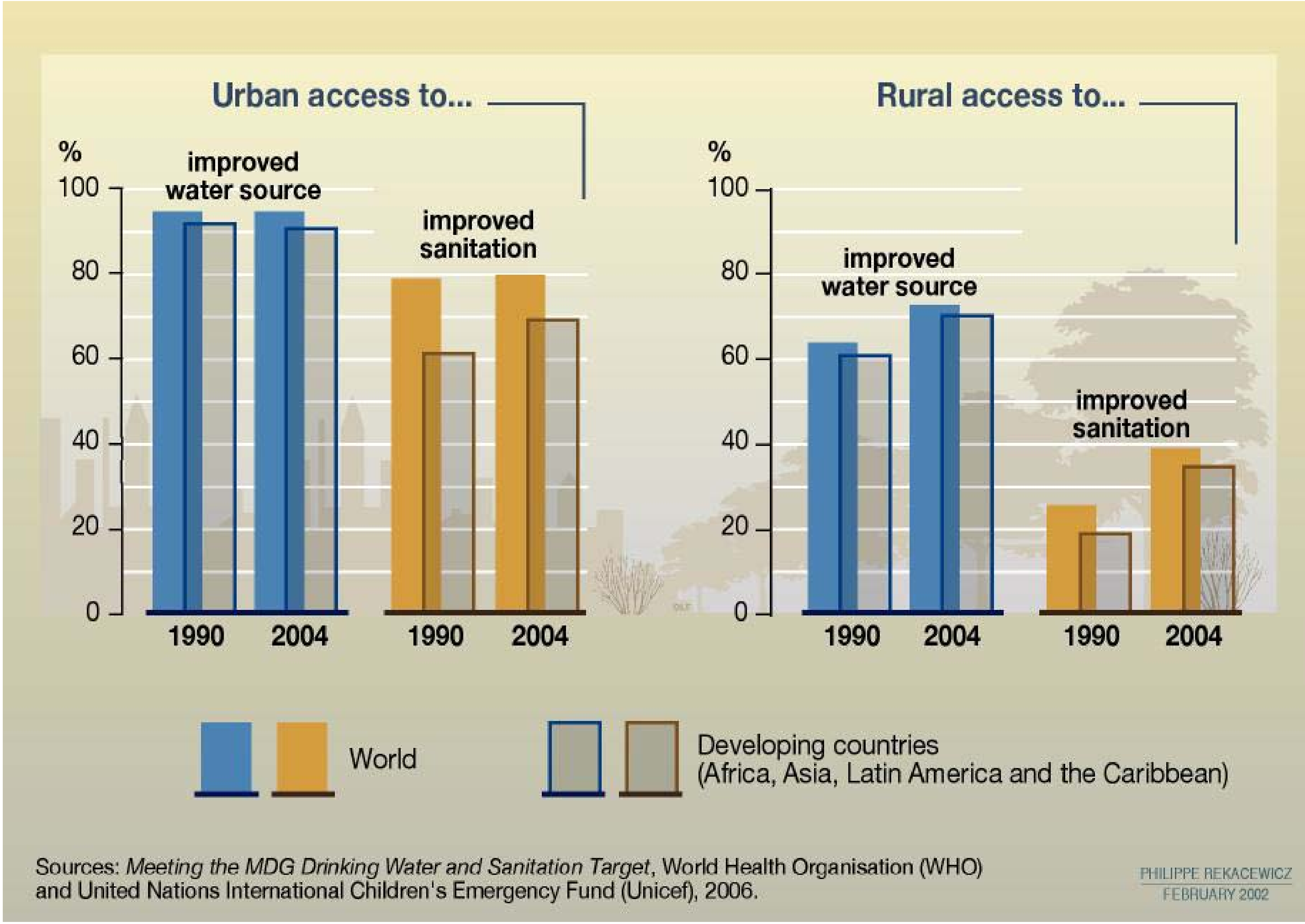

Urban access to...
Rural access to...
%
improved water source
improved sanitation
100
80
60
40
20
0
1990
2004
World
Developing countries
(Africa, Asia, Latin America and the Caribbean)
Sources: Meeting the MDG Drinking Water and Sanitation Target, World Health Organisation (WHO) and United Nations International Children's Emergency Fund (Unicef), 2006.
PHILIPPE REKACEWICZ
FEBRUARY 2002

Current Global Water Supply and Sanitation Situation

- Water
  - 1.1 billion people lack improved water supply
  - 17% of the global population
  - 2/3 live in Asia
- Sanitation
  - 2.6 billion people lack improved sanitation
  - 42% of the global population
  - >50% live in China and India
  - 69% lack access in rural areas
  - 22% lack access in urban areas
- Health care
  - 40 % hospital beds occupied by individuals with enteric infections

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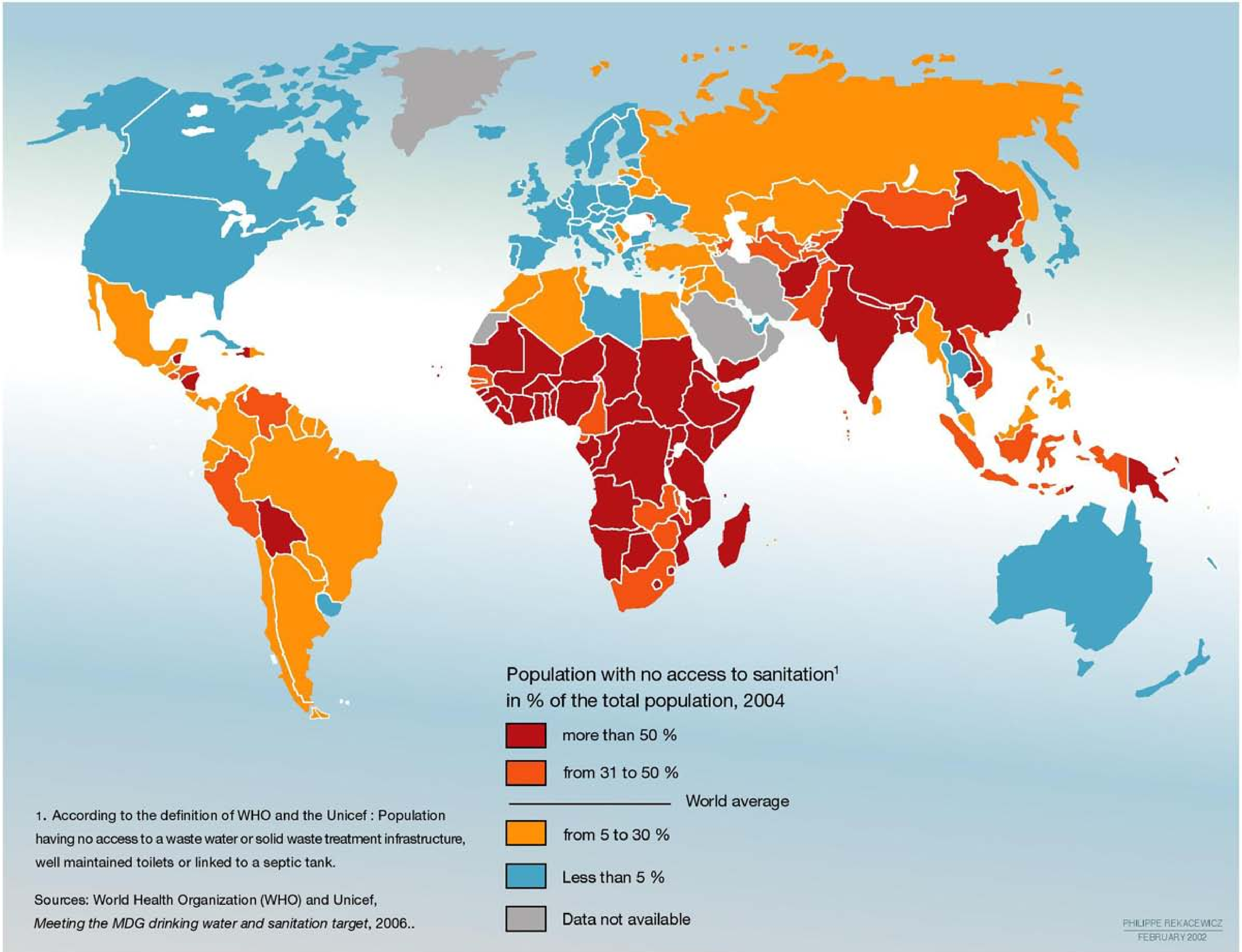

1. According to the definition of WHO and the Unicef : Population having no access to a waste water or solid waste treatment infrastructure, well maintained toilets or linked to a septic tank.

Sources: World Health Organization (WHO) and Unicef, *Meeting the MDG drinking water and sanitation target*, 2006..

The Bradley Classification of Water-Related Infections

Transmission Route	Description
Water-washed (or water scarce)	Person-to-person transmission due to inadequate personal and domestic hygiene
Water-based	Transmission of infections via an obligatory aquatic host (e.g., snail)
Water-related insect vector	Transmission by insects which breed in (or bite near) water
Water-borne	You drink it/eat it

White, G. F., Bradley, D. J., and White, A. U. (1972). *Drawers of water: Domestic water use in East Africa. Chicago Univ. Press, Chicago, Ill.*

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Reference Sources

- Cairncross, S. and Feachem, R. (1993) *Environmental Health Engineering in the Tropics* John Wiley & Sons, Chichester.
- Feachem RG *et al*. (1983) *Sanitation and Disease: Health Aspects of Excreta and Wastewater Management.* John Wiley Sons, Chichester.

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Water-Washed Infections

eg Trachoma (*Chlamydia trachomatis*)

An obligate intracellular bacterial pathogen causing visual impairment and blindness

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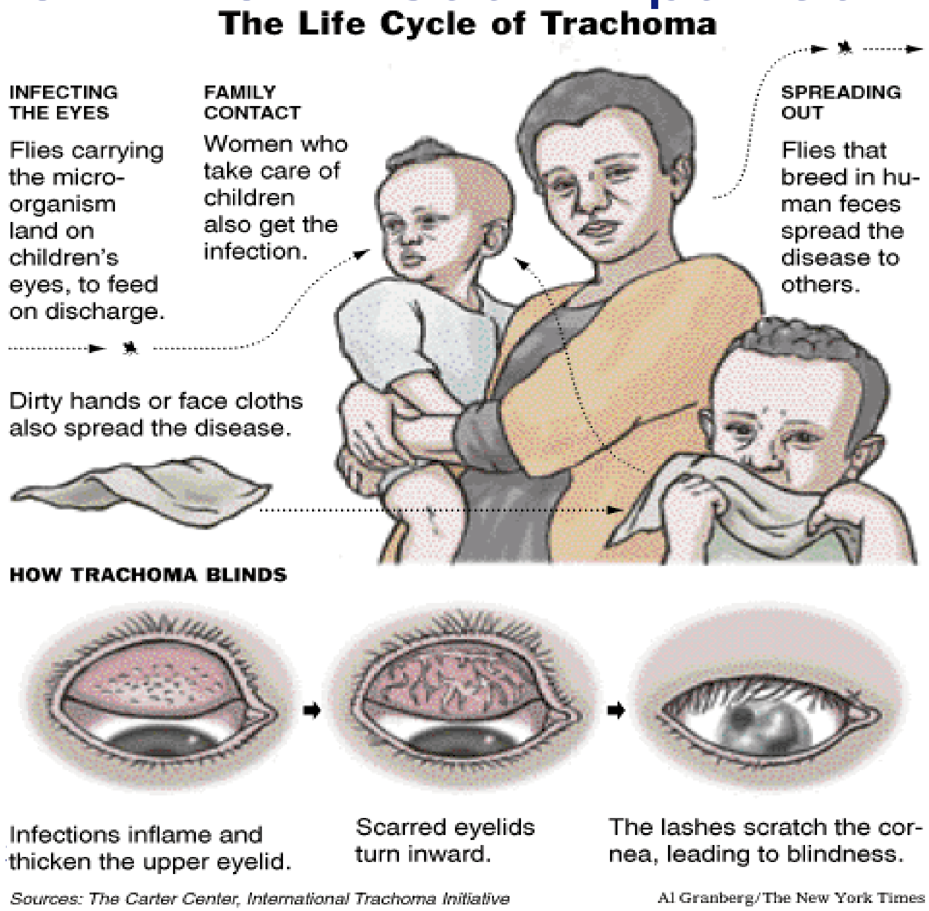
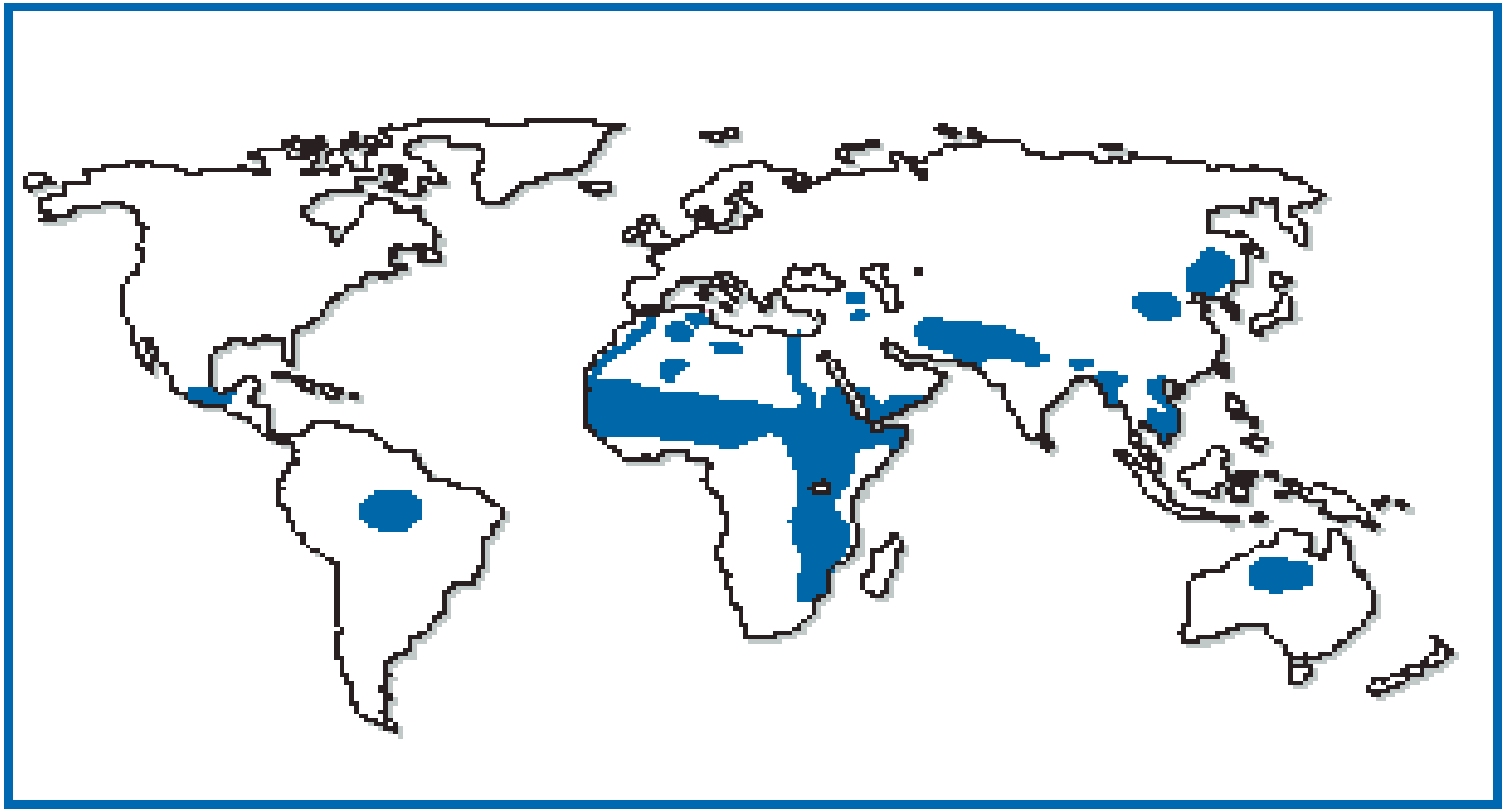
Trachoma (*Chlamydia trachomatis*)

- 84 million affected
- 8 million visual impaired



Trachoma endemic regions as identified by WHO



Source: WHO

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Trachoma Control

- **S**urgery for advanced cases
- **A**ntibiotics
- **F**acial cleanliness
- **E**nvironmental improvements

- Infection rate could be reduced by 27% with improved water supply

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Water-Based Infections

eg Schistosomiasis (bilharzia)

A parasitic disease caused by several species of fluke (or flatworm) of the genus *Schistosoma* that damage internal organs (eg liver) and impair growth and cognitive development in children

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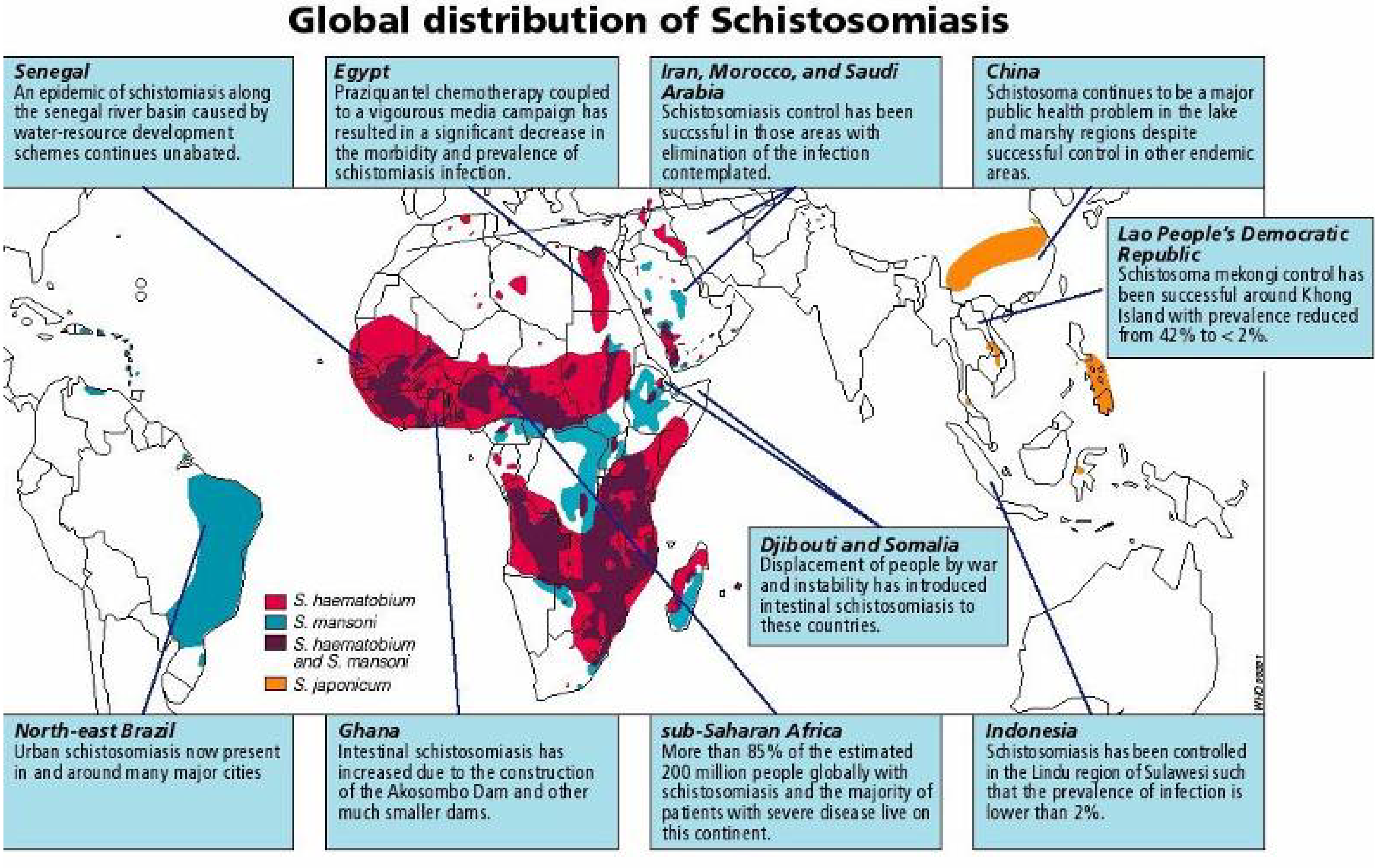
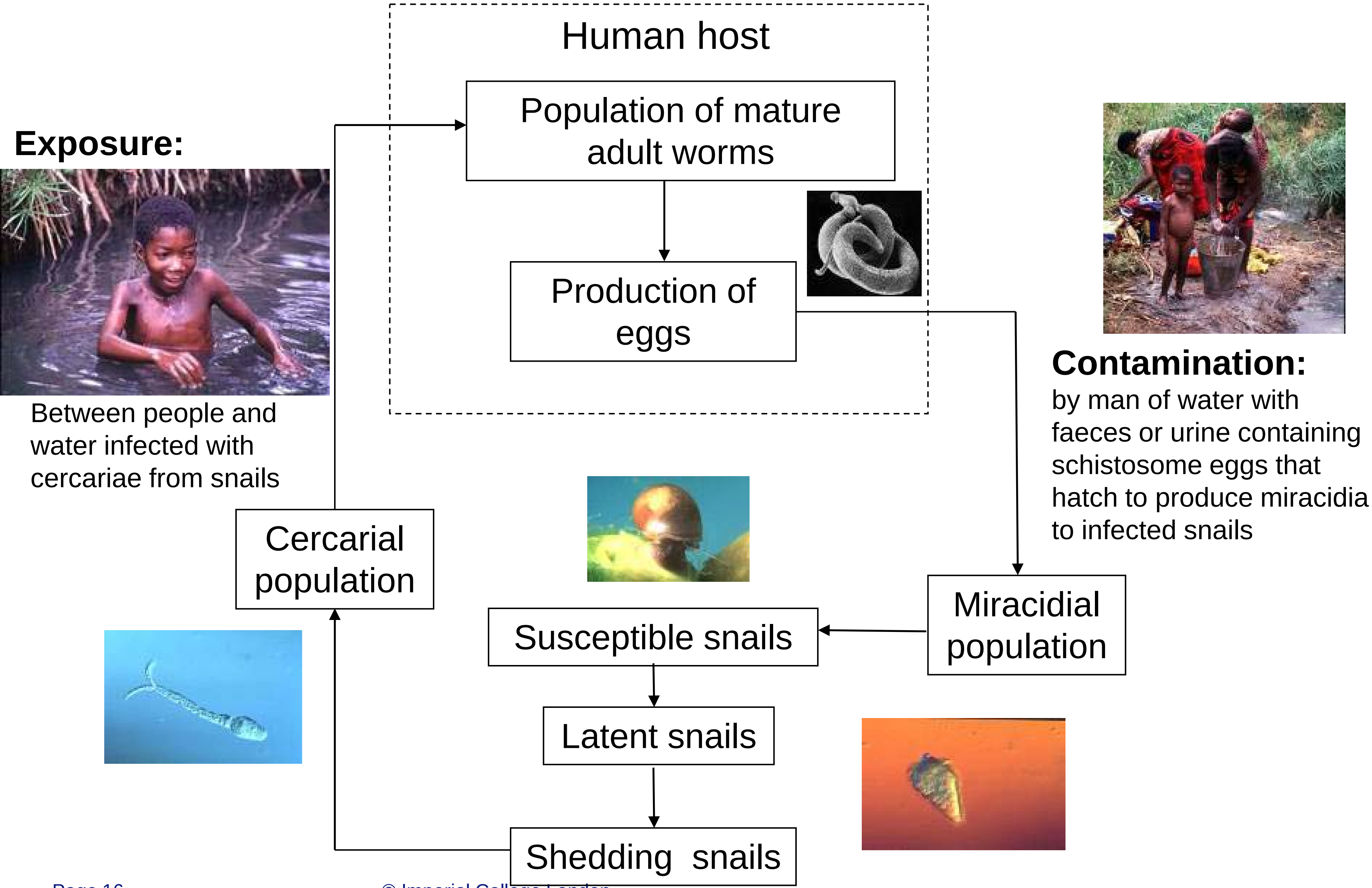
Schistosomiasis

- 300 million people infected with bilharzia





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Control of Schistosomiasis

- Reduction of eggs excreted by infected people
  - Treatment with antischistosomal drugs
- Reduction in number of excreted eggs reaching snail-inhabited freshwater
  - Water & sanitation and health education
- Reduction of contact between miracidia and snails
  - Snail control
  - Improved drainage
  - Lining canals with concrete discouraging vegetation growth
  - Molluscicides
- Reduction of probability of humans encountering cercariae
  - Water & sanitation and health education

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Water-related Insect Vector Infections

eg Malaria

A vector-borne infectious vascular (blood) disease caused by protozoan parasites of the genus *Plasmodium*

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Impacts of Water-Related Disease: Insect Vector Transmission – eg Malaria

- 1.3 million people die of malaria each year, 90% are children <5y
- There are 396 million episodes of malaria every year, most of the disease burden is in Africa south of the Sahara

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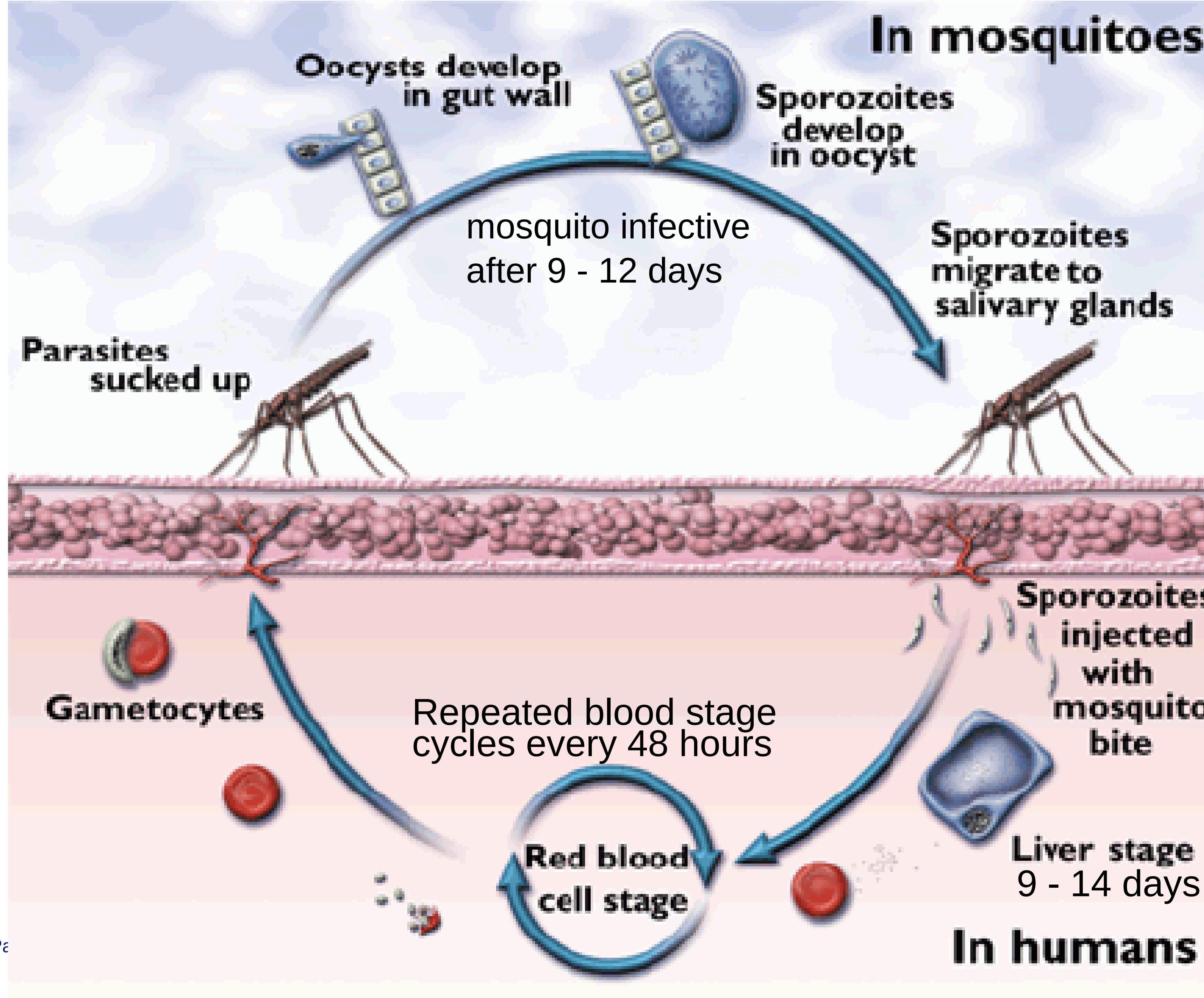
In mosquitoes
Oocysts develop in gut wall
Sporozoites develop in oocyst
mosquito infective after 9 - 12 days
Sporozoites migrate to salivary glands
Parasites sucked up
Sporozoites injected with mosquito bite
Gametocytes
Repeated blood stage cycles every 48 hours
Red blood cell stage
Liver stage 9 - 14 days
In humans

Pa

Vector Control – Main Options

- Personal protection
  - Bed nets, repellents
- Chemical application
  - Insecticides
- Biological control
  - Larvivorous fish, e.g. *Gambusia*

- Environmental Management
  - habitat modification, a physical change (often long term) to prevent, eliminate or reduce vector habitats
  - drainage, land levelling, filling, modification of streams/canals
  - Environmental manipulation, e.g. flushing of streams/canals, water level changes in reservoirs
  - Modification of human habitations or behaviour, e.g. house screening, housing location, housing structure (e.g raised)

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Water-Borne Infections

Many different types of enteric pathogens and parasites including bacteria, viruses, protozoa and helminth worms

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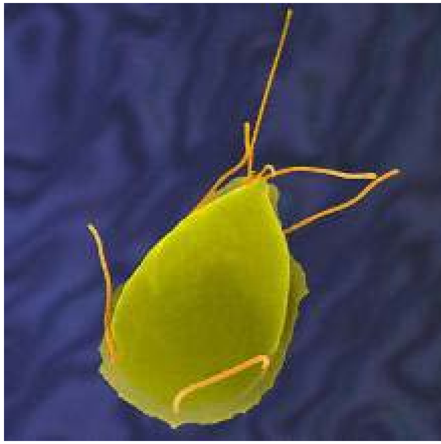
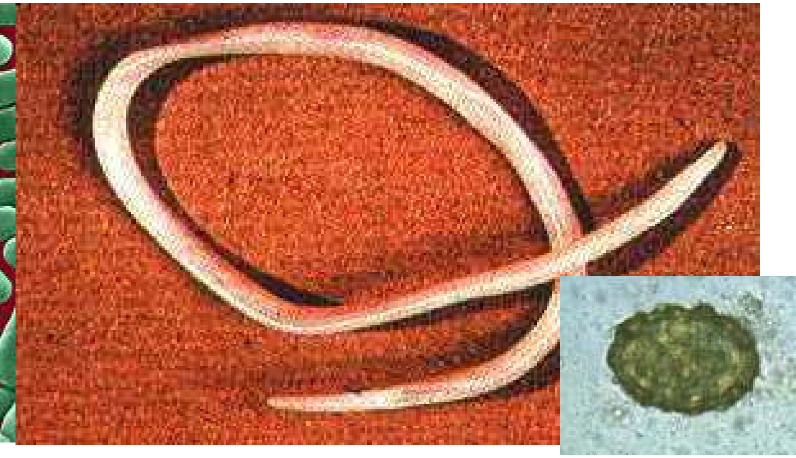
Microorganisms Causing Intestinal Disease



Bacteria	**Protozoa**	**Enteric viruses**	**Helminth worms**
Salmonella spp.	*Cryptosporidium*	Hepatitis A and E viruses	*Ascaris lumbricoides*
Shigella spp.	*Entamoeba histolytica*	Adenovirus	*Ascaris suum*
Yersinia	*Giardia lamblia*	Norovirus	*Trichuris trichirua*
Vibrio cholerae	*Balantidium coli*	Enteroviruses	*Toxocara canis*
Campylobacter jejuni	*Toxoplasma gondii*	Polio viruses	*Taenia saginata*
Escherichia coli O157		Coxsackie viruses	*Taenia solium*
Listeria spp.		Echoviruses	*Necator americanus*
		Enteroviruses 68-91	*Hymenolepis nana*
		Reoviruses	
		Astroviruses	

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Enteric Pathogens

- Transmitted by faecal contamination of food and water (eg use as fertiliser)
- Occur in the intestinal tract
- Leave host in faeces or urine
  - Re-enter by ingestion through mouth
  - Relocate in intestine
- High prevalence with poor sanitation
- High rate of transmission
- Can infect with good sanitation
  - vector transmission eg flies, rodents
  - asymptomatic carriers handling food

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Impacts of Water-Borne Disease - Enteric Organisms

- **Diarrhoeal Diseases**
  - About 4 million cases leading to 1.8 million deaths (3.1 %) a year attributed to unsafe water, sanitation and hygiene
  - Mainly infectious diarrhoea
  - 90 % of deaths are children <5y
  - virtually all (99.8 %) of the deaths are in developing/poor countries
  - Disease burden exceeds many major diseases (eg malaria, tuberculosis)
  - Diarroheal disease alone = 4.3 % of total global disease burden
- **Gut Nematodes and Filariasis, *Ascaris*, *Trichuris*, Hookworms, Elephantiasis**
  - 133 million people suffer from high intensity intestinal infections – cognitive impairment, massive dysentery or anaemia
  - A third of the world's population, mostly children, infected with intestinal worms (*Ascaris lumbricoides*, hookworm, and *Trichura trichiura)* causing malnutrition, anaemia, malabsorption syndrome, intestinal obstruction, and mental and physical growth retardation or massive dysentery
  - Safer water, sanitation and improved hygiene can reduce morbidity from ascariasis by 29%

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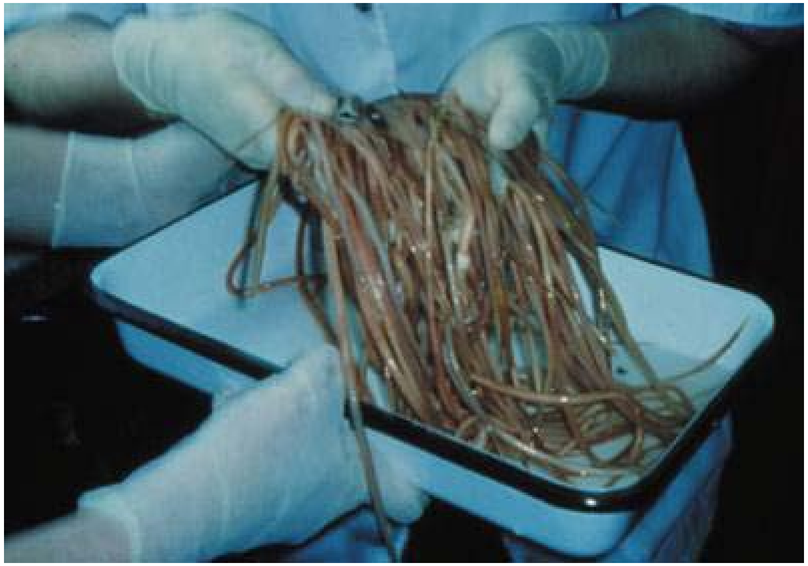
Intestinal Worm Infections

Ascariasis – *Ascaris lumbricoides*



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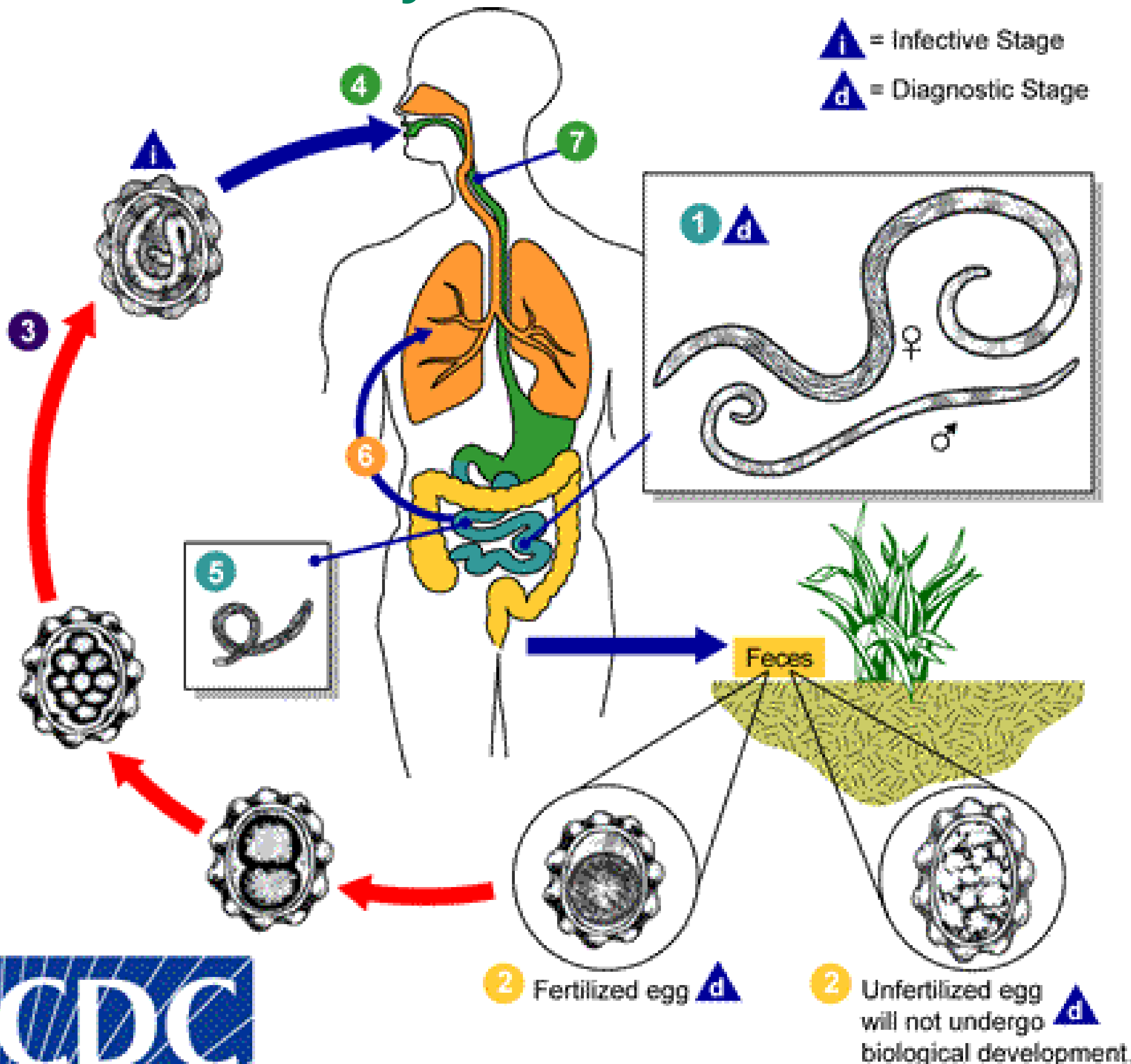
Ascaris Lumbricoides - Lifecycle

Ascaris is one of the persistent enteric parasites and its eggs can survive for several years in soil. Where endemic in the population effectiveness of treatment processes to protect human health from infection is determined on the basis of eliminating this and, therefore, all other organisms, from faecal sludge



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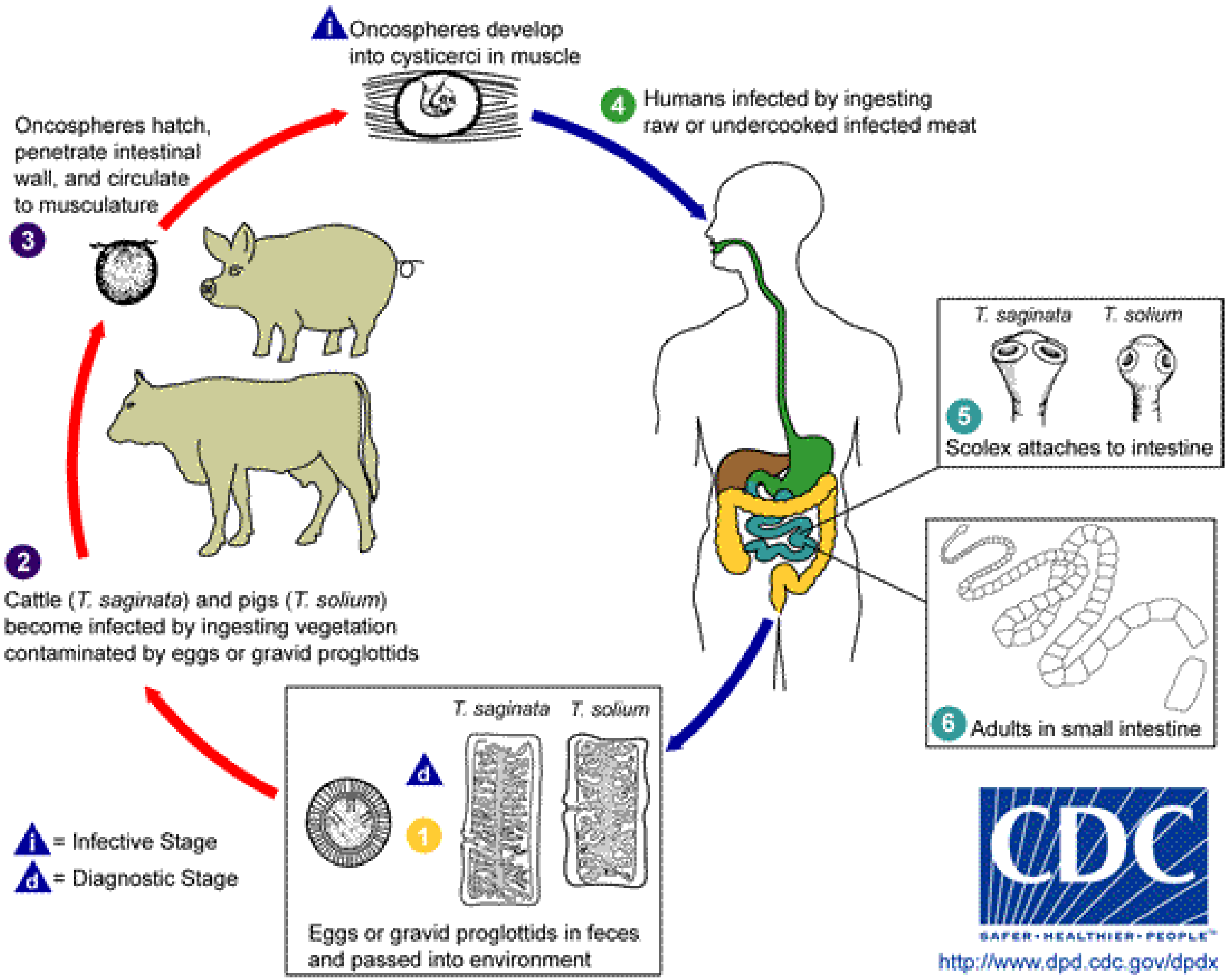
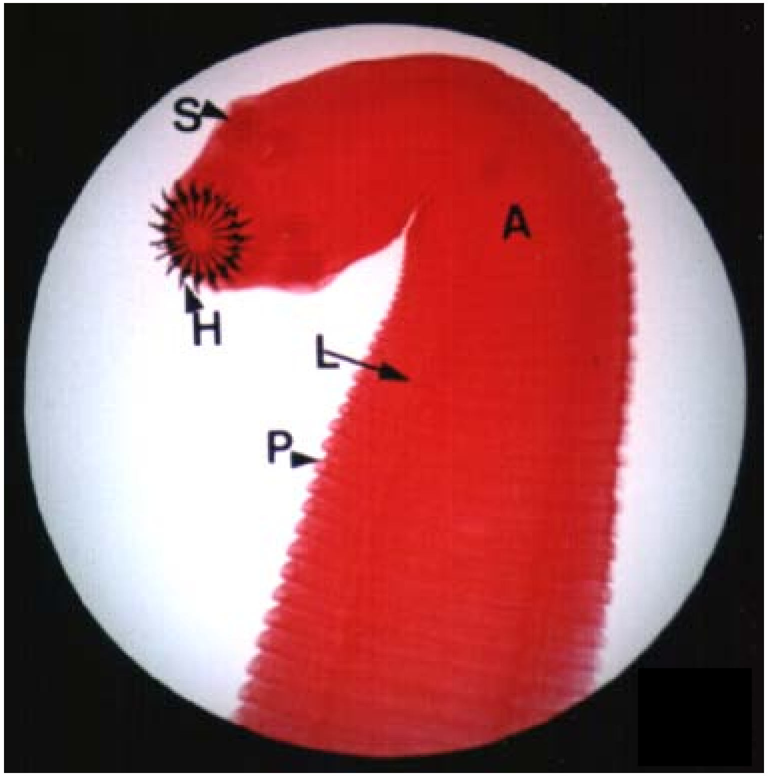
Taenia saginata - Lifecycle



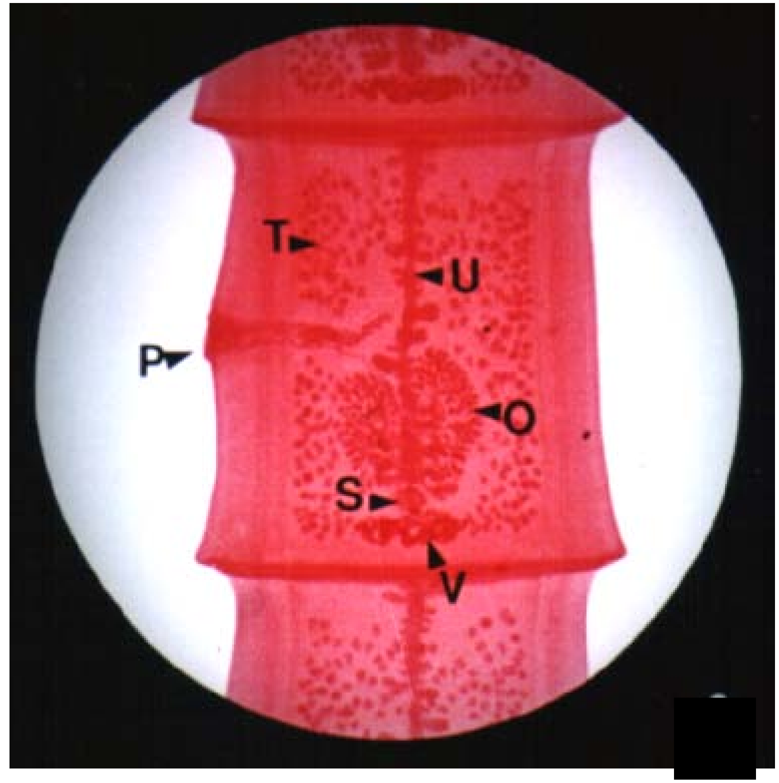
Taenia saginata

Head structure



H – hooks; S – suckers (H+S=skolex); A – new proglottids form behind skolex; L – excretory canals & nerves; P - proglottids

Proglottid



Hermaphrodite. ♀ = ovaries (O), uterus (U), shell gland (S), vitelline gland (V); ♂ = testes; pore – opening allows cross fertilisation

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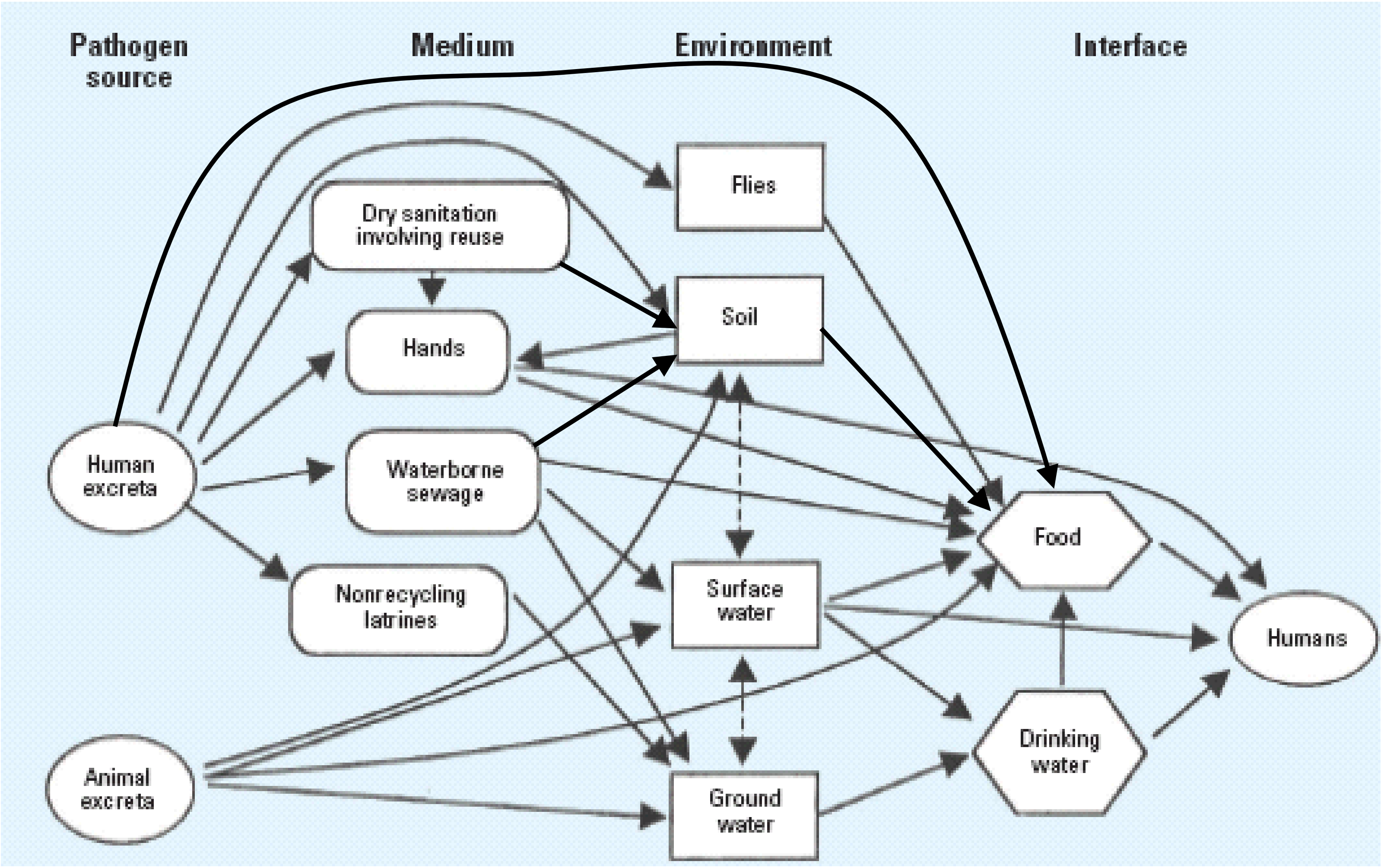
Faecal Oral Transmission Pathways



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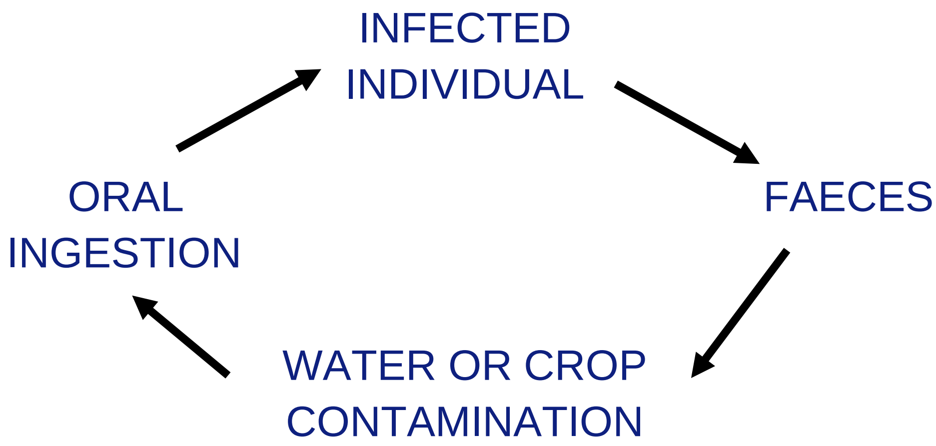
Cycle of Disease Transmission



CONTROL = breaking transmission cycles

1. 'Complete' control (single barrier) by disinfection

   Reduce pathogens to levels naturally present in the environment and well below numbers necessary for infection

2. Multiple barriers to transmission without disinfection

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Barriers to Disease Transmission from Agricultural Use of Sewage Sludge

- Single barriers
  - Treatment to eliminate pathogens
  - Eg pasteurisation, thermophilic digestion, alkaline/lime
- Multi-barriers
  - Treatment to reduce pathogens
  - Eg mesophilic anaerobic digestion
  - ***PLUS*** restrictions on land use
  - Eg avoid application to crops that may be consumed uncooked
- Time-temperature exposure basis to treatment conditions for pathogen removal

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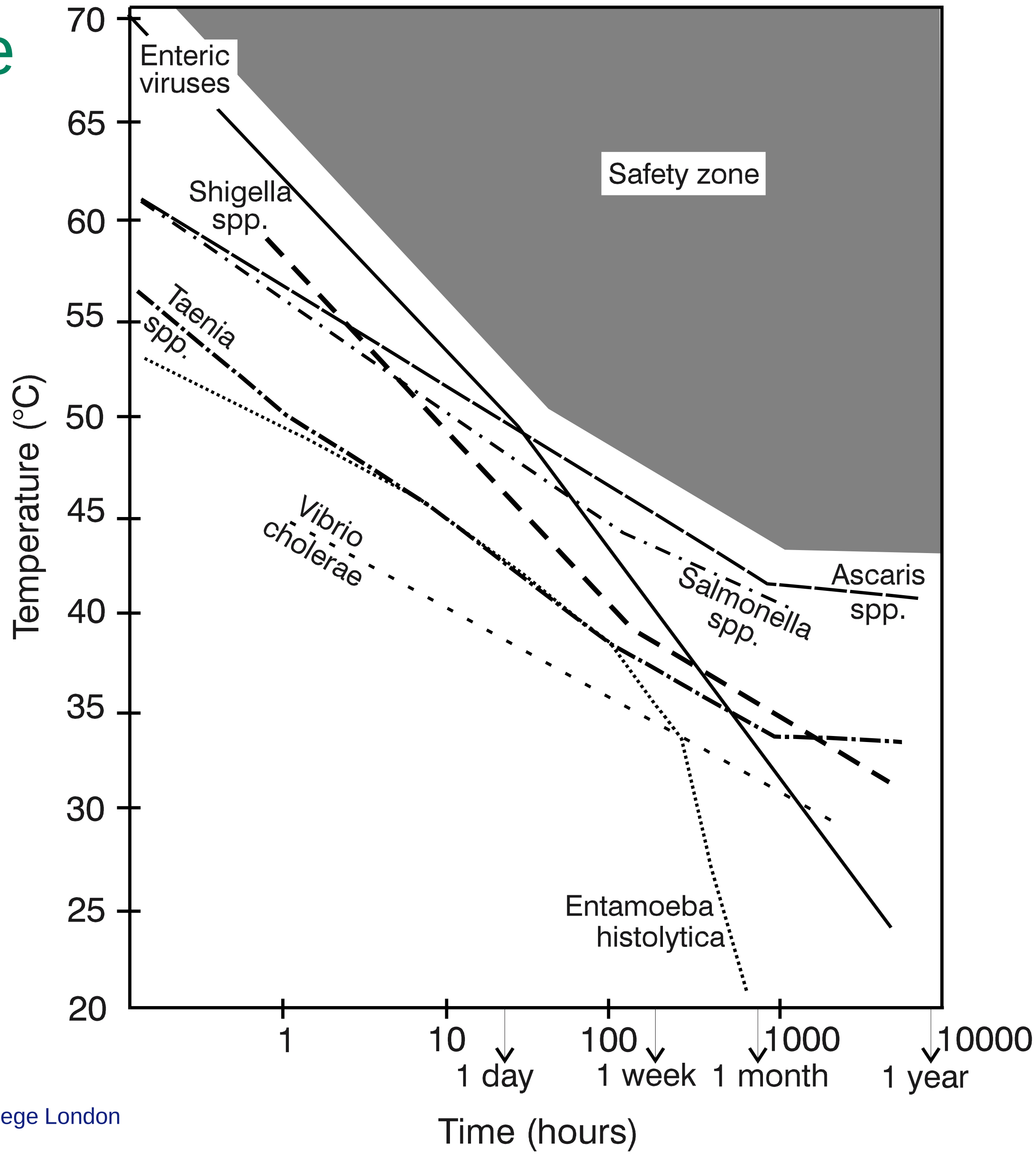
Time-temperature 'Safety Zone'



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UK Code of Practice Agricultural Use of Sewage Sludge

Effective treatment processes to significantly reduce the pathogenic content of sludge (ie ≥2 log)

Process	Descriptions
Sludge Pasteurisation	Minimum of 30 minutes at 70°C or minimum of 4 hours at 55°C (or appropriate intermediate conditions), followed in all cases by primary mesophilic anaerobic digestion.
Mesophilic Anaerobic Digestion	Mean retention period of at least 12 days primary digestion in temperature range 35°C±3°C or of at least 20 days primary digestion in temperature 25°C±3°C followed in each case by a secondary stage which provides a mean retention period of at least 14 days.
Thermophilic Aerobic Digestion	Mean retention period of at least 7 days digestion. All sludge to be subject to a minimum of 55°C for a period of at least 4 hours.
Composting (Windrows or Aerated Piles)	The compost must be maintained at 40°C for at least 5 days and for 4 hours during this period at a minimum of 55°C within the body of the pile followed by a period of maturation adequate to ensure that the compost reaction process is substantially complete.
Lime Stabilisation of Liquid Sludge	Addition of lime to raise pH to greater than 12.0 and sufficient to ensure that the pH is not less than 12 for a minimum period of 2 hours. The sludge can then be used directly.
Liquid Storage	Storage of untreated liquid sludge for a minimum period of 3 months.
Dewatering and Storage	Conditioning of untreated sludge with lime or other coagulants followed by dewatering and storage of the cake for a minimum period of 3 months. If sludge has been subject to primary mesophilic anaerobic digestion, storage to be for a minimum period of 14 days.

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Typical Microbiological Standards

Treatment	*E. coli*	*Salmonella*
Conventional	2 log reduction $<10^5$ g^{-1}ds	
Enhanced	6 log reduction <1000 g^{-1} ds	Absent in 2 g ds
Compost	<1000 g^{-1} ds	Absent in 25 g

When helminth infections are prevalent in the population: <1 egg g^{-1} ds

Enteric viruses (US EPA 503 Rule): <1 PFU per 4 g ds

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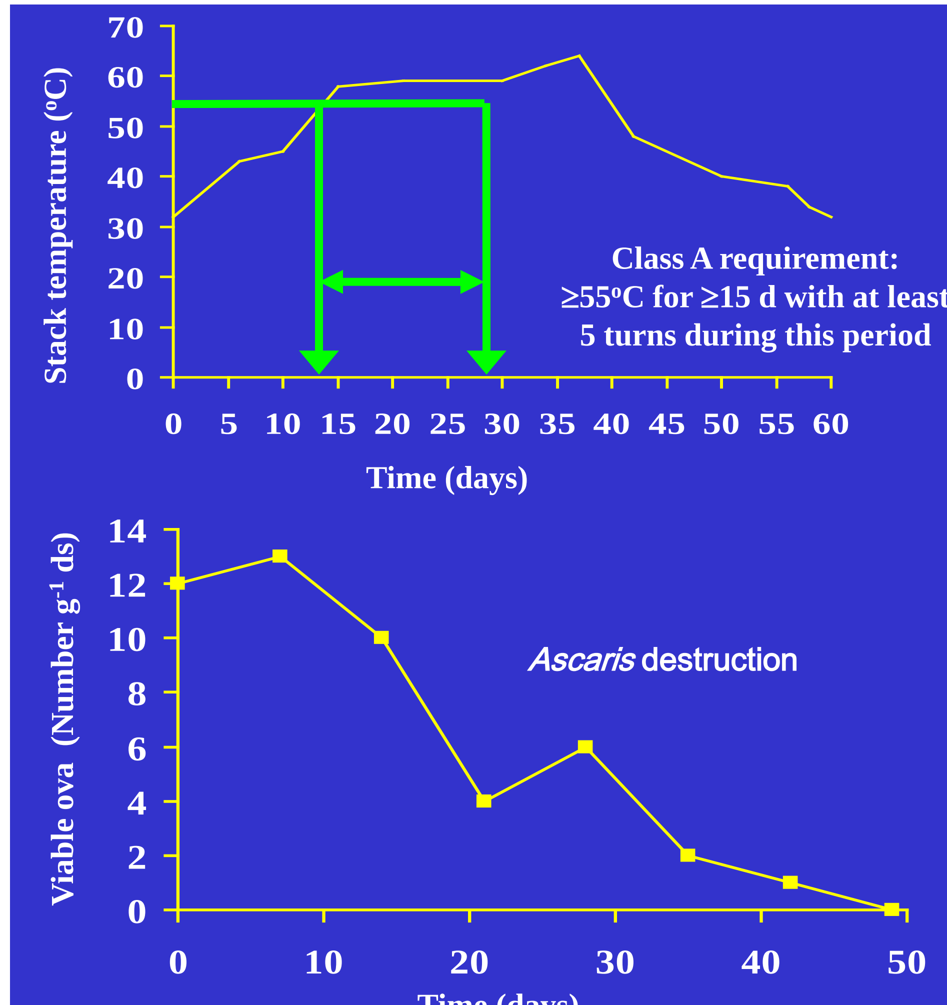
Making Sludge Safe – Developing Countries

- Solar dry, followed by >6 months storage
- Composting
- Simple and flexible



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Wastewater Stabilisation Ponds

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WHO Microbiological Quality Guidelines for Greywater and Faecal Sludge/Excreta Reuse

Table 4.2 Guideline values for verification monitoring in large-scale treatment systems of greywater, excreta and faecal sludge for use in agriculture

	Helminth eggs (number per gram total solids or per litre)	***E. coli* (number per 100 ml)**
Treated faeces and faecal sludge	<1/g total solids	<1000/g total solids
Greywater for use in:		
• Restricted irrigation	<1/litre	$<10^5$ [a]
		Relaxed to $<10^6$ when exposure is limited or regrowth is likely
• Unrestricted irrigation of crops eaten raw	<1/litre	$<10^3$
		Relaxed to $<10^4$ for high-growing leaf crops or drip irrigation

[a] These values are acceptable due to the high regrowth potential of *E. coli* and other faecal coliforms in greywater.

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Performance of 5 Ponds in NE Brazil (mean pond temp 26^{o}C)

Sample	Retention time (days)	BOD_5 (mg/l)	Suspended solids (mg/l)	Faecal coliforms	Intestinal nematode eggs (per litre)
Raw wastewater	–	240	305	4.6×10^7	804
Effluent from:					
Anaerobic pond	6.8	63	56	2.9×10^6	29
Facultative pond	5.5	45	74	3.2×10^5	1
Maturation pond 1	5.5	25	61	2.4×10^4	0
Maturation pond 2	5.5	19	43	450	0
Maturation pond 3	5.8	17	45	30	0
Total	29				
For unrestricted use				≤1000	≤1

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Advantages and Disadvantages

- Very effective pathogen destruction
- Effective design criteria well established
- Low cost of construction, operation and maintenance compared to conventional treatment
- No energy expenditure (except sunlight)
- Simple to operate and maintain
- High resilience and buffering
- Wide range of industrial, domestic and agricultural wastes treated

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- Large land area restrictive in urban sites