Environmental pathogens

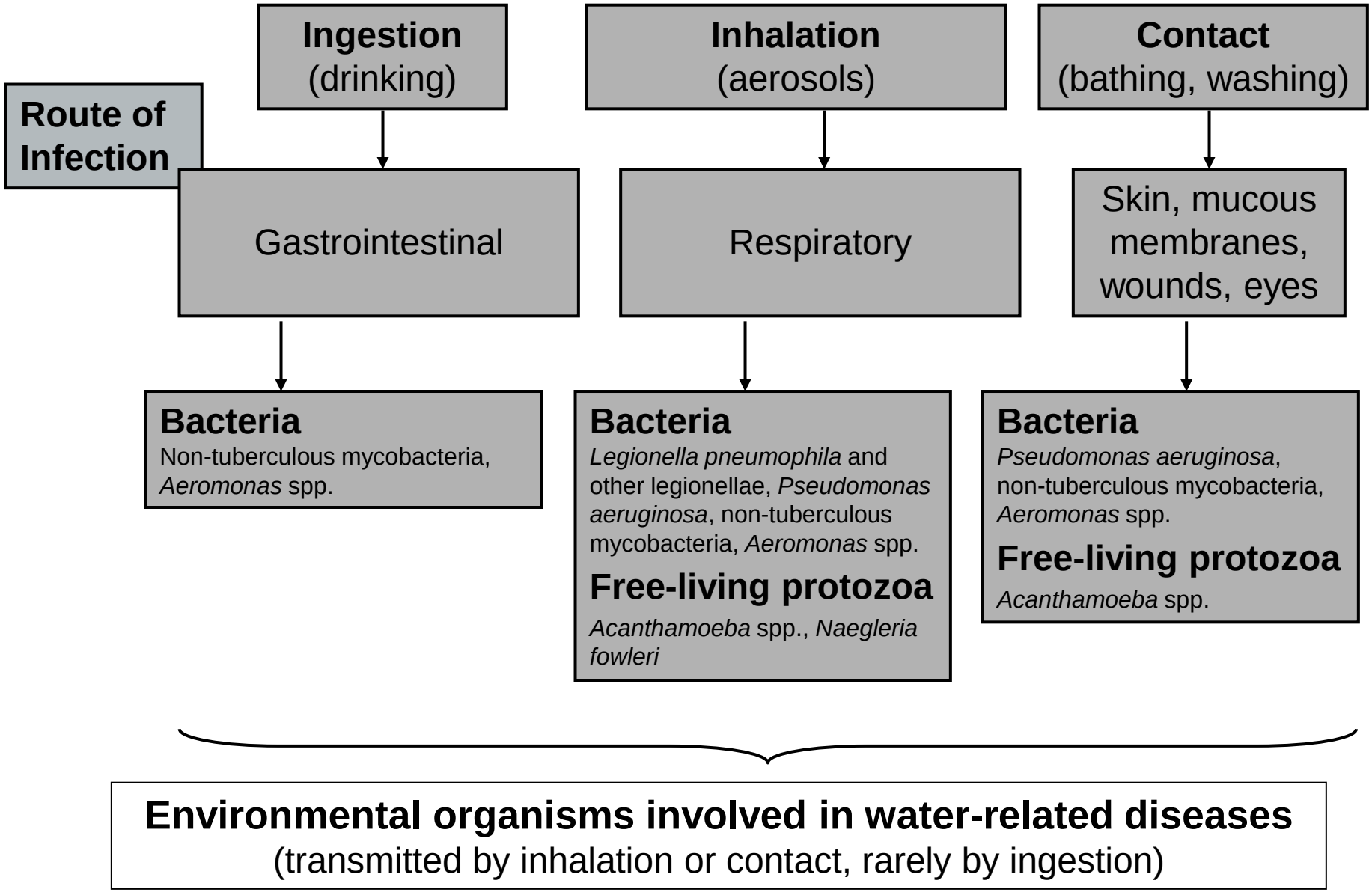
Legionella, *Mycobacterium*, *Pseudomonas aeruginosa*

Common characteristics of environmental pathogens in engineered water systems

- **Non-enteric pathogens**.
- **Environmental, saprozoic pathogens** causing human diseases (sapronoses) transmissible from largely abiotic environments (water, soil, etc.).
- **Facultative/opportunistic human pathogens,** important for increasing number of susceptible individuals in the human population.
- **Colonization and growth in artificial/engineered water systems:** drinking water distribution systems, plumbing of buildings (premise plumbing), water storage tanks, recreational water systems (e.g. whirlpool spas), industrial water systems (e.g. cooling towers).
- **Persistence and growth**: primarily in biofilms/sediments.

Biofilms are the key niche for environmental pathogens in engineered water systems.

Transmission pathways



Environmental organisms involved in water-related diseases
(transmitted by inhalation or contact, rarely by ingestion)

Environmental water-related bacterial pathogens

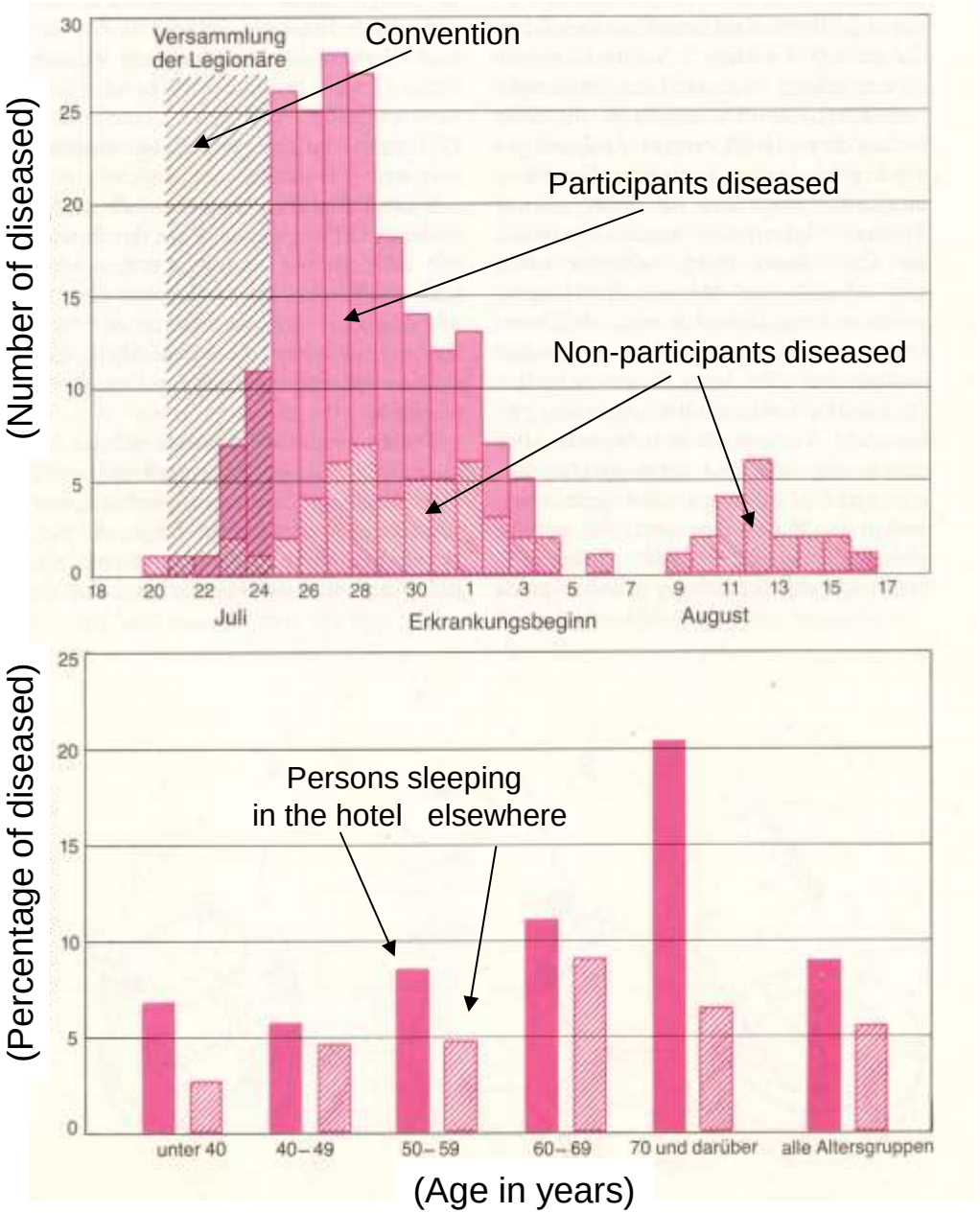
Bacterial pathogen	Transmission route	Symptoms
Legionella spp. (legionellae)	Inhalation, aspiration	Pontiac fever (flu-like illness), pneumonia
Mycobacterium spp. (non-tuberculous mycobacteria)	Inhalation, ingestion, contact	Infections of the lungs, gastrointestinal tract, and skin
Pseudomonas aeruginosa	Contact (skin, mucous membranes, ears, eyes), inhalation	Wound, ear, eye and skin infections, pneumonia
Aeromonas spp. (aeromonads)	Skin contact, aspiration, ingestion	Wound infections, pneumonia, diarrhoea

Present assessment of epidemiological relevance:

Most of the recognized health burden from engineered water systems (in particular, drinking waters) is driven by legionellae, non-tuberculous mycobacteria and, to a lesser extent, *Pseudomonas aeruginosa*.

Legionella pneumophila: historical aspects

- **Epidemic in summer 1976**
  American Legion convention at a hotel in Philadelphia (PA, USA)
  - 221 persons became ill (severe pneumonia), 34 persons died.
  - Transmission: aerosols from air-conditioning system.
- **Discovery of new bacterium as causative agent at the beginning of 1977:**
  Legionella pneumophila



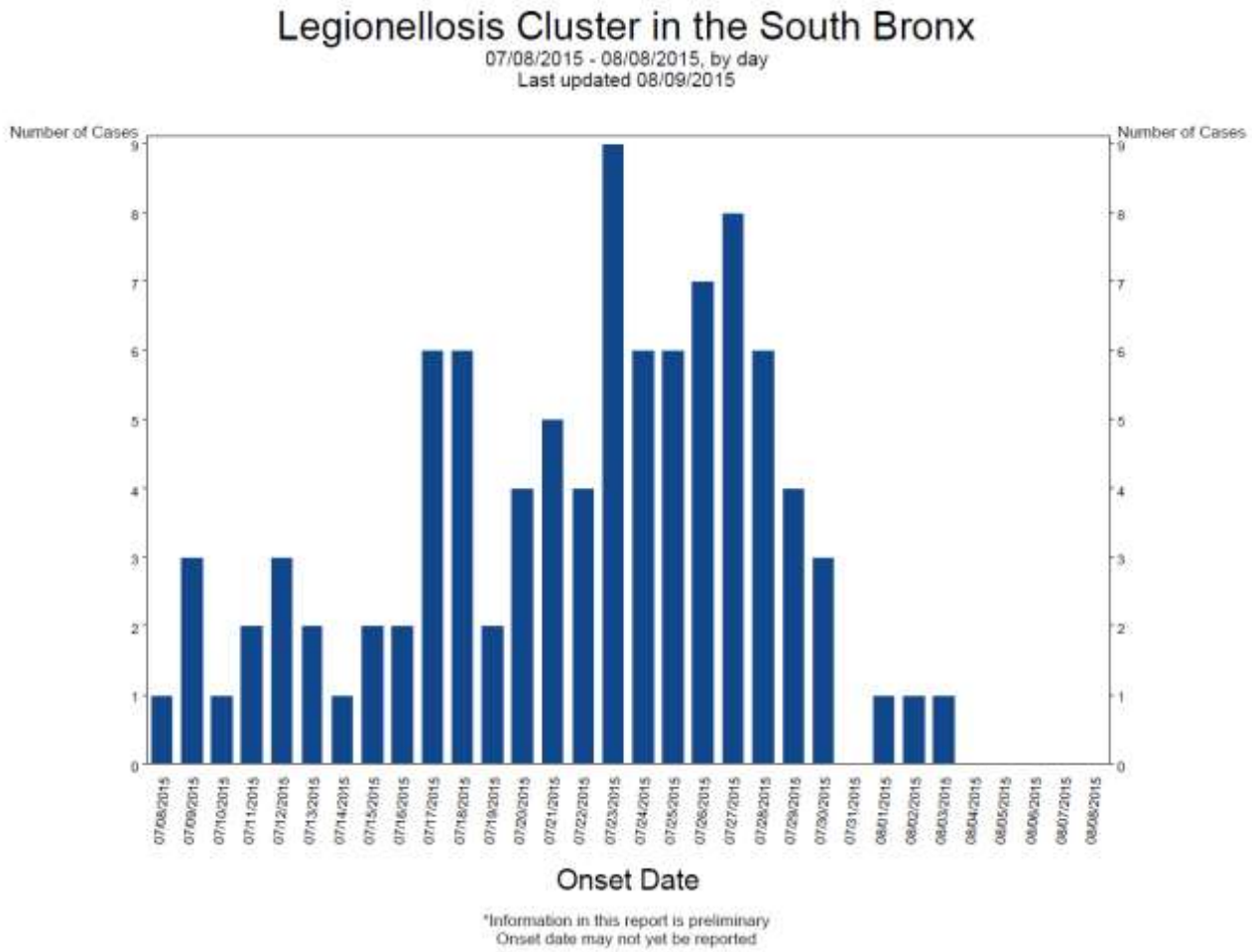
Epidemics caused by *L. pneumophila*

Year	City and source of infection	Diseased	Deaths
1968	Pontiac (USA), Health Department building, air-conditioning system	144	0
1976	Philadelphia (USA), hotel, air-conditioning system	221	34
1999	Bovenkarspel (The Netherlands), flower show, whirlpools	188	29
1999	Kapellen (Belgium), commercial fair, whirlpool and ornamental fountain	93	5
2001	Murcia (Spain), community outbreak, cooling tower at a city hospital	> 800	6
2003/04	Harnes (France), cooling tower of a petrochemical factory	86	18
2005	Toronto (Canada), nursing home, cooling tower	127	21
2009/10	Ulm/Neu-Ulm (Germany), cooling tower on the roof of a building	65	5
2013	Warstein (Germany), industrial cooling tower	159	1
2014	Vila Franca de Xira (Portugal), cooling tower (?)	336	11
2015	New York, South Bronx (USA), cooling tower	124	12

Vox EXPLAINERS

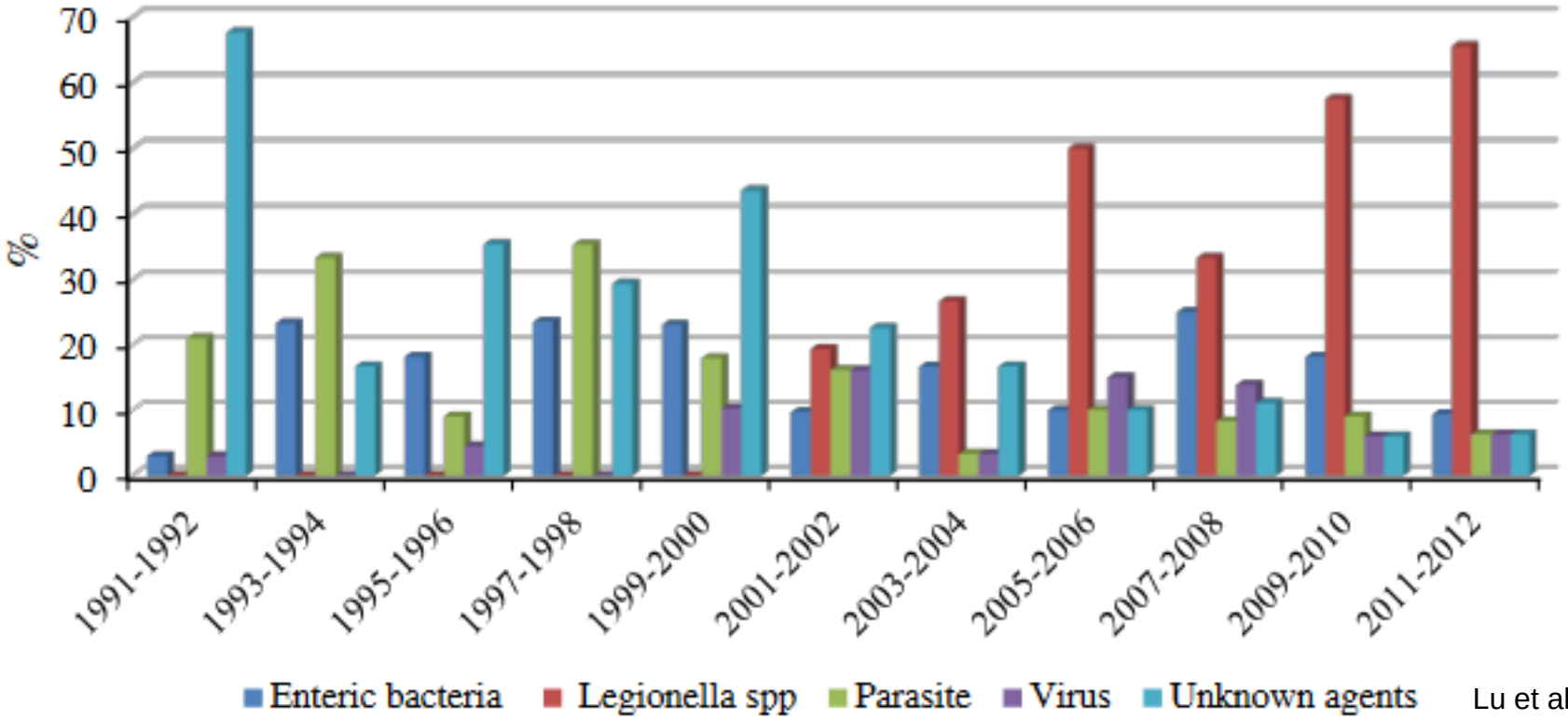
The deadly Legionnaires' outbreak in New York, explained

Updated by Julia Belluz on August 7, 2015, 10:34 a.m. ET *@juliaoftoronto* *julia.belluz@voxmedia.com*



Drinking water disease outbreaks - USA, 1991-2012

Data from the Centers for Disease Control (CDC, USA)



Lu et al., 2015

- **In the first 10 years**: diseases mainly caused by enteric bacteria, parasitic protozoa and unknown agents.
- **In 2001**: legionellosis became a reportable disease; since then *L. pneumophila* has been recognized as leading cause of drinking water disease burden.

Classification of *Legionella*

- Genus *Legionella* (*Legionella* spp.):
  57 species including 79 serogroups (*L. pneumophila* with 15 serogroups).
- Legionellae are regarded as emerging pathogens.
- Among all legionellae, *L. pneumophila* causes most of the diseases worldwide.

  Exception: in Australia, New Zealand and Japan, reported cases of *L. longbeachae* occur as often as cases of *L. pneumophila*.
- Other important pathogenic *Legionella* species:
  L. micdadei, *L. dumoffii*, *L. bozemanii*, *L. gormanii*, *L. anisa*.

Biology of *Legionella*

- Gram-negative, rod-shaped or filamentous bacteria (up to 2 µm long and 0.3 – 0.6 µm in width).
- Heterotrophic growth
  Utilization of amino acids (e.g., L-cysteine) as carbon and energy source.
- High demand of iron ions for growth.
- Cultivation only possible on special nutrient media (e.g., activated carbon-yeast extract medium GVPC agar).

Transmission electron micrograph of a thin section of *L. pneumophila* cells

Colonies of *L. pneumophila* on GVPC agar (5 d, 36 °C)

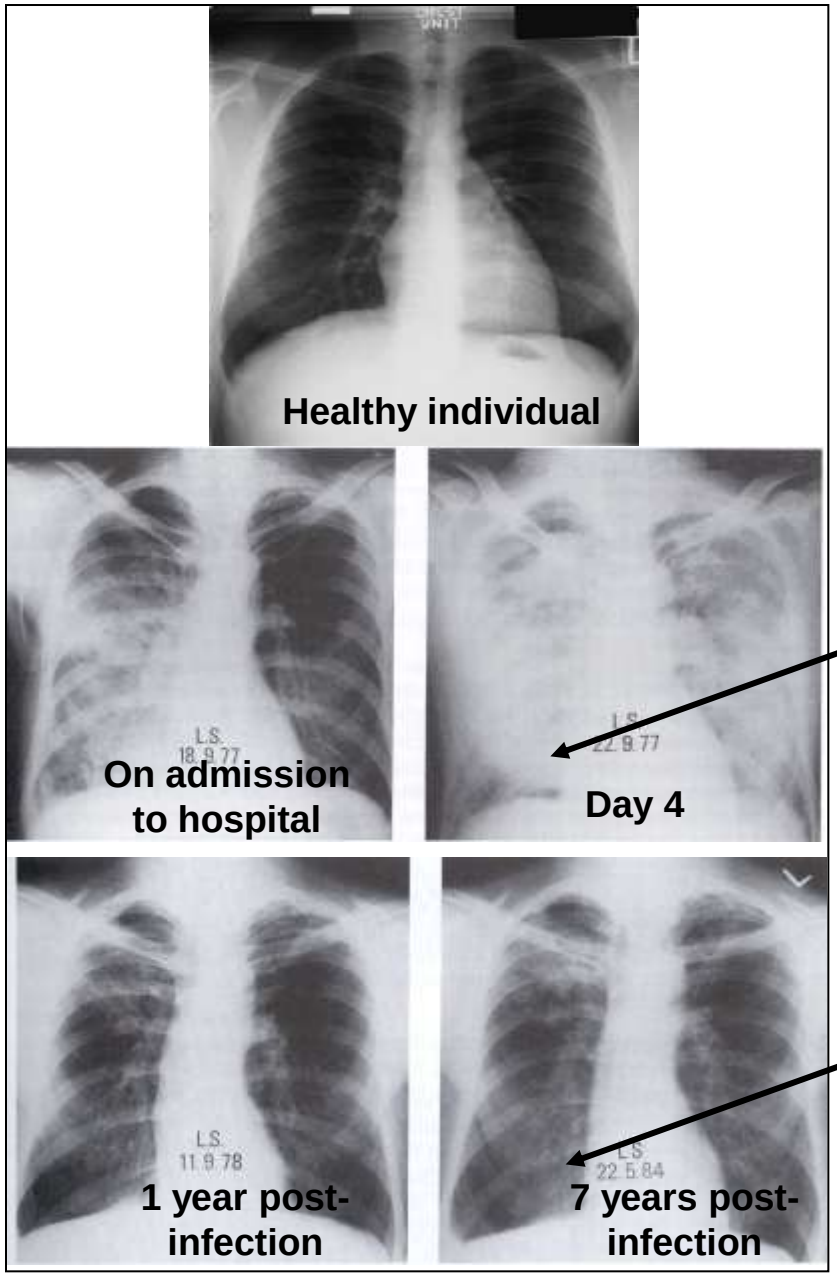
Medical relevance of *Legionella*

- ***Legionella* spp.**
  - Many species are opportunistic human pathogens,
  - *L. pneumophila* is the most important human pathogen (especially serogroup 1)
- **Transmission**
  - Most common form: inhalation of contaminated aerosols (water sprays, jets, mists; droplet size < 5 µm),
  - Occasionally aspiration of contaminated water.
  - No direct human-to-human transmission.
- **Sources of infection**
  - Contaminated aerosols
  - Composts and potting mixes (*L. longbeachae*)
- **Legionellosis**
  - Caused by *L. pneumophila* and other *Legionella* species,
  - Varies from mild febrile illness (Pontiac fever) to a severe form of pneumonia (Legionnaires' disease).

Legionellosis

Characteristic	Legionnaires` disease	Pontiac fever
Attack rate	0.1 - 5 % of general population, 0.4 - 14 % in hospitals	Up to 95 %
Incubation time	2 to 10 days	1 to 2 days
Symptoms	High fever (39 °C - 41 °C), dry cough, muscle pain (myalgia), headache, diarrhoea, vomiting, nausea	High fever, dry cough, myalgia, headache, vomiting, nausea
Affection of the lung	Pneumonia	None
Other organs affected	Kidney, liver, gastro-intestinal tract, nervous system (multi-organ failure)	None
Case-fatality rate	Overall death rate 5 - 10 %; 40 - 80 % in untreated immuno-suppressed patients	No deaths

Lung damage caused by *Legionella*



Chest X-rays of a legionellosis patient

Infiltration of the lungs (acute phase)

Long-term damage to the lungs

Source: McCoy, 2005

Legionella spp. are natural aquatic bacteria

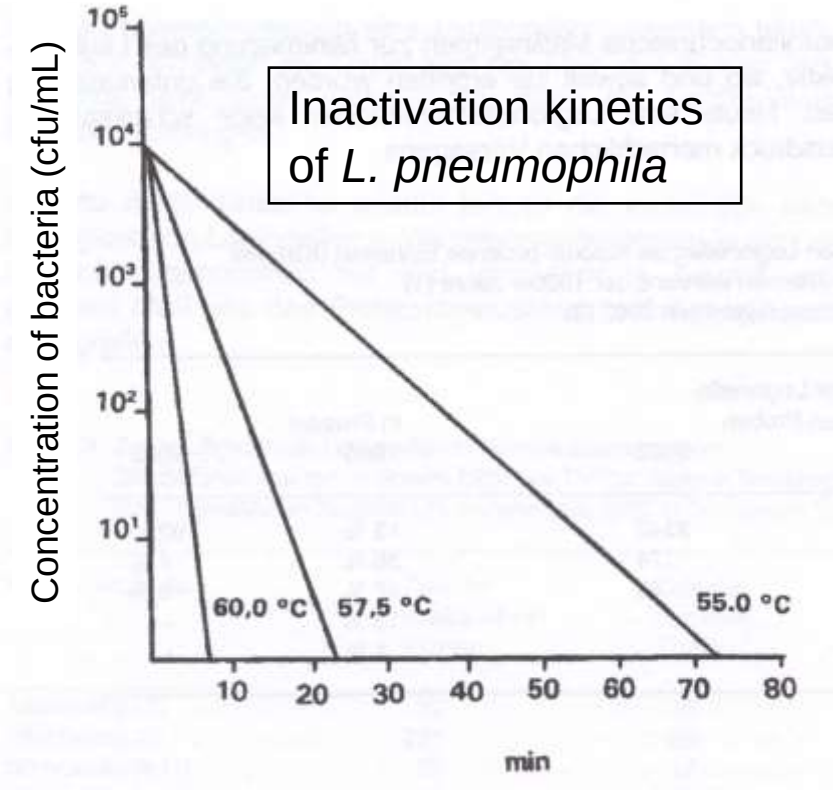
Worlwide occurrence

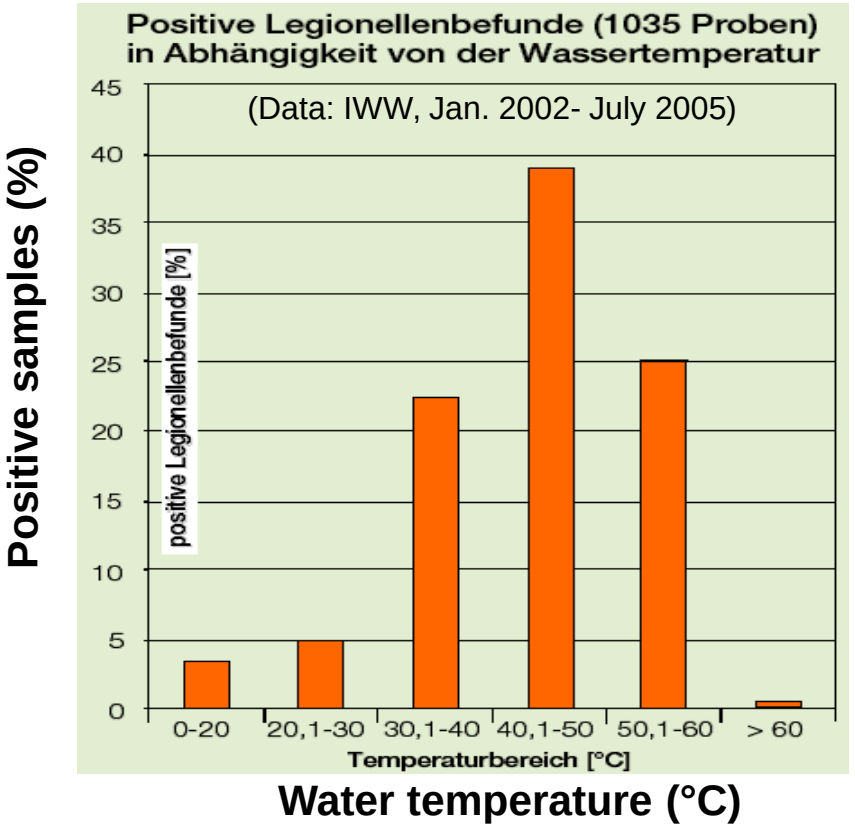
- Freshwater: groundwater, springs, wells, surface waters (rivers, lakes); in sediments
- Marine environments (coastal waters),
- Wet soil, horticultural growing media (potting soil, compost),
- Artificial water systems: plumbing systems of hospitals, dental offices, hotels, schools, private homes, in whirlpools, cooling towers and evaporative condensers, wastewater treatment plants.

  Survival and growth is significantly enhanced in warm water, in particular in large hot water systems with extensive piping and under stagnation conditions.

Water temperature: major factor determining growth of *Legionella* spp. in water systems

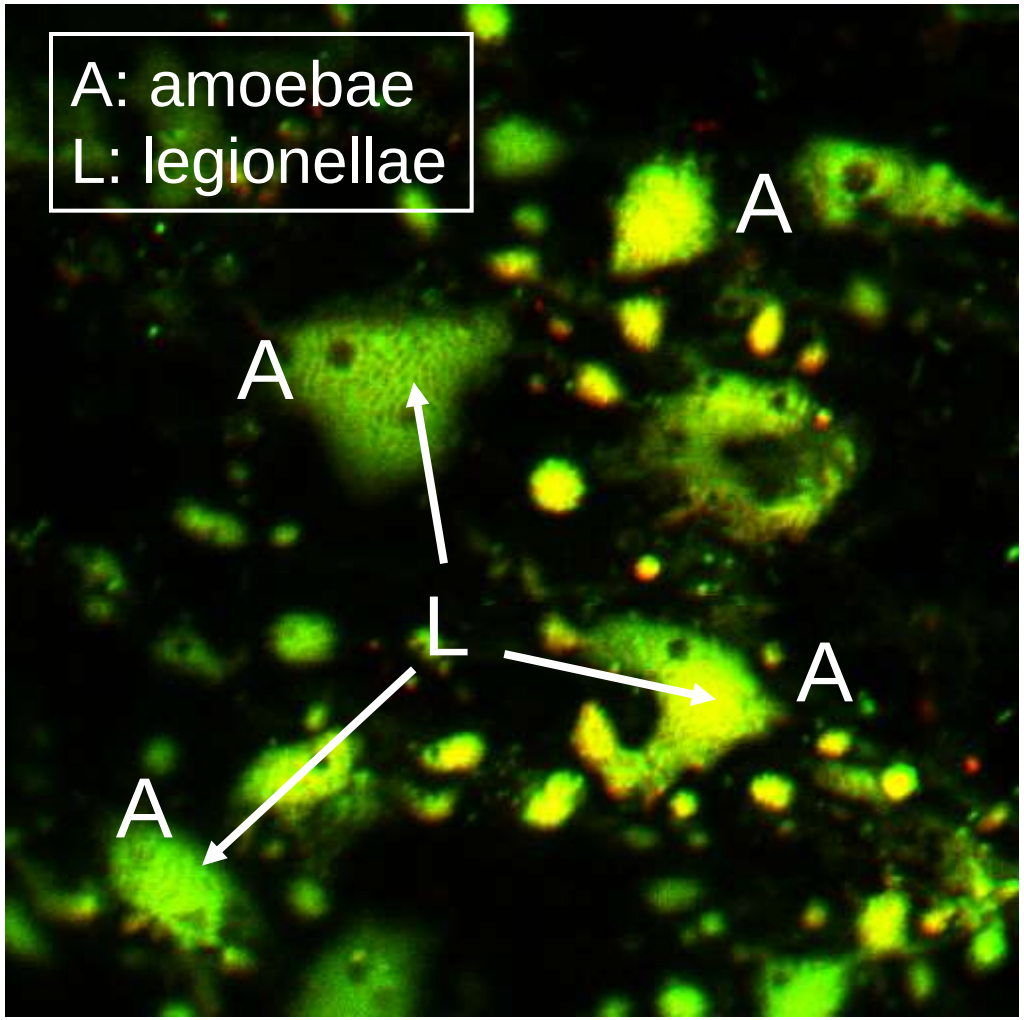
5 °C - 25 °C	Persistence or slow growth
25 °C - 50 °C	Range of favorable growth temperatures
> 50 °C	No more multiplication
≥ 60 °C	Die-off within minutes
≥ 70 °C	Die-off within seconds





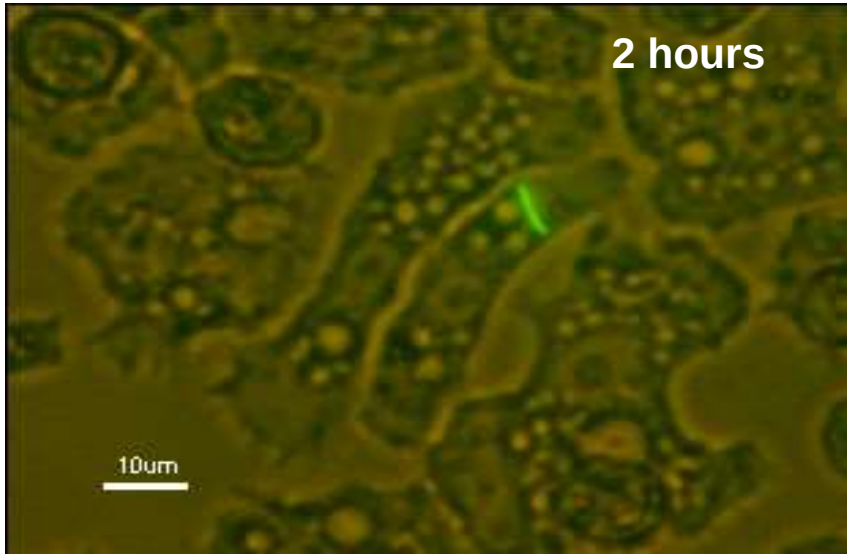
Legionella spp. in biofilms

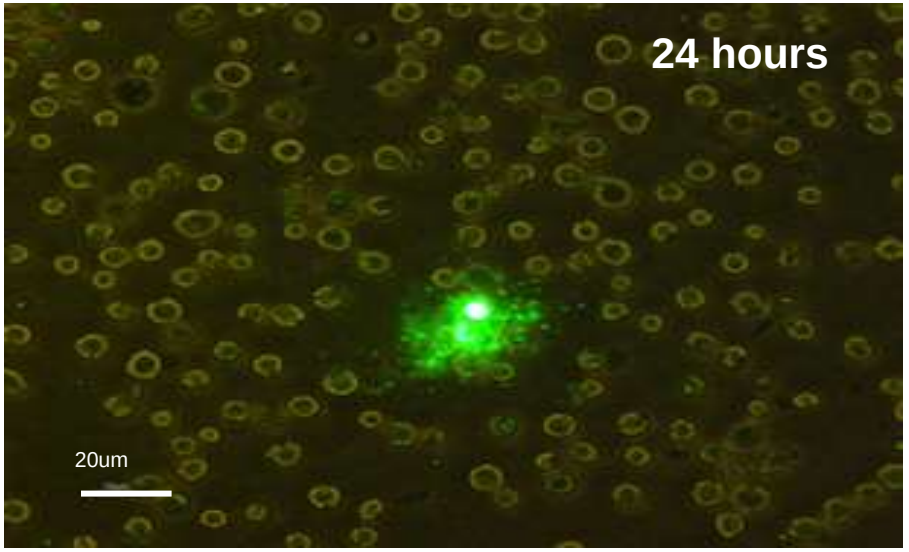
- Biofilms are the primary environmental reservoirs of legionellae.
- Occurrence of *Legionella* bacteria in biofilms:
  - Associated with free-living amoebae (*Acanthamoeba*, *Vermamoeba vermiformis*) and other protozoa: survival in vegetative host cells, persistence in cysts of amoebae.
  - Occurrence as free cells is possible.
- Legionnellae are facultative intracellular bacteria with protozoa as their natural hosts.



Multiplication of *L.* pneumophila within amoebae

- *L. pneumophila* not only persists, but also multiplies within amoebal cells, and is released again.



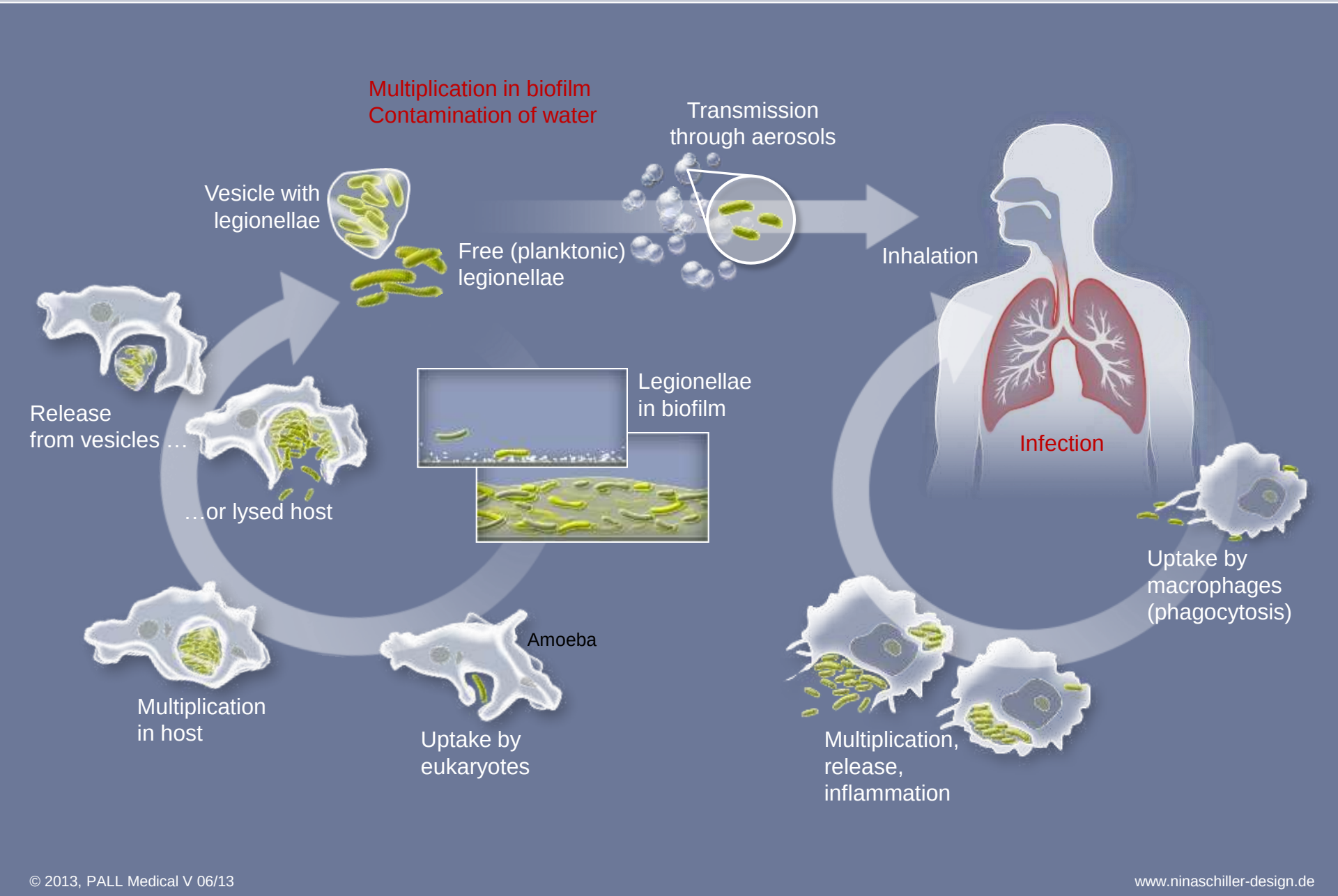


Multiplication of *L. pneumophila* within *Acanthamoeba castellanii*

- Passage through amoebae enhances the infectivity of *L. pneumophila* for human cells and their resistance against biocides.

Source: Université Paris Sud – Pharmacie – Labo Santé Publique Environnement

Life cycle of *L. pneumophila*
Multiplication and infection



Legionellae in biofilms: consequences

- Interaction between *Legionella* spp. and protozoa in biofilms is central to the ecology and pathogenesis of these bacteria.
- Biofilms are natural reservoirs of legionnellae.
- Biofilms are important infection sources of legionellae for the human population.
- Biofilms are the cause for the contamination of water systems by legionellae.
- Legionellae in biofilms show enhanced resistance against disinfectants.
- Interaction with amoebae enhances virulence of *L. pneumophila*.

Practical aspect: aims of effective strategies for the control of legionellae in water systems must be

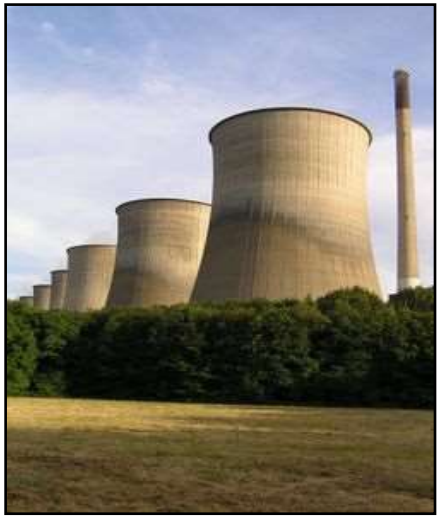
a) to kill, and

b) to remove biofilms including protozoa from surfaces!

Important sources of infection

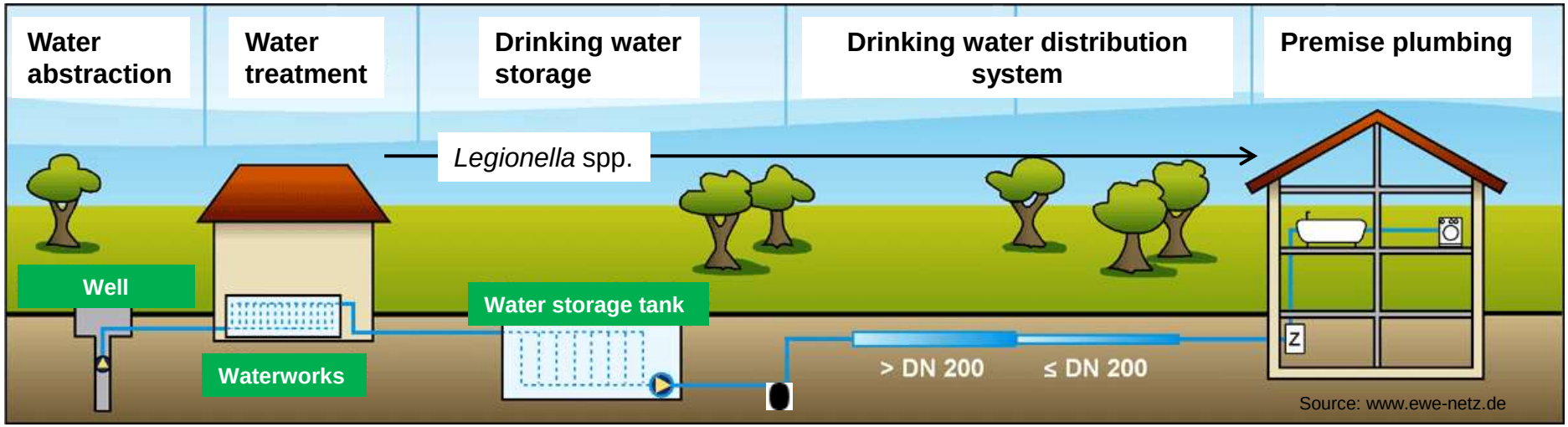
Potential sources of infection are all aerosol-generating sites of *Legionella*-contaminated water systems.

- Domestic hot water systems (plumbing systems of buildings) with storage and distribution of warm water (water outlets, showers, indoor fountains, etc.) ("domestic" refers to commercial, residential and healthcare settings),
- Swimming-pool environments (e.g., whirlpool spas, showers),
- Air-conditioning systems (air humidifiers, cooling towers),
- Cooling water systems in industry (cooling towers).



Legionella spp. in drinking water systems

Legionella spp. enter drinking water distribution systems mainly through water treatment as free bacteria or associated with amoebae.



Sporadic occurrence in culturable form (water, biofilms, sediments in drinking water storage tanks)

Diversity of non-pathogenic and pathogenic *Legionella* spp. with *L. pneumophila* as a minority of only a few percent of all legionellae.

Legionella spp. mostly unculturable, regularly detected by culture-independent methods, e. g. qPCR or fluorescence in situ hybridization (FISH).

Persistence and growth, preferentially in biofilms.

Increase in *Legionella* spp. numbers may occur, with *L. pneumophila* frequently dominating in hot water.

Environmental water-related bacterial pathogens

Bacterial pathogen	Transmission route	Symptoms
Legionella spp. (legionellae)	Inhalation, aspiration	Pontiac fever (flu-like illness), pneumonia
Mycobacterium spp. (non-tuberculous mycobacteria)	Inhalation, ingestion, contact	Infections of the lungs, gastrointestinal tract, and skin
Pseudomonas aeruginosa	Contact (skin, mucous membranes, ears, eyes), inhalation	Wound, ear, eye and skin infections, pneumonia
Aeromonas spp. (aeromonads)	Skin contact, aspiration, ingestion	Wound infections, pneumonia, diarrhoea

Present assessment of epidemiological relevance:

Most of the recognized health burden from engineered water systems (in particular, drinking waters) is driven by legionellae, non-tuberculous mycobacteria and, to a lesser extent, *Pseudomonas aeruginosa*.

Epidemiology of legionellosis

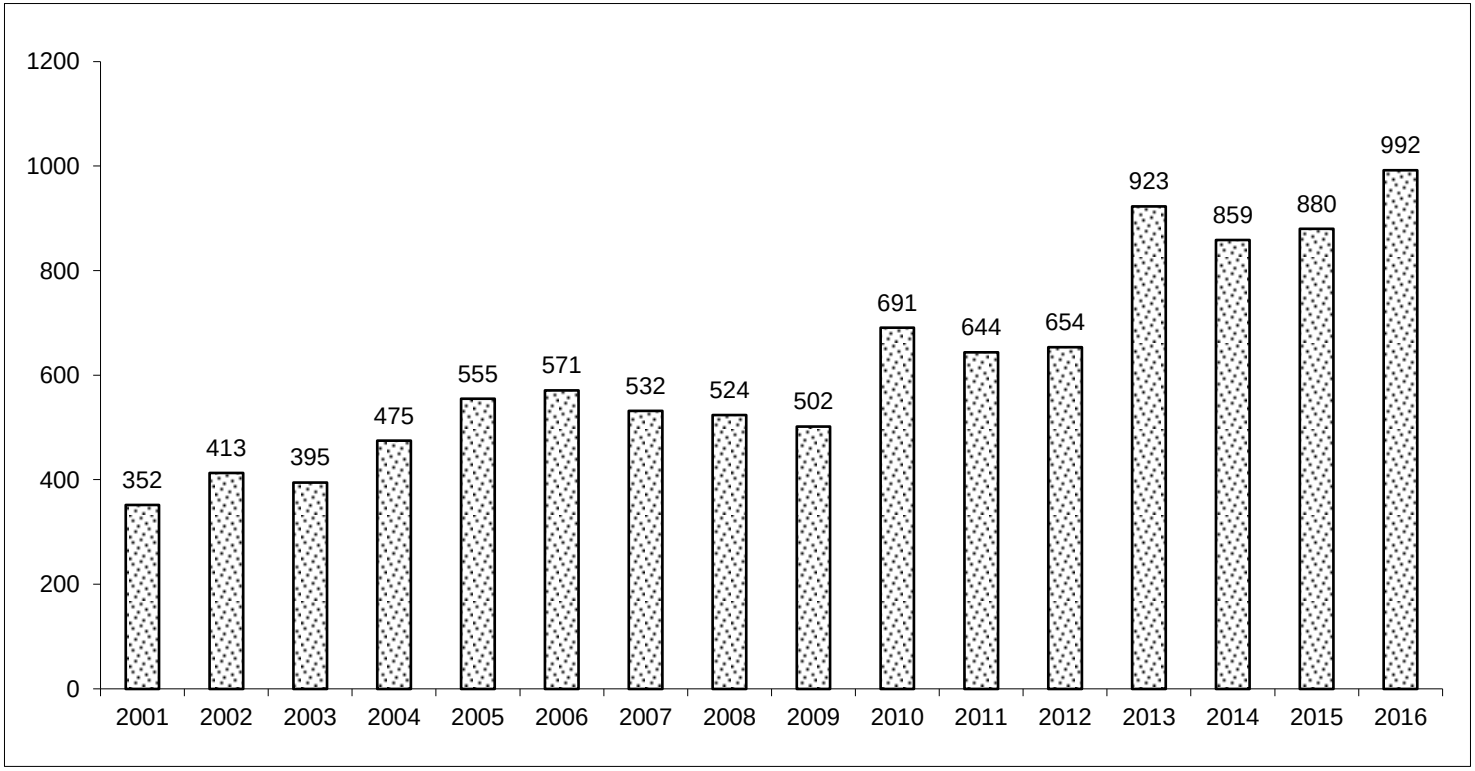
- Legionellosis: mostly sporadic, less frequently epidemic
- Acquisition of disease
  - **community-acquired**: in domestic, recreational or occupational environments,
  - **travel-associated:** acquired during travel, e.g. during stay in hotels,
  - **nosocomial:** acquired during stay in hospital.

Data for Europe, 2000 – 2004: 19,488 registered disease cases

Type of disease	Number of outbreaks	Number of cases
Sporadic	-	16,954
Outbreaks	407	2,534
- community-acquired	87	1,516
- nosocomial	62	320
- travel-associated	254	687
- private households	4	11

Situation in Germany

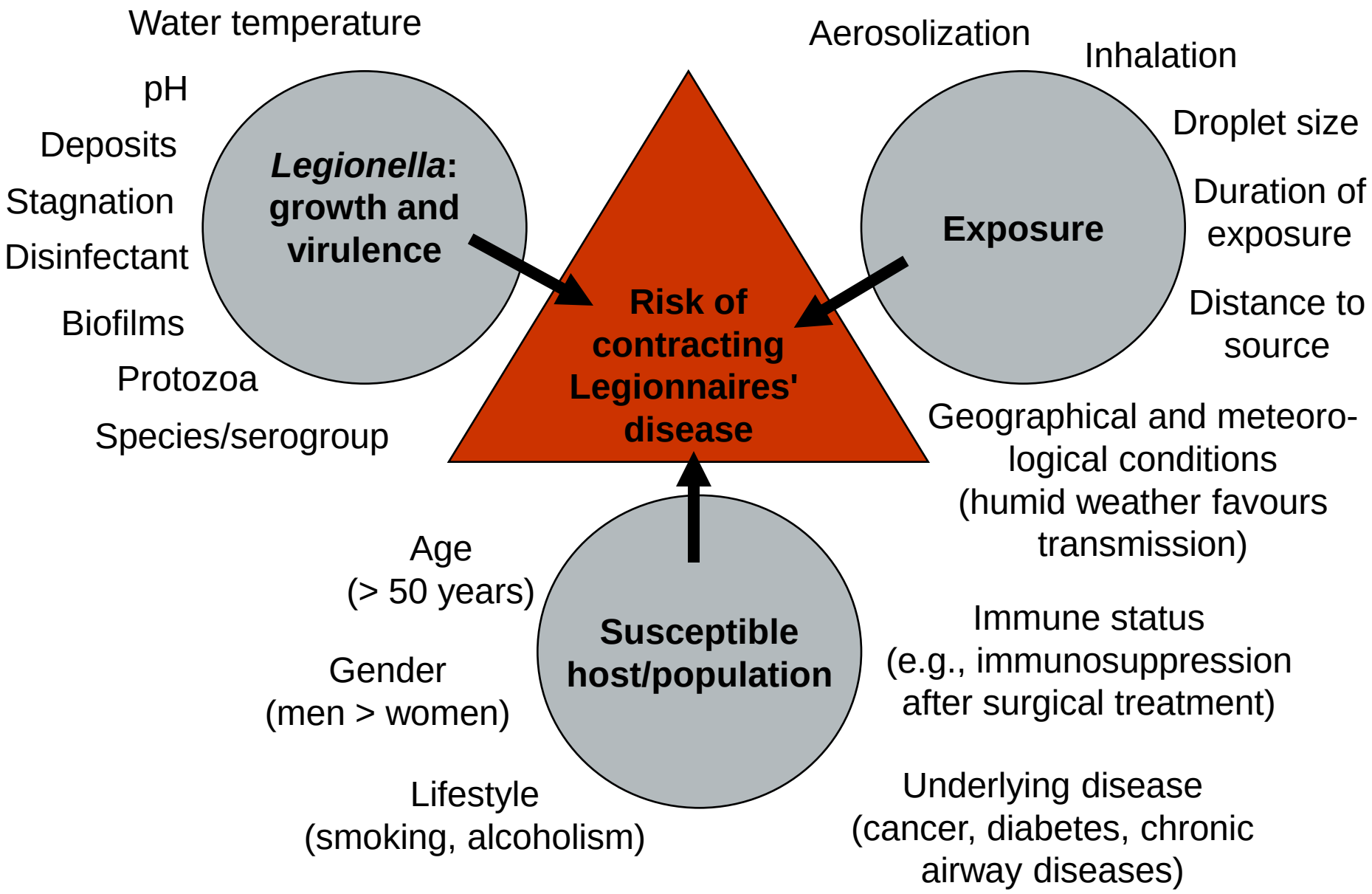
Cases of legionellosis officially reported to the German "Robert Koch-Institut", 2001 - 2016



Estimates for Germany (cases per year)

- Legionnaires' disease: 20,000 – 32,000 diseases, and 1,000 – 2,000 deaths.
- Pontiac fever: 10- to 100-fold higher numbers than Legionnaires‘ disease cases.

Risk factors of infection by *Legionella*



Measures to control and prevent contamination of plumbing systems by *Legionella* spp.

- Keeping hot water at ≥ 60 °C and cold water below 20 °C.
- Thermal disinfection (short-term heating ≥ 70 °C).
- Chemical disinfection (chlorination/hyperchlorination, disinfection using chlorine dioxide, copper-silver ionization).
- Installation of 0.2 µm point-of-use filters in risk areas of hospitals.

- Prevention of stagnation and corrosion.
- Prevention/removal of sediments, sludge, rust, etc.
- Removal of pipe systems that are no longer in use (e.g.,"dead-ends") .
- Exchange of contaminated parts (e.g., rubber fittings, shower heads).
- Use of plumbing material that does not support microbial growth.
- Installation and maintenance of water systems according to acknowledged technical rules.
- Running water before use (e.g., before showering).
- Action value („technischer Maßnahmewert“) according to the German Drinking Water Ordinance (2012): 100 colony-forming units/100 mL.

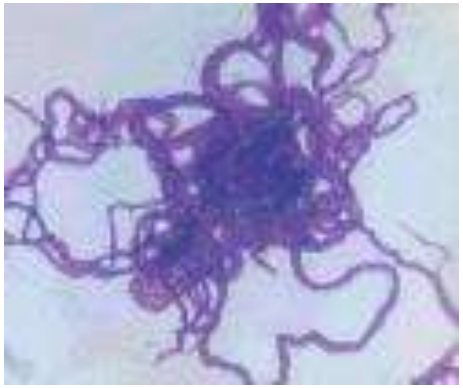
Mycobacterium spp.

- **Non-tuberculous mycobacteria**
  - Environmental mycobacteria (formerly "atypical mycobacteria"): living in aquatic environments, include facultative/opportunistic pathogens that are transmitted by water.
  - "Typical" or "tuberculous" mycobacteria like *M. tuberculosis* and *M. leprae*: growth in human tissue, obligate pathogens, not transmitted by water.

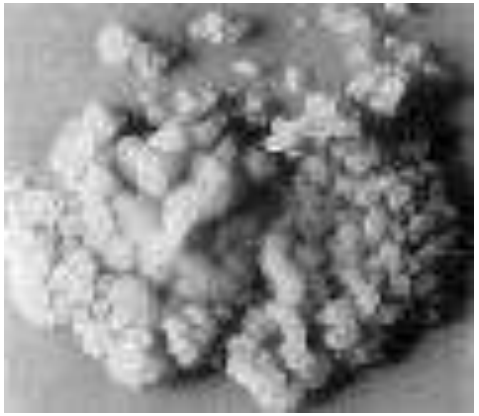
- **Morphology**

  Gram-positive, non-motile, pleomorphic, aerobic bacteria with hydrophobic cell wall due to high lipid content.

Scanning electron micrograph



Stained myobacteria, light microscope



Growth on agar medium

Opportunistic mycobacteria

More than 140 species of non-tuberculous mycobacteria known, with about 50 pathogenic species.

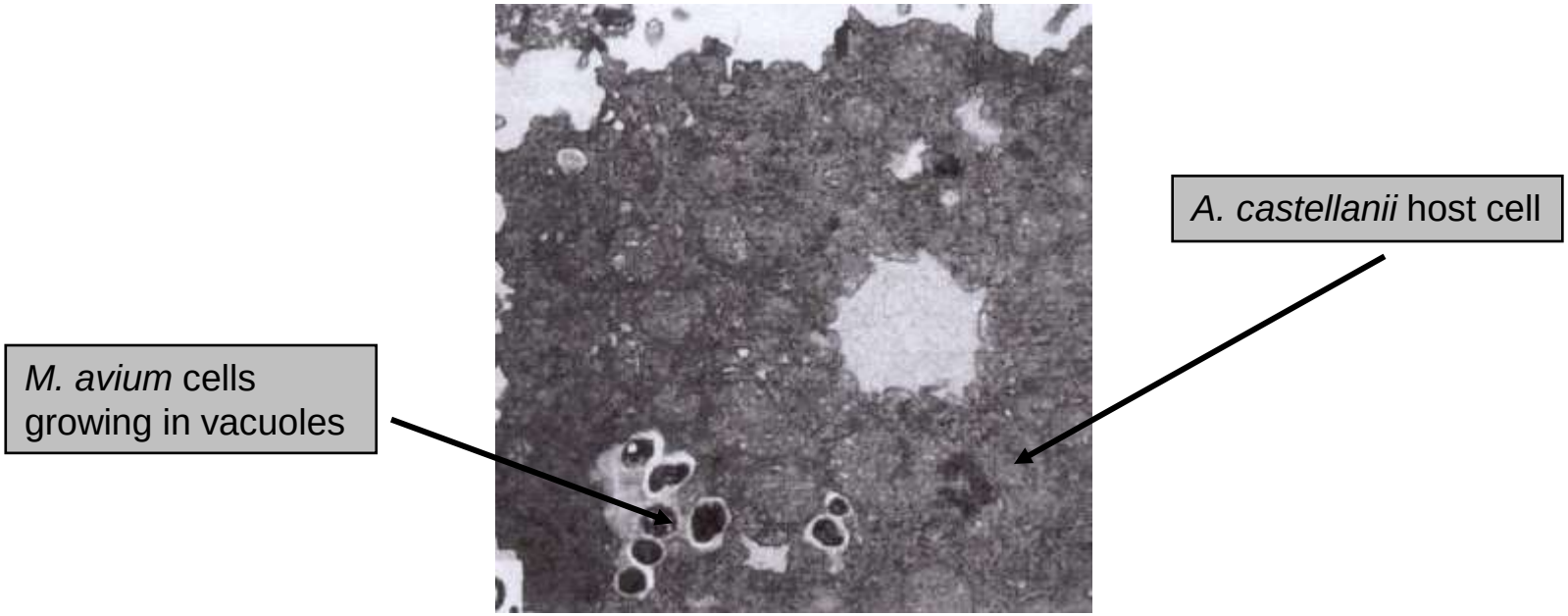
Non-tuberculous mycobacterial species involved in human disease and occurring in drinking water/plumbing systems:

Slowly growing mycobacteria (colony formation ≥ 7 days)	**Rapidly growing mycobacteria** (colony formation 3 - 7 days)
Mycobacterium avium *Mycobacterium gordonae* *Mycobacterium intracellulare* *Mycobacterium kansasii* *Mycobacterium lentiflavum* *Mycobacterium malmoense* *Mycobacterium marinum* *Mycobacterium simiae* *Mycobacterium xenopi*	*Mycobacterium abscessus* *Mycobacterium chelonae* *Mycobacterium fortuitum* *Mycobacterium canariasense*

Mycobacterium avium complex (MAC): group of the pathogenic species *M. avium* and *M. intracellulare* that commonly infect humans together.

Mycobacterium spp.
- facultative intracellular bacteria -

- Mycobacteria are facultative intracellular pathogens: growth within amoebae (environmental host) and in human macrophages.
- Virulence and resistance to antimicrobials is enhanced by passage through amoebae.



Mycobacterium avium within *Acanthamoeba castellanii*, two 2 days post infection.
(Transmission electron micrograph; Cirillo et al., 1997)

Diseases caused by non-tuberculous mycobacteria

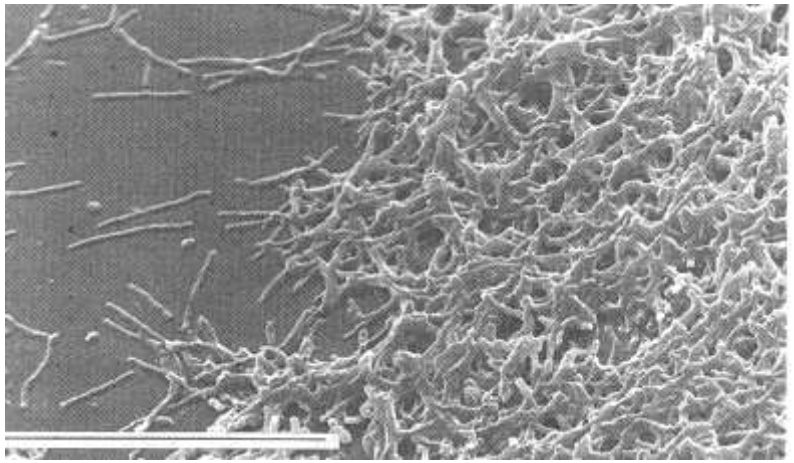
- Transmission from environment by ingestion, inhalation and contact with skin, mucous membranes; usually no person-to-person transmission.
- Cause of diseases involving respiratory and gastrointestinal tract, skeleton, lymph nodes, skin and soft tissues.
- Manifestations: pulmonary disease, swimming pool granulomas, skin infections, Buruli ulcer, osteomyelitis and arthritis in people without predisposing factors, systemic infections in immunocompromised patients, a common cause of death in HIV-positive persons (25 % - 50 % of late stage AIDS patients are infected).

Swimming pool granuloma caused by *M. marinum*. Hof and Dörries, 2005

Non-tuberculous mycobacteria

- **Habitats**

  Soil, natural waters, drinking-water distribution systems, plumbing of buildings, hospitals and households, spas; widespread in biofilms (typical biofilm inhabitants).



Biofilm of *Mycobacterium fortuitum*, SEM, scale bar 20 µm
(Hall-Stoodley and Lappin-Scott, 1998)

- **Resistance to disinfectants**

  - Mycobacteria are resistant to water disinfection (can survive 7-day exposure to 10-15 mg/L free chlorine),
  - Lipid-rich cell wall and growth in biofilms enhances survival in the presence of disinfectants,
  - Disinfection kills off competing microorganisms, thus selecting for mycobacteria.

Predictions on mycobacterial infections in humans

- There will be increasing clinical cases of diseases caused by environmental (non-tuberculous) mycobacteria.
- Likely reasons
  - disinfection of drinking water with chlorine, selecting mycobacteria by reducing competition,
  - disinfection in medical and industrial settings with the same effect,
  - the increasing percentage of the population with predisposing conditions, most importantly AIDS, age, and immunosuppressive treatments, e.g., after transplantation.
- There will be the identification of novel environmental opportunistic mycobacterial species, by new sophisticated methods for identification, and by the increasing number of individuals predisposed to mycobacterial infection.

Pseudomonas aeruginosa

- **Morphology**

  Gram-negative, flagellated, aerobic bacterium.

- **Distribution**

  Worldwide in soil, wastewater and surface waters, in technical water systems (especially important in plumbing systems of large buildings, hospitals, and swimming pools); growth under nutrient-sufficient and nutrient-limited conditions.

Scanning electron micrograph of *P. aeruginosa* cells

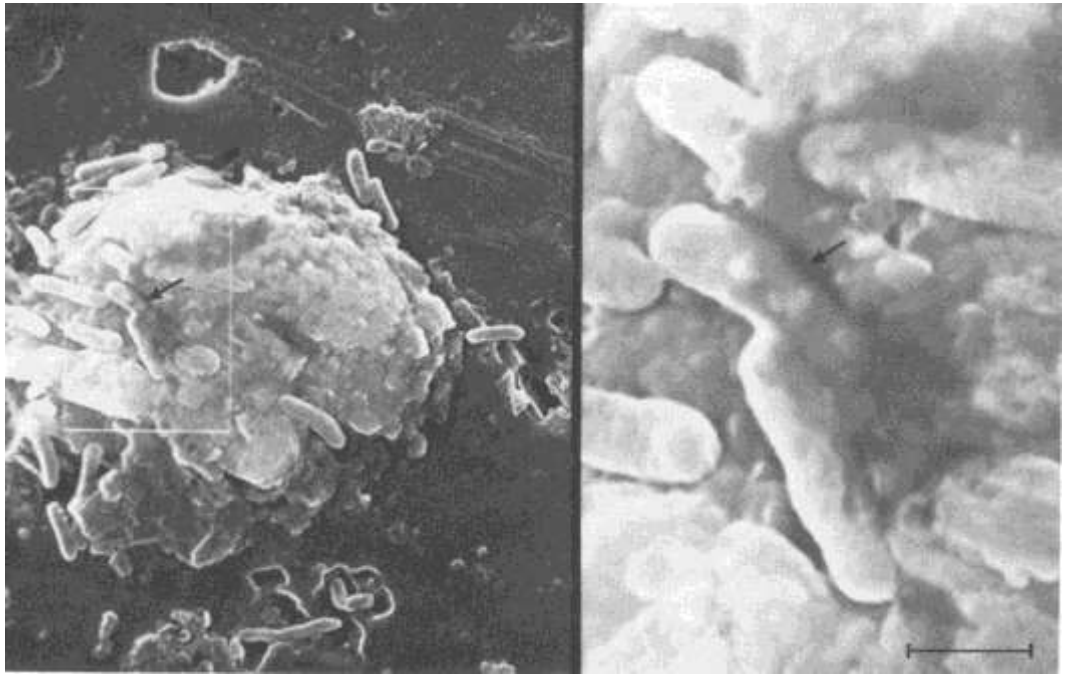
Colonies of *P. aeruginosa* on CN agar medium (48 h, 36 °C)

Source: Wingender et al., 2009

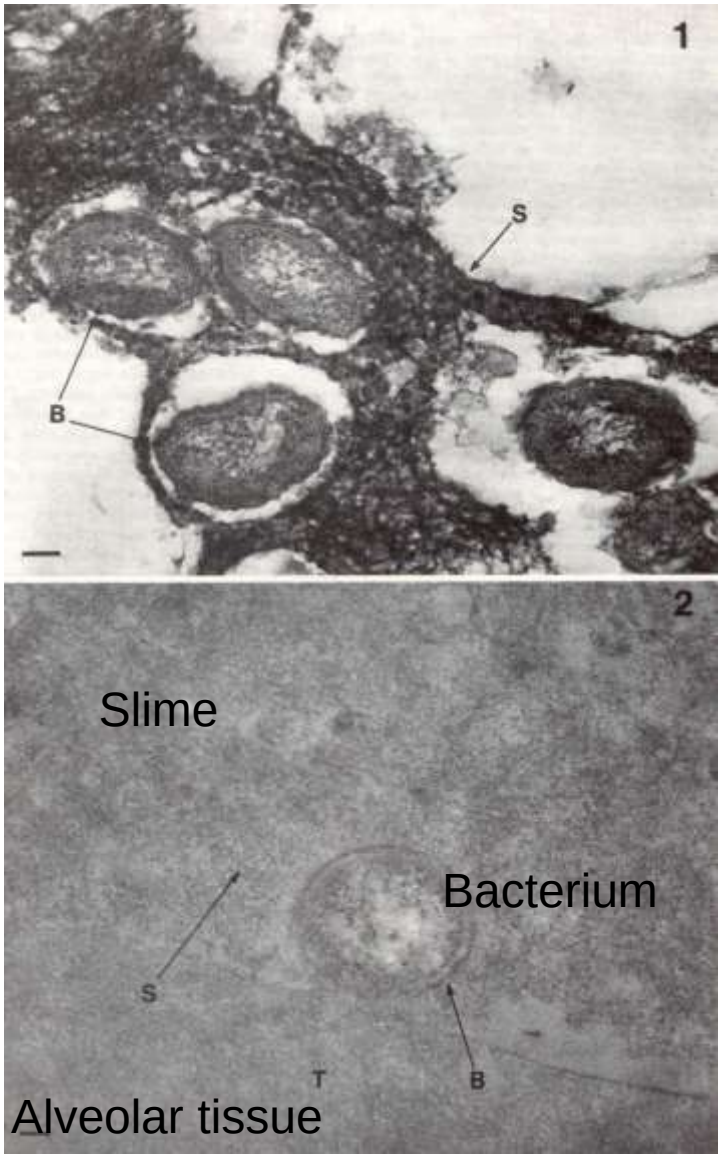
Health effects of *Pseudomonas aeruginosa*

- Pathogenic for humans, animals and plants.
- Transmission from environment by contact with skin (wounds), mucous membranes, eyes, ears; inhalation of aerosols.
- Frequent cause (10 % - 20 %) of nosocomial infections.
- Cause of systemic and local, acute or chronic infections: pneumonia of cystic fibrosis patients or intubated patients, infections of burn wounds, postoperative wound infections, chronic wound infections, urinary tract infections, endocarditis, skin and eye infections, otitis externa (ear infections, „swimmer‘s ear“).
- Emergence of multidrug-resistant strains.
- *P. aeruginosa*: one of the most important facultative pathogens with the property of forming biofilms or living in biofilms in chronic infections (e.g. lungs, wounds), on catheters and in all types of technical water systems.

P. aeruginosa is a typical biofilm organism



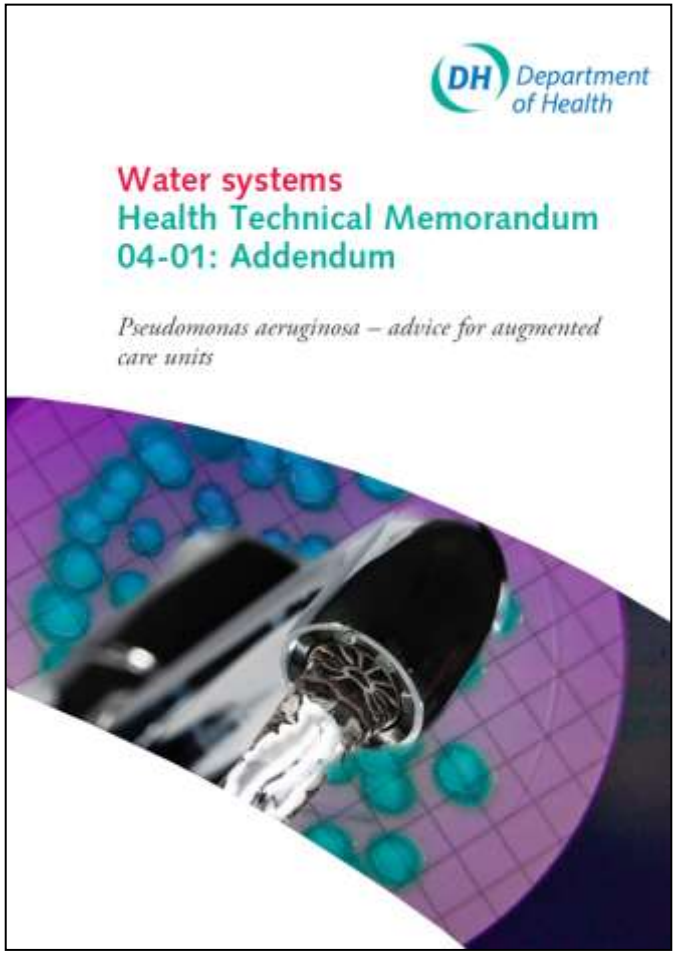
P. aeruginosa attached to the interior suface of a PVC pipe; in this form, the bacteria survived exposure for 7 d to 10-15 mg/L of free chlorine (Vess et al., 1993)



Biofilms of *P. aeruginosa* on lung tissue of cystic fibrosis patients, causing chronic lung infections (Chan et al., 1980).

Pseudomonas aeruginosa infections: association with water

- Between 30 % - 40 % of all hospital-acquired infections with *P. aeruginosa* are associated with contamination of tap water.
- Estimation: in the USA, about 1,400 deaths occur annually due to hospital-acquired pneumonia as a water-related infection caused by *P. aeruginosa* (Anaissie et al., 2002).
- Risk of infection is increased in persons with impaired immune defense, with other underlying diseases, or under medical treatment.
- The general population is supposed to be relatively resistant to infection with *P. aeruginosa*, when it occurs in **drinking water**.



Department of Health, UK, 2013

Pseudomonas aeruginosa infections: association with recreational water

Occurrence of *P. aeruginosa* in **recreational waters** (swimming-pools, whirlpools, hydrotherapy pools, recreational lakes) is associated with sporadic cases and outbreaks of dermatitis/folliculitis and otitis externa.

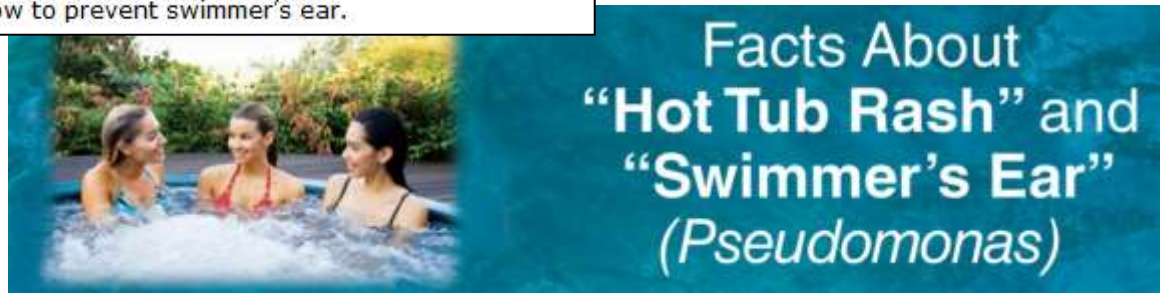
Example: Outbreak of otitis externa with 98 cases after swimming in recreational freshwater lakes containing *P. aeruginosa* (Netherlands, 1994).

Recreational Water Illness and Injury (RWII) Prevention Week

The week before Memorial Day has been designated National Recreational Water Illness and Injury (RWII) Prevention Week. RWII Prevention Week 2011 will take place May 23-29, 2011, marking the seventh anniversary of this observance.

Each year, RWII Prevention Week focuses on simple steps swimmers and pool operators can take to ensure a healthy and safe swimming experience for everyone.

The theme of RWII Prevention Week 2011 is swimmer's ear (otitis externa). Swimmer's ear is a common problem for swimmers of all ages and can cause severe pain and discomfort. During RWII Prevention Week 2011, CDC's Healthy Swimming Program and its partners will provide the public with new information and recommendations on how to prevent swimmer's ear.



CDC, 2011

Water-associated opportunistic pathogens in health-care facilities

Health-care facilities

- Hospitals
- Health centres
- Residential care facilities
- Nursing homes
- Dental offices
- Dialysis centres

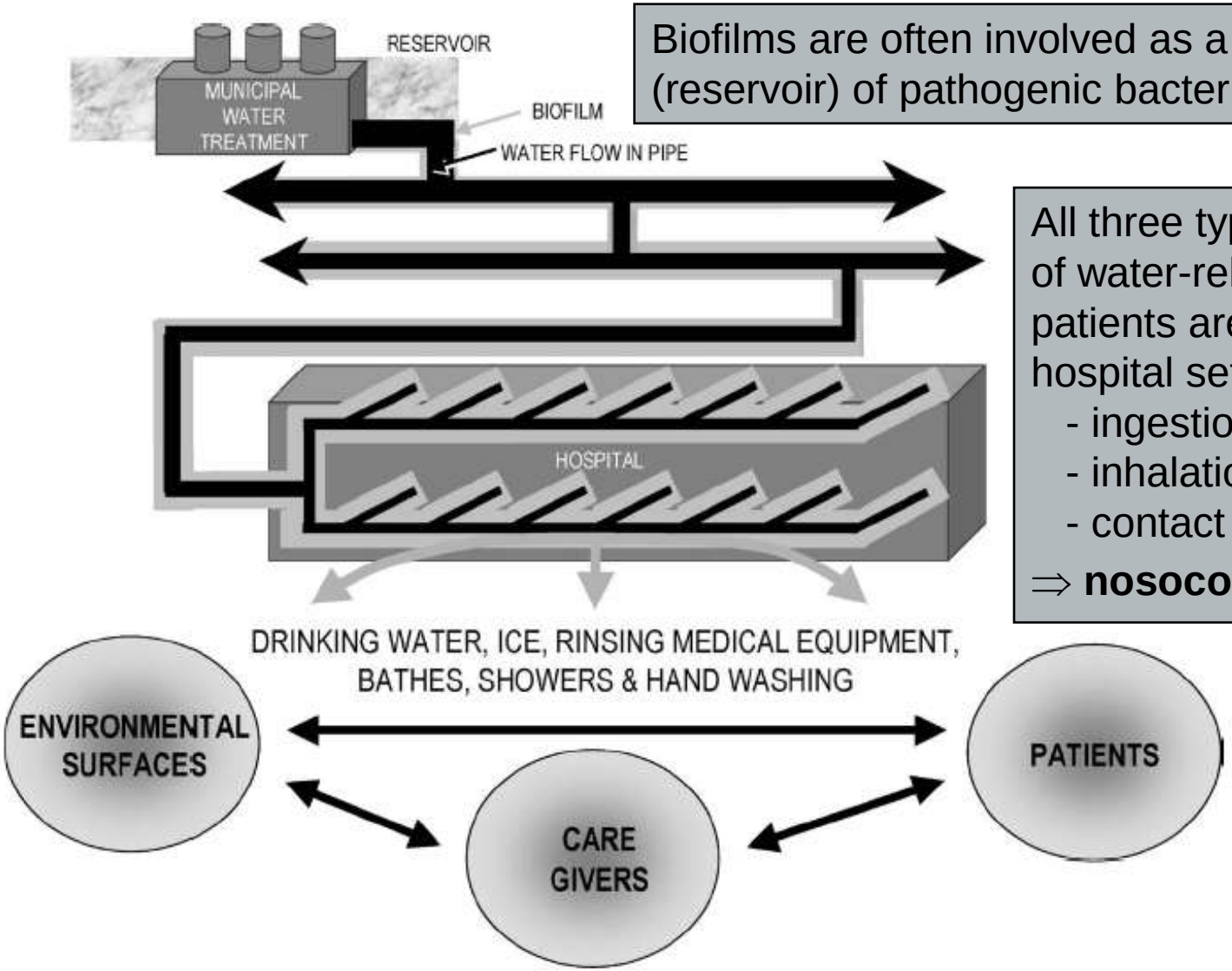
Drinking-water quality in health-care facilities

- Hospitals are high-risk environments:
  potential of serious opportunistic infections in patients (especially infants, the elderly, individuals with weakened immune system).
- Hospital water supply, including biofilms, can be a source of nosocomial infections.
- Drinking water may not be suitable for all uses and for all patients such as severely immunosuppressed persons within health-care facilities.
- Potential risk of infection:
  - by water used to wash burns or wounds,
  - by water used to wash medical devices such as endoscopes, respiratory equipment and catheters,
  - by water used for renal dialysis.

  $\Rightarrow$ Use of sterilized water may be required in health-care facilities, depending on use.

Transmission routes of water-related pathogens in the hospital setting

Biofilms are often involved as a source (reservoir) of pathogenic bacteria and fungi.



All three types of transmission of water-related pathogens to patients are possible in the hospital setting:

- ingestion
- inhalation and aspiration
- contact with skin

⇒ **nosocomial infections**

Source: Ortolano et al., 2004

Biofilms in health-care facilities

Example: biofilm on a copper pipe distributing aldehyde-containing disinfectant

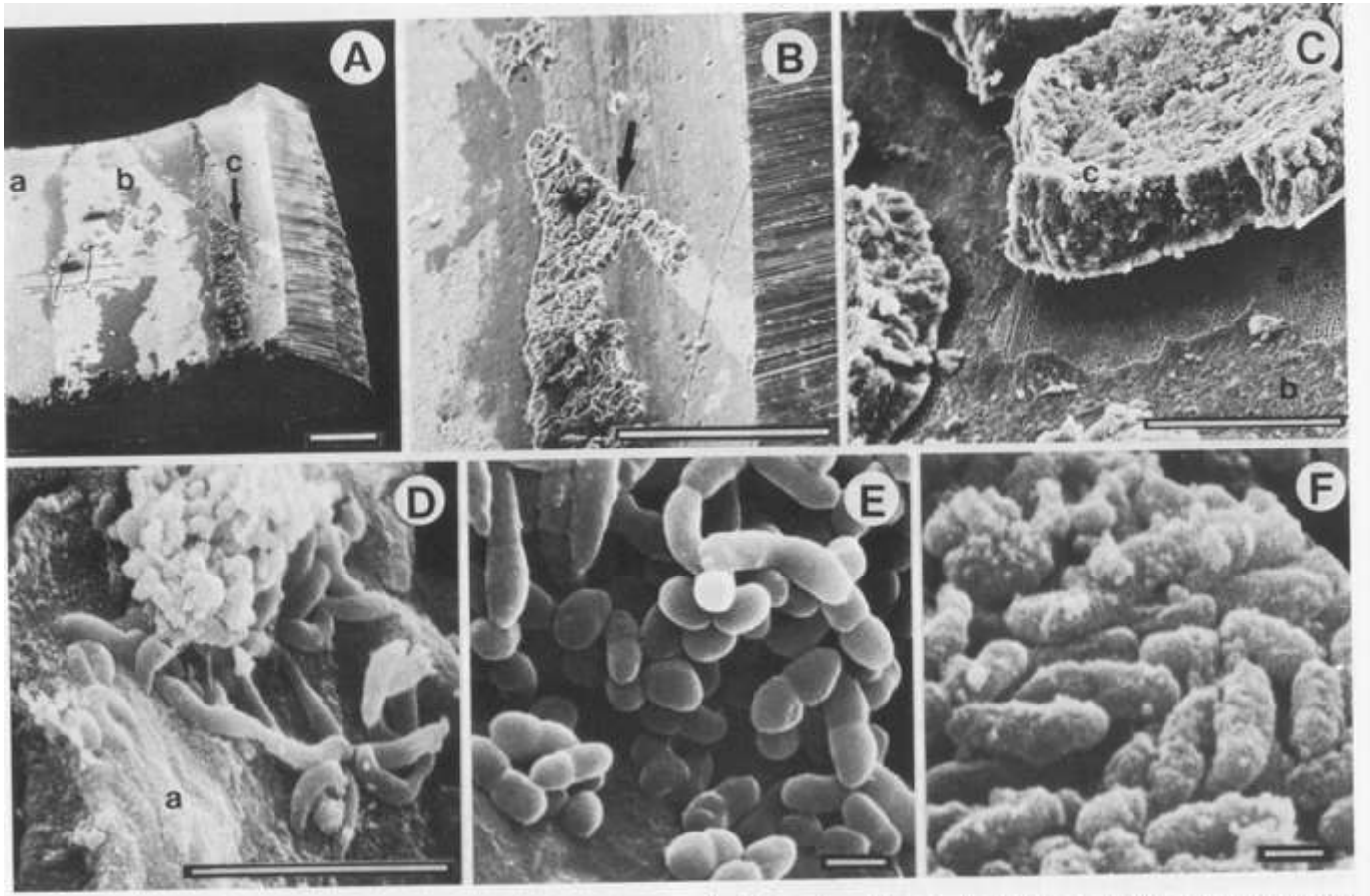
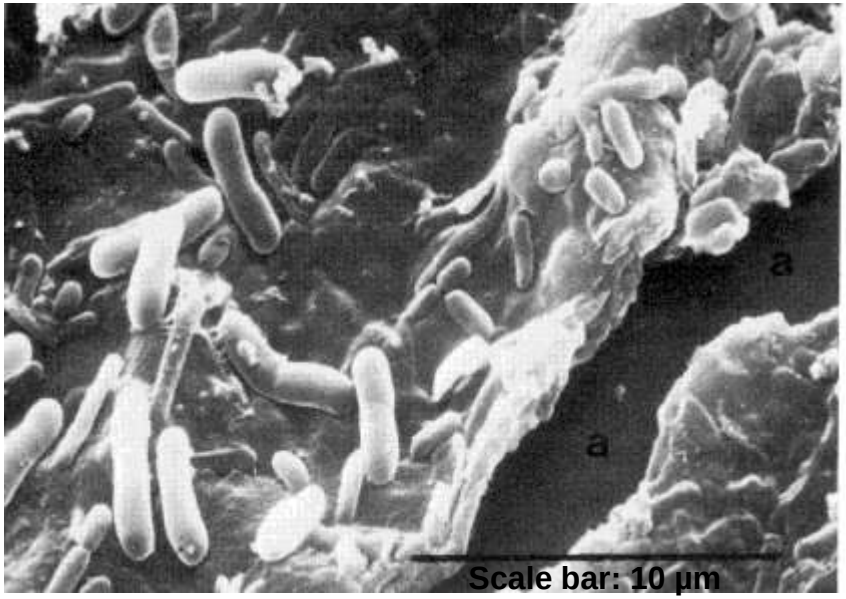


Abb. 3 Belag an der Innenwandung des Kupferrohres aus einer zentralen Desinfektionsmitteldosieranlage (REM-Aufnahmen)
A) Übersichtsaufnahme eines Teilstücks des Rohres: Die Orientierung des Rohres wird durch den weißen Pfeil angegeben; bei ‚a' ist die freie Kupferoberfläche zu sehen, bei ‚b' befinden sich Reste des teilweise abgehobenen Belags und bei ‚c' der Belag; Länge des Balkens = 1 mm
B) Belag auf Kupferoberfläche: Die Vergrößerung des auf der Abbildung A durch einen Pfeil markierten Bereiches läßt bei ‚B' die Verteilung des Belags, von dem sich Teile bereits abgelöst haben, deutlich werden; Länge des Balkens = 1 mm
C) Übersichtsaufnahme des Belags: Während der Probenpräparation für die REM-Untersuchung kommt es zur Austrocknung des Belags, dieser schrumpft, reißt auseinander und hebt sich schließlich von der Kupferoberfläche ab: ‚a' freie Kupferoberfläche mit Korrosion, ‚b' Reste von unvollständig abgehobenem Belag, ‚c' abgehobenes Stück des Belags; Länge des Balkens = 0,1 mm
D) Unterste Schicht des Belags: Bei ‚a' ist die nicht-zelluläre Schicht zu erkennen, darüber sind Bakterien zu sehen, die teils frei vorliegen, teils bedeckt sind; Länge des Balkens = 10 µm
E) Bakterien aus dem Innern des Belags: Die glatte Oberfläche der Mikroorganismen weist auf das Fehlen einer Bekapselung hin; Länge des Balkens = 1 µm
F) Bakterien aus der obersten Schicht des Belags: Die rauhe Oberfläche der Mikroorganismen weist auf die Ausbildung von Kapselsubstanzen hin; Länge des Balkens = 1 µm.

(Exner and Tuschewitzki, 1984)

Water biofilms in health-care facilities



Biofilm on the inner surface of a silicone tube from a dental unit.
(Exner and Tuschewitzki, 1984)

Biofilm on corroded faucet flow straightener.
(Trautmann et al., 2005)

Biofilms in dental waterlines can harbour opportunistic pathogens such as *Legionella pneumophila* and *Pseudomonas aeruginosa*.

Biofilms in water outlets can act as important infection sources of *Pseudomonas aeruginosa* for hospital patients.

Water-related pathogens involved in health care-associated infections

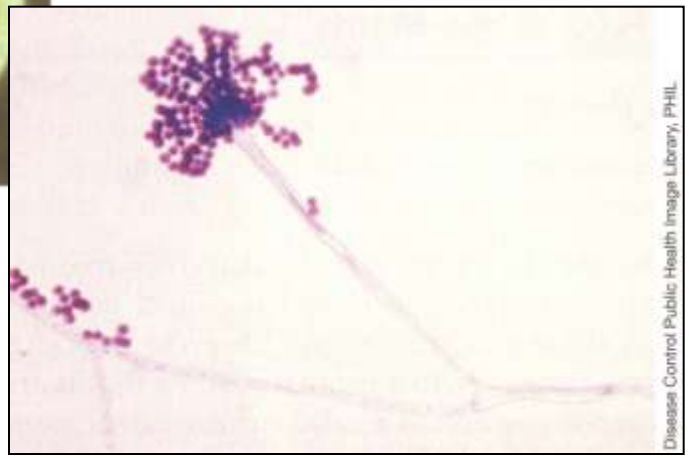
Organisms	Sites of infection
Bacteria	
Legionella spp.	Lungs, other organs
Pseudomonas aeruginosa	Blood, lungs, urinary tract, skin, wounds
Mycobacterium spp. (*M. avium*, *M. chelonae, M. fortuitum*, *M. kansasii*, *M. xenopi*)	Disseminated, respiratory tract, wounds, blood, stomach
Stenotrophomonas maltophilia	Blood, respiratory/urinary tract, skin
Acinetobacter baumannii	Skin, wounds
Aeromonas hydrophila	Blood
Serratia marcescens	Eyes
Elizabethkingia meningoseptica	Respiratory tract
Fungi	
Aspergillus fumigatus	Lungs
Exophiala jeanselmei	Disseminated
Fusarium solani, *F. oxysporum* and other *Fusarium* species	Disseminated

Fungi in municipal and hospital water

- Fungi (molds and yeasts): ubiquitous in municipal water systems, in water and in biofilms (mainly as spores).
- Fungi in water may be associated with taste and odour problems, contamination in food and beverage production, and health-related effects.
- Fungi are an emerging cause of nosocomial infections, and pose a health threat mainly to immunocompromised persons.
- Hospital water is a potential source of filamentous fungi; transmission may occur through aerosolization of shower water or from reaerosolization of fungi from shower walls.
- An important nosocomial water-related pathogen is *Aspergillus fumigatus* causing aspergillosis (fungal pneumonia).

Aspergillus colonies on an agar medium

Microscopic picture of *Aspergillus fumigatus* conidiophore and conidia



Prevention and control of nosocomial water-related infections (recommendations)

- Minimization of exposure of immunocompromised patients to tap water.
- Further processing of water, depending on use in hospital.
- Education of staff, patients, facilities engineers, risk managers, and other professionals involved in health care.
- Implementation of surveillance for infections and monitoring of water systems.
- Construction, maintenance and operation of plumbing systems according to acknowledged technical rules.
- Cleaning and disinfection of plumbing systems (flushing, chlorination, use of chlorine dioxide, UV irradiation, heating, installation of point-of-use filters).