Legionella, Cyanobacteria, Cryptosporidium and Giardia in Water Quality

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HydroQual Laboratories Ltd.

Golder Associates

Water Technologies Symposium 2013, April 10 – 12, 2013
Environmental Services Association of Alberta (ESAA)

WATER QUALITY

Key Concepts

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Cryptosporidium/Giardia

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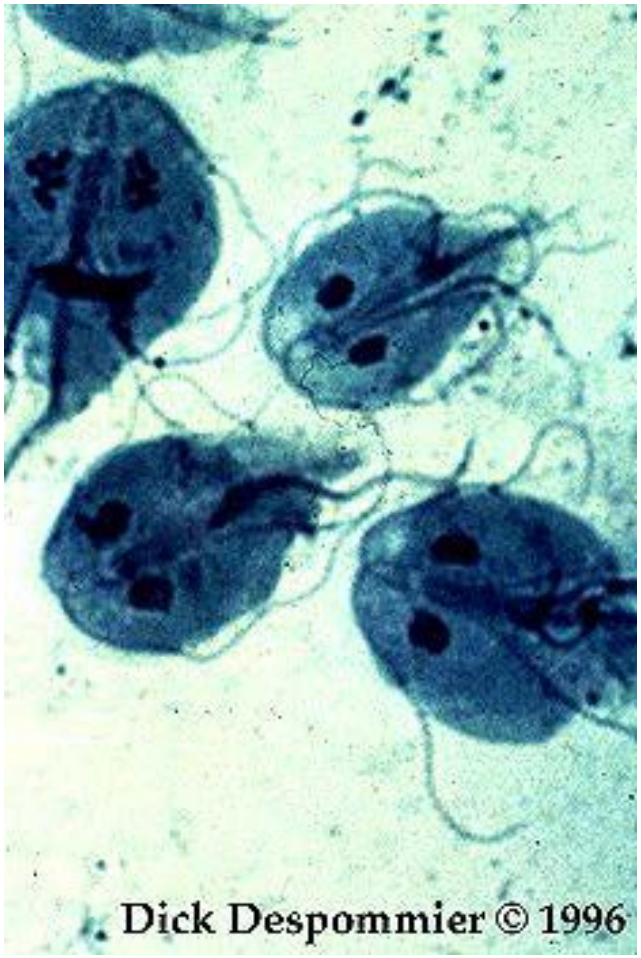
GIARDIA LAMBLIA

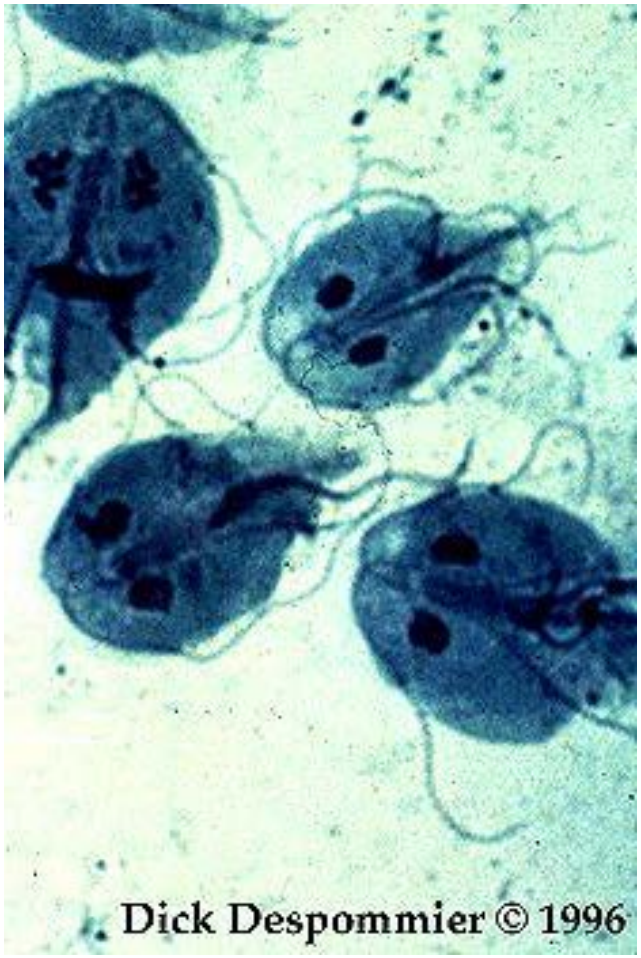


- What are they?
  - Small flagellated protozoan parasites → human pathogens
    - Small intestines
  - Hardy cysts
    - Environmentally Stable
    - Survive up to 77 days in water

http://microculture.tumblr.com/post/607552001/giardia-lamblia-trophozoites-cute-when-theyre

US CDC/Health Canada

GIARDIA LAMBLIA



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- Most common intestinal protozoan in NA/worldwide
  - WHO: 200 million cases/year
  - Canada: 5-10%
    - Occurrence: 2 – 200 cysts/100 L up to 8700 cysts/100L

Epcor 2005

- Global disease
  - Developed countries
    - 2% adults
    - 6-8% children
  - Developing countries
    - 33% of people

US CDC/Health Canada

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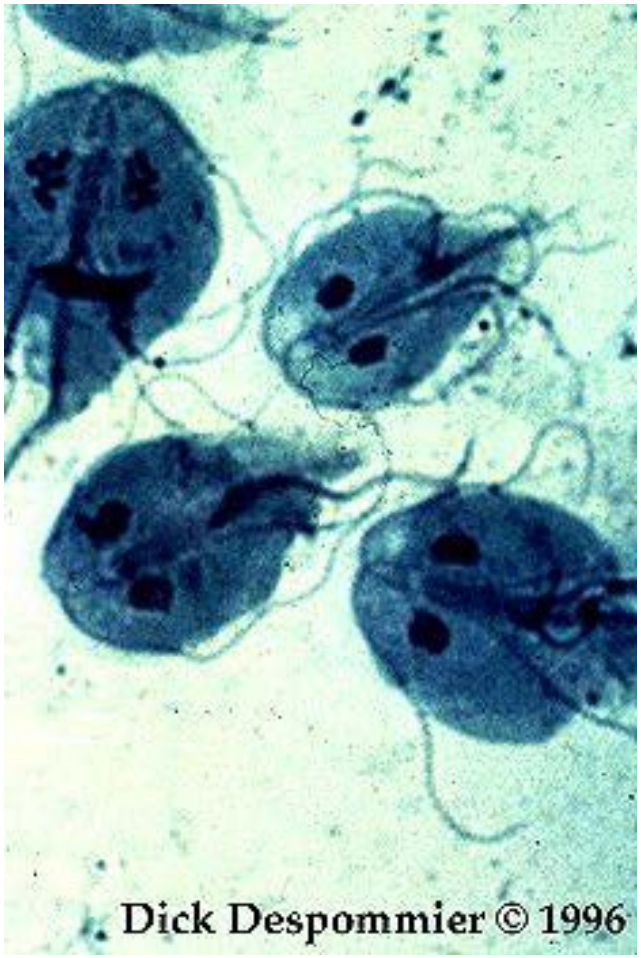
GIARDIA LAMBLIA



http://microculture.tumblr.com/post/607552001/giardia-lamblia-trophozoites-cute-when-theyre

- Infection rates
  - ‘ summer
  - US: 2X > June – October vs January – March
- Transmission
  - Fecal – Oral via Contaminated
    - Food
    - Water
  - Ingestion: 10 cysts
- Ingestion → Giardiasis
  - Self limiting
  - Immunocompromised

US CDC/Health Canada

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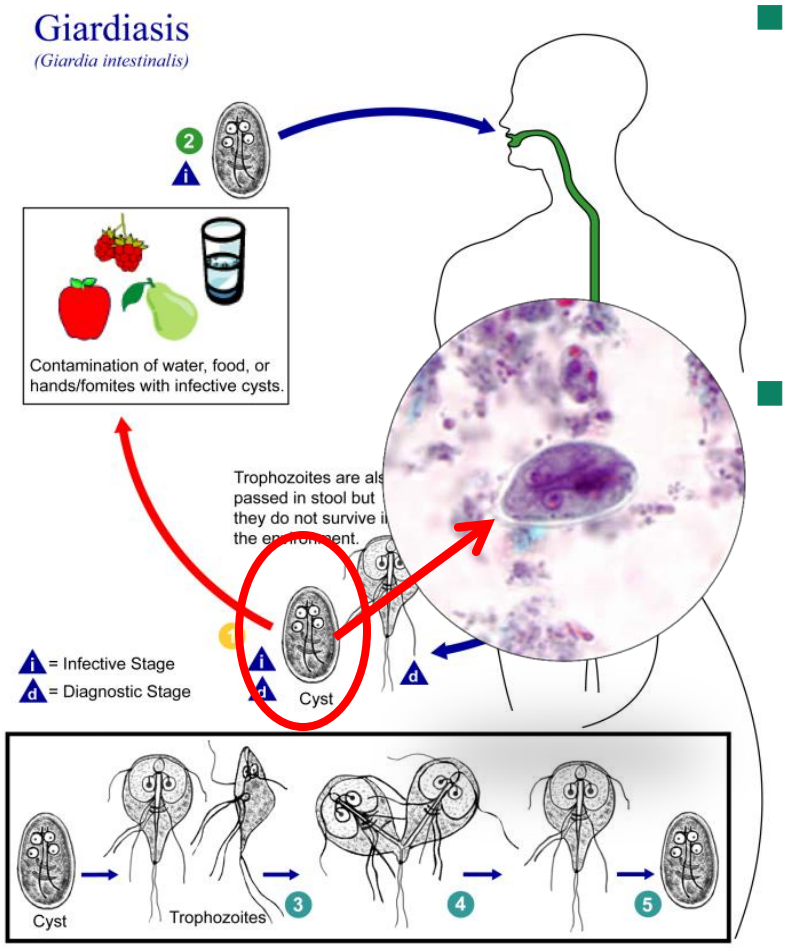
GIARDIA LAMBLIA

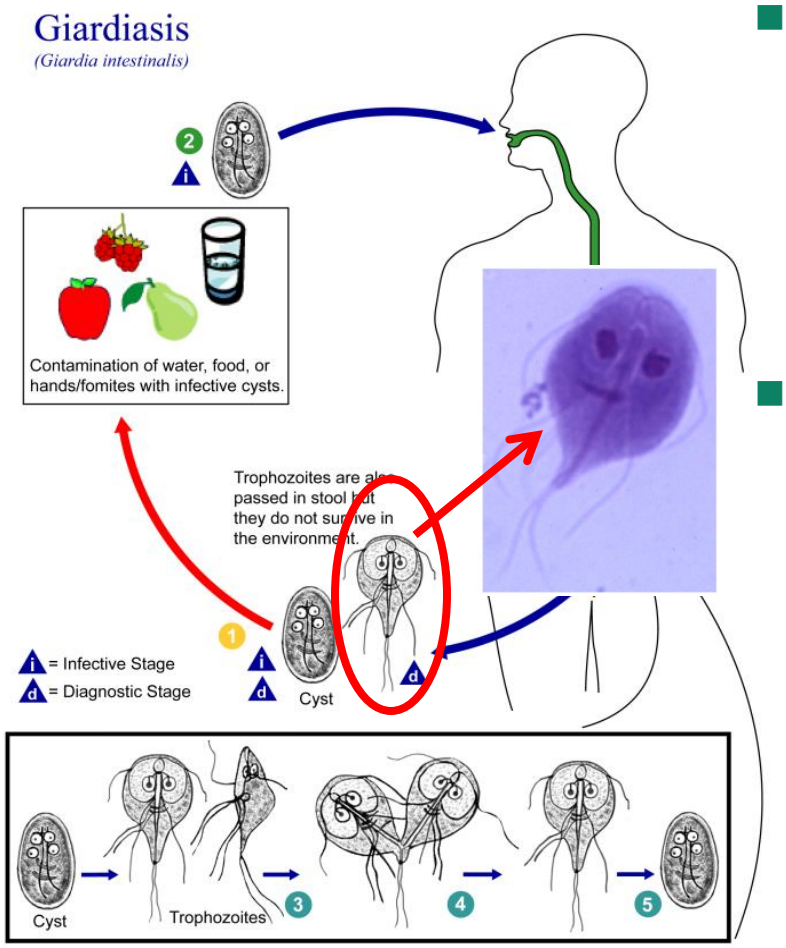


US CDC

- Cysts
  - Environmentally stable
  - Passed in faeces
  - Ingestion
    - Stomach acid triggers life cycle
- Trophozoites
  - 9-21 um long
  - 5-10 um wide
  - 2-4 um thick
  - Attaches to intestines

US CDC/Health Canada

GIARDIA LAMBLIA



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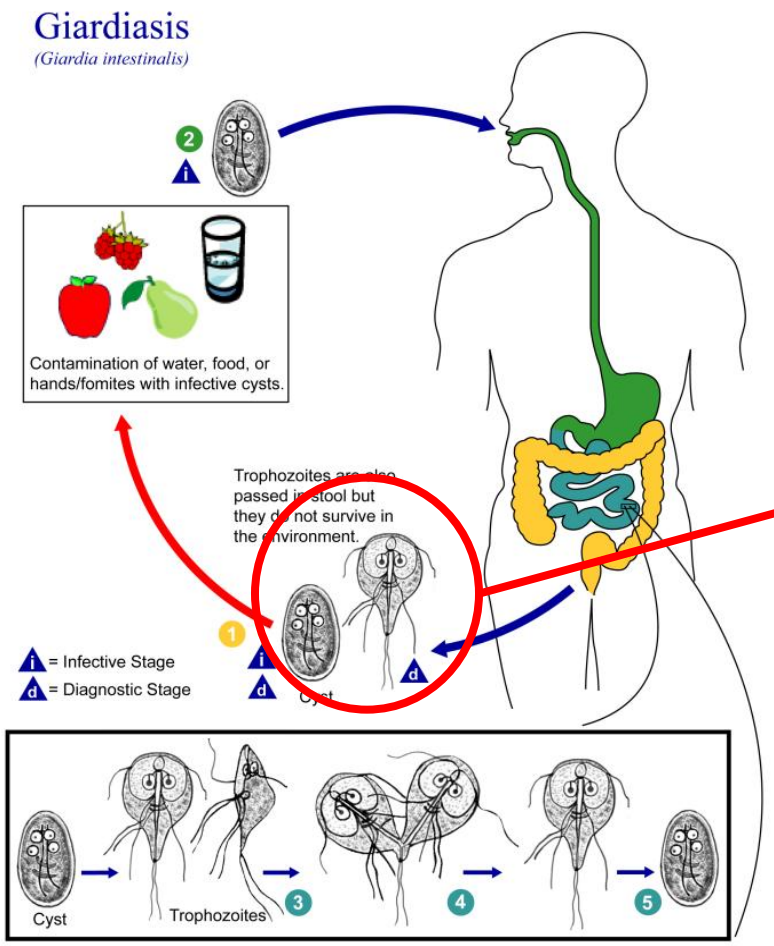
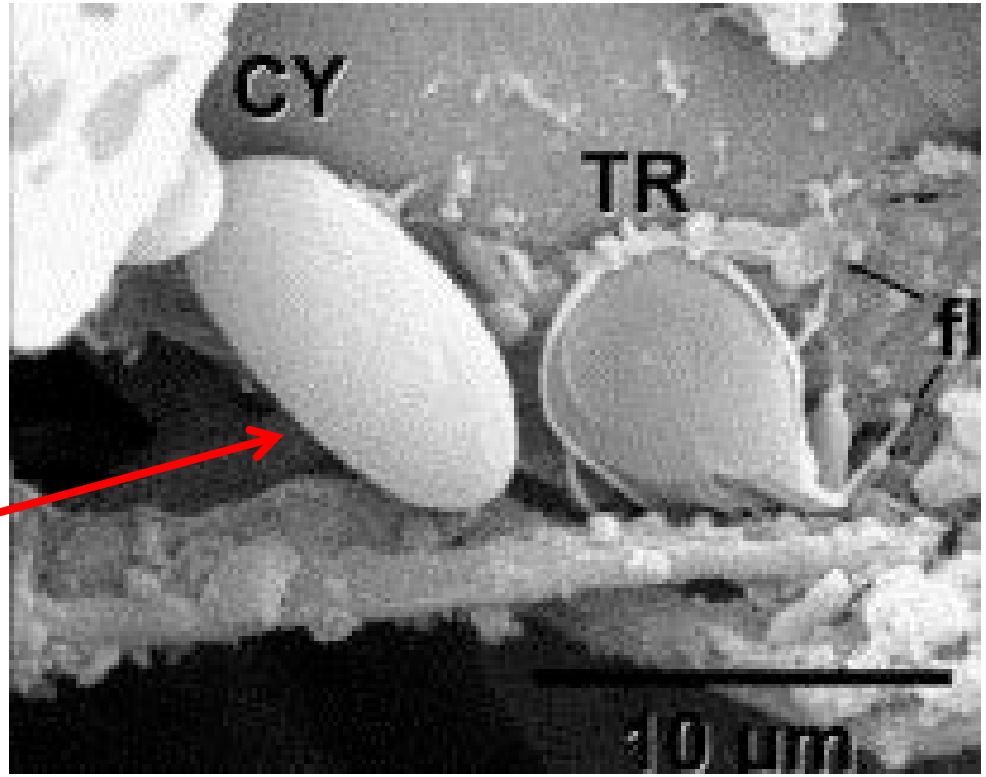


US CDC



CY: Cysts; TR: Trophozoites; fl: Flagella

Muller & von Allmen 2005 (November), Recent insights into the mucosal reactiosn associated with *Giardia lamblia* infections. International Journal of Parasitology, 35(13): 1339 - 1347

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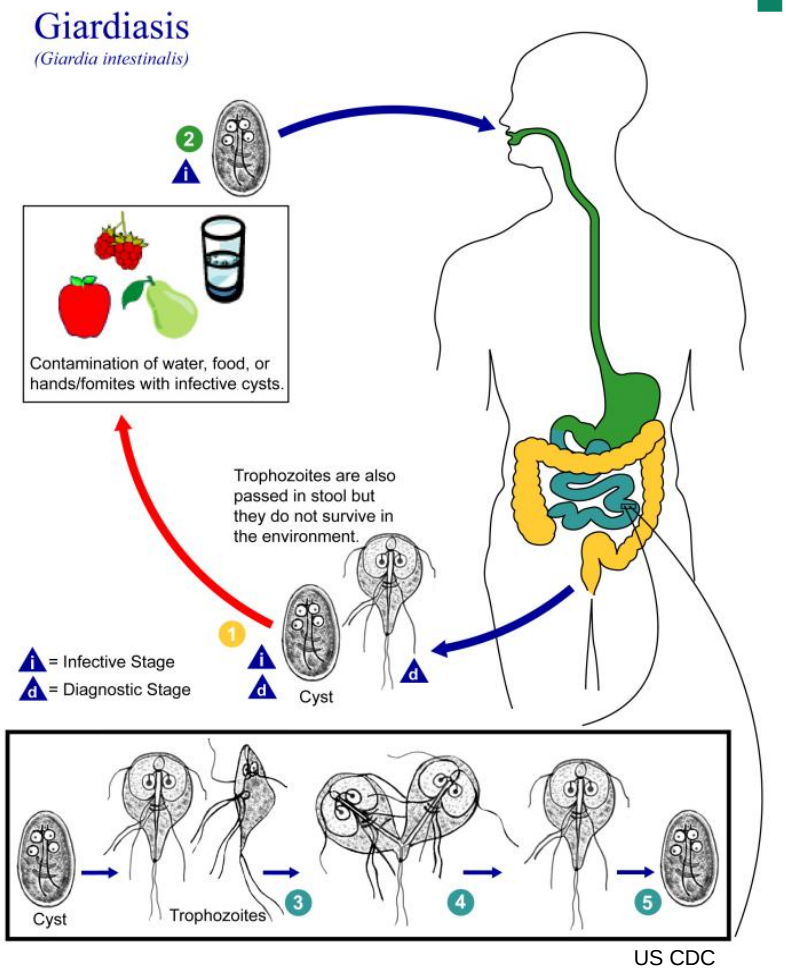
GIARDIA LAMBLIA



US CDC

- Cross Canada Survey
  - 162 raw sewage samples
    - 52% contained cysts
    - 1 – 88 000 cysts/L
  - 1215 raw/treated drinking water samples
    - 10% contained cysts
    - 0.001 – 2 cysts/L

Wallis et al., 1995 Risk assessment for waterborne giardiasis and cryptosporidiasis in Canada. Unpublished report to Health Canada.

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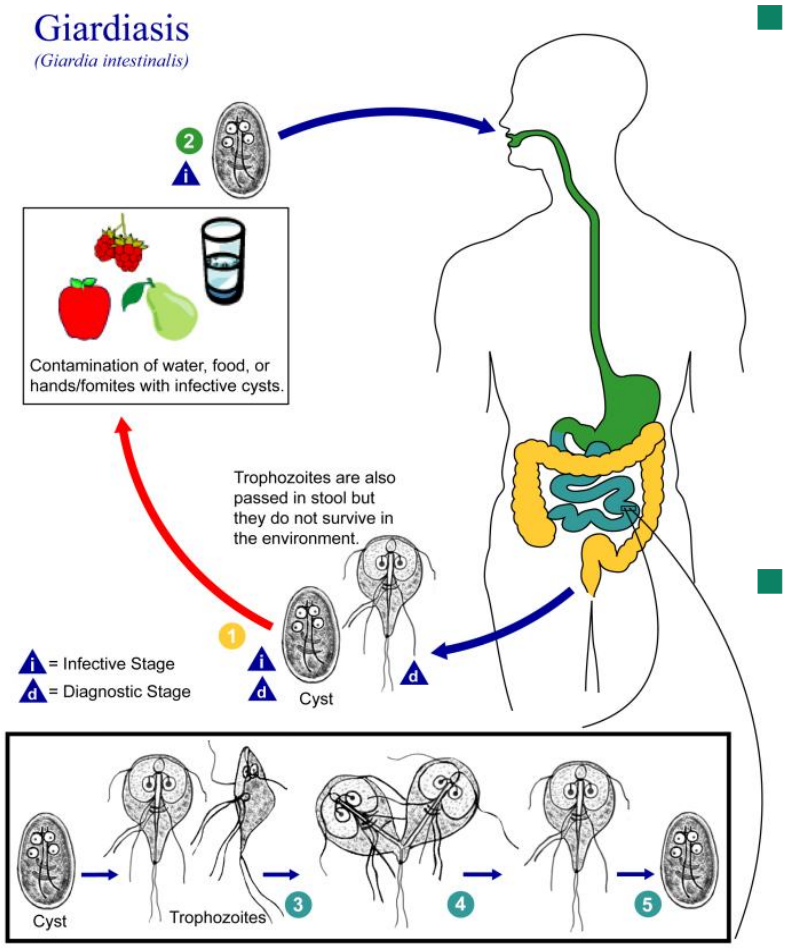

US CDC

- Edmonton, Alberta
  - Raw water (1990 – 1996)
    - 8 – 193 cysts/100 L
  - 1997 – heavy spring run off
    - 2500 cysts/100 L of raw water
    - 24 cysts/1000 L of treated water → water advisory
- Minimum infective dose: 1- 10 cysts
  - ID_{50}: 19 cysts

Goatcher and Fok, 2000. A Giardia/Cryptosporidium near miss? In: Proceedings of the 8th National Conference on Drinking Water, Quebec City, Quebec, October 28 – 30, 1998. Canadian Water and Wastewater Association, Ottawa, Ontario.

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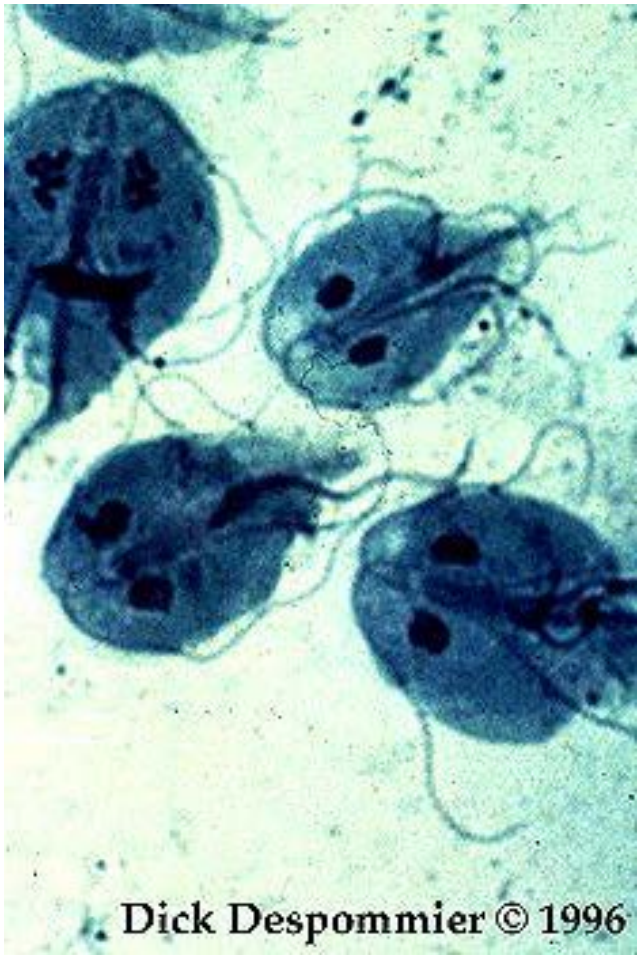
GIARDIA LAMBLIA



- Treatment methods
  - Chlorination
  - Filtration
- Standard treatment methods are effective during normal conditions
- May decrease during isolated events
  - Spring run off
  - Power outage

US CDC

CRYPTOSPORIDIUM

- What are they?
  - Cryptosporidium → Hidden spores
  - Protozoan parasites → human pathogens
  - Hardy Cysts
    - Survive lengthy periods outside of host
    - Environmentally stable
    - Resistant to treatment
      - Specifically Chlorine based
      - Standard filtration → 99% removal

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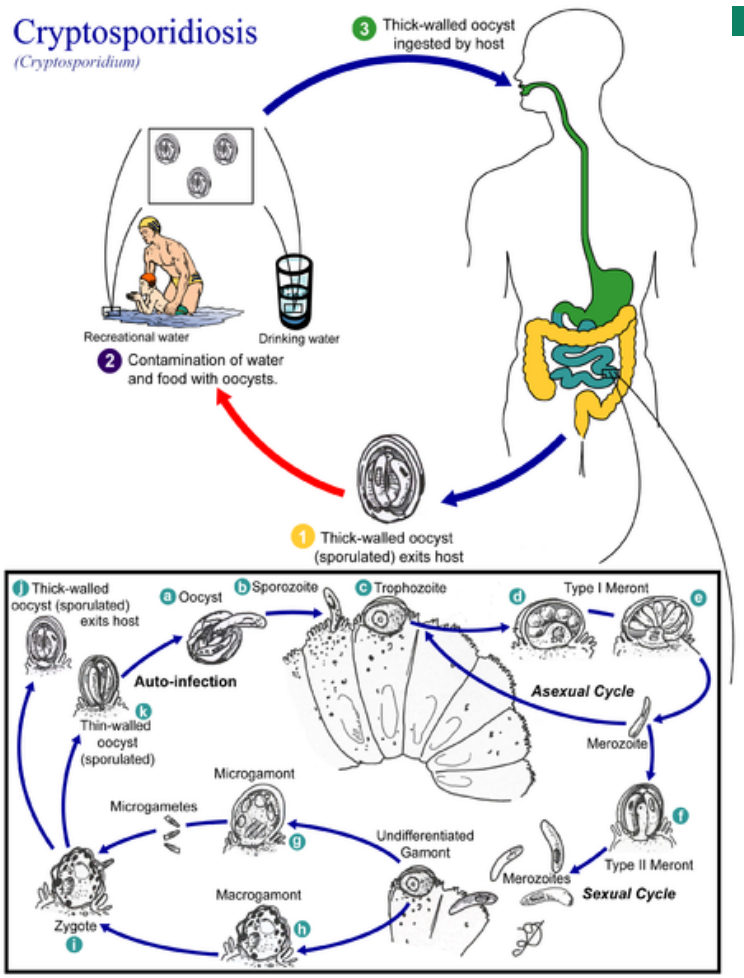
CRYPTOSPORIDIUM

- Global Disease
  - Developed → 1- 4.5%
  - Developing → 3 - 20%
  - Immunocompromised
    - US → 3 – 20%
    - Africa/Haiti → 50 – 60%
  - Daycares
  - Swimming Pools

Health Canada

- Outbreaks
  - Canada - North Battleford, Saskatchewan (2001)
  - United States - Milwaukee (1993)

CRYPTOSPORIDIUM



- Transmission
  - Fecal – Oral
    - Person to person
    - Animal to person
    - Foodborne
    - Waterborne
- Ingestion → Cryptosporidiasis
  - Self limiting
  - Immunocompromised

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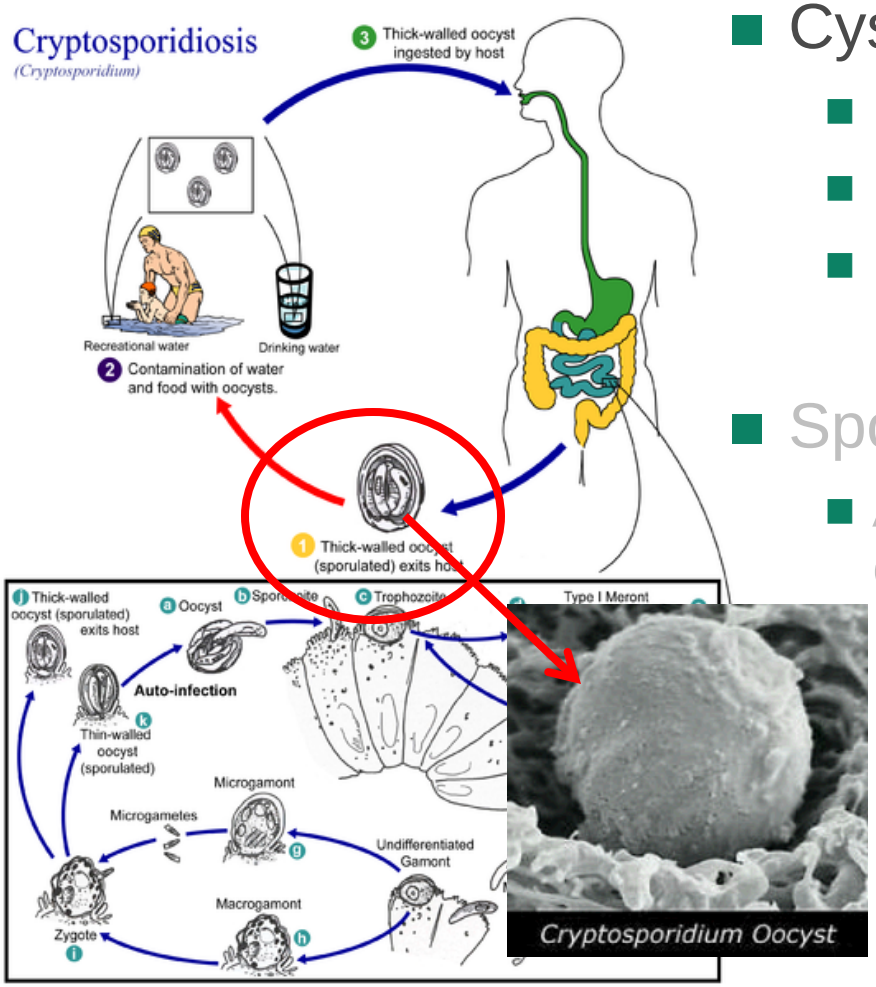
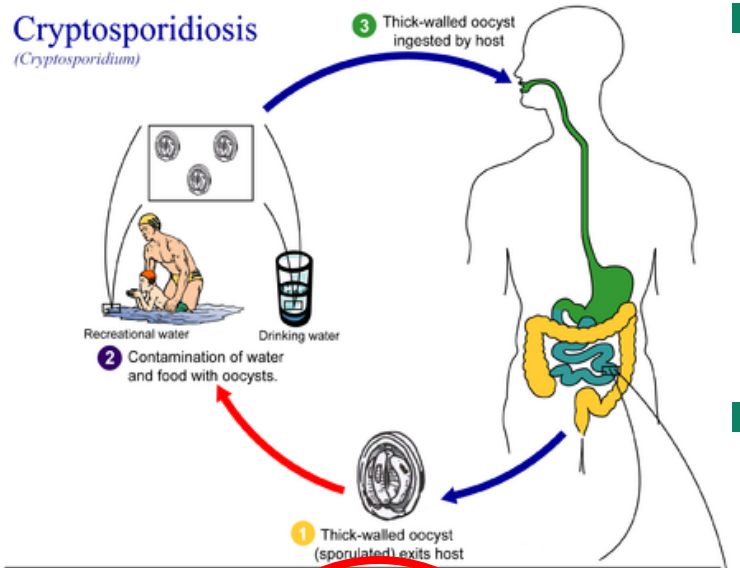
CRYPTOSPORIDIUM

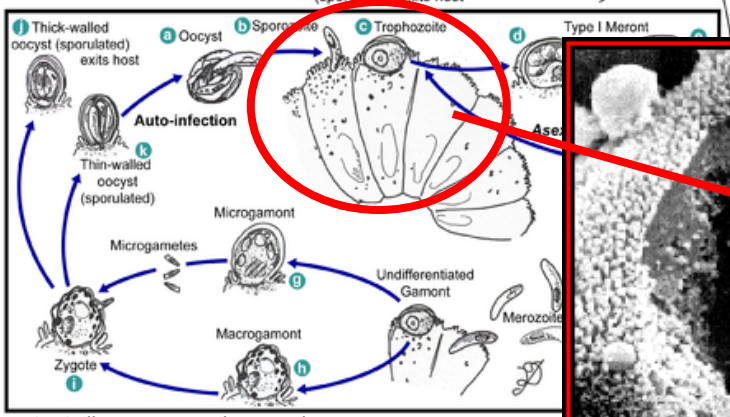


- Cysts
  - Environmentally Stable
  - Passed in faeces
  - Ingestion → Excystation
- Sporozoites
  - Attaches to the epithelial surface of the GI tract

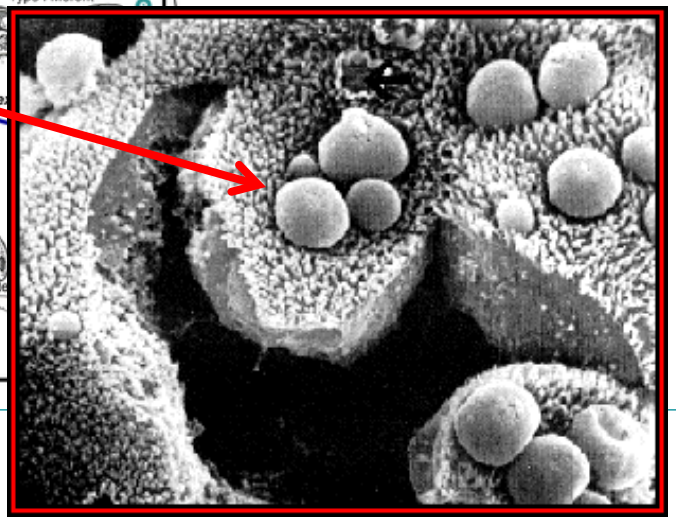
CDC; www.marvistavet.com/html/body_cryptosporidium.html

CRYPTOSPORIDIUM





CDC; jhyoung.myweb.uga.edu



- Cysts
  - Environmentally Stable
  - Passed in faeces
  - Ingestion → Excystation
- Sporozoites
  - Attaches to the epithelial surface of the GI tract → illness

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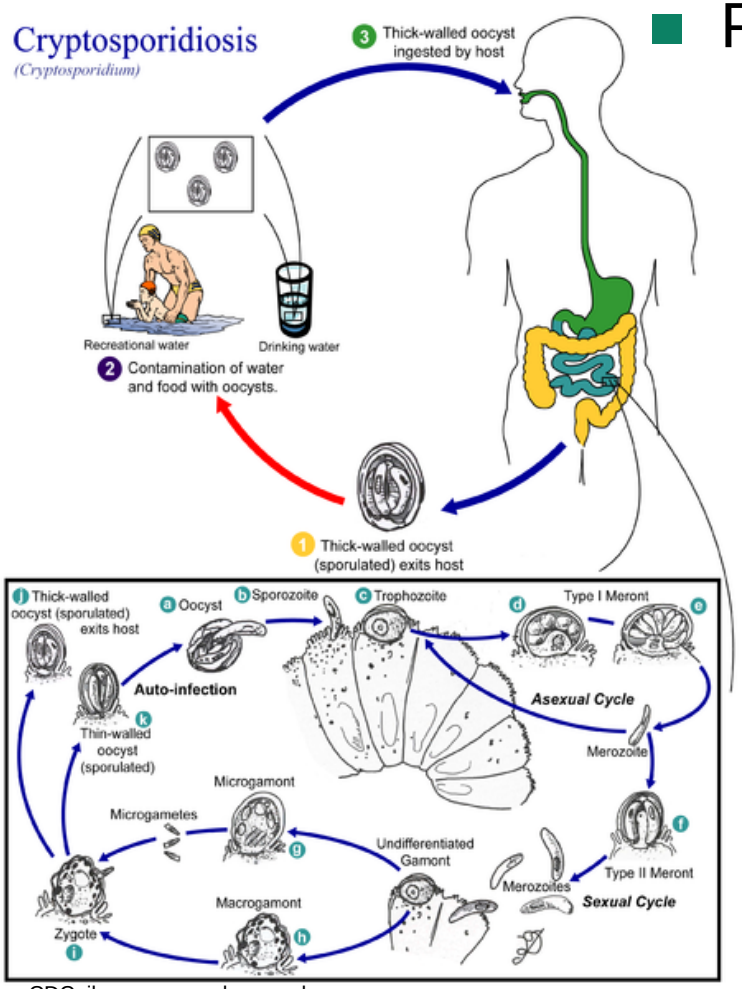
CRYPTOSPORIDIUM

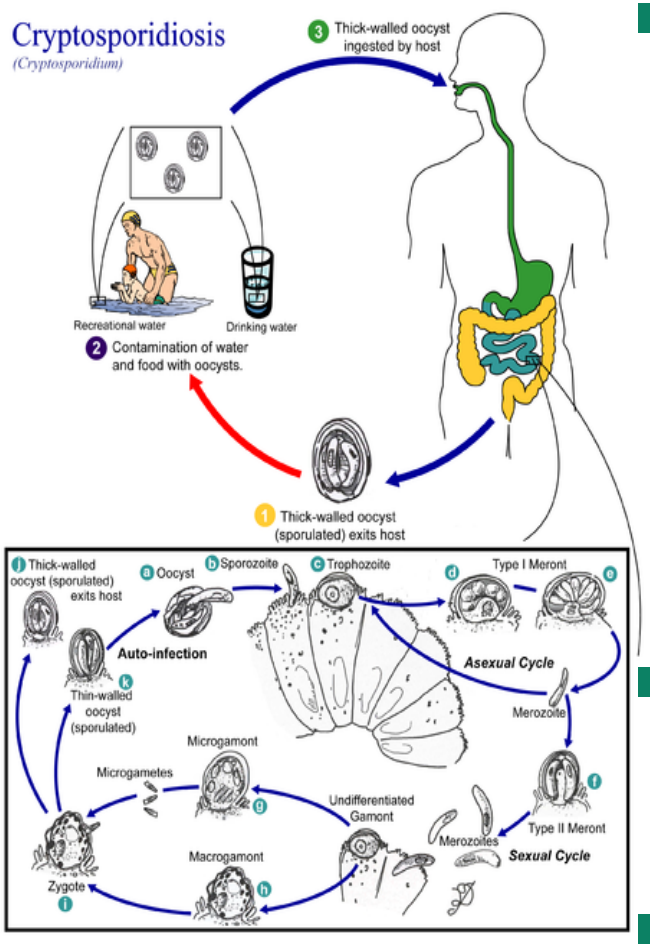


CDC; jhyoung.myweb.uga.edu

- Prevalence
  - Wastewater → 3.3 – 20 000/L
  - Surface waters receiving agricultural or wastewater discharges → 0.006 – 2.5/L
  - Pristine surface water → 0.02 – 0.08/L
  - Drinking water → 0.006 – 4.8/L
  - Recreational water → 0.66 – 500/L

Smith, 1990. Environmental aspects of *Cryptosporidium* species: a review. J.R. Soc. Med., 83:629 - 631

CRYPTOSPORIDIUM



CDC; jhyoung.myweb.uga.edu

- Cross Canada Survey
  - 162 raw sewage samples
    - 11.1% contained oocysts
    - 1 – 120/L
  - 1215 raw/treated drinking water sample
    - 6.4% contained oocysts
    - 0.001 – 0.005 oocysts/L

Wallis et al., 1995 Risk assessment for waterborne giardiasis and cryptosporidiasis in Canada. Unpublished report to Health Canada

- Canada
  - 1 – 100 oocysts/100 L up to 10 300 oocysts/100 L
- Infection: ID_{50}: 132 oocysts

Health Canada

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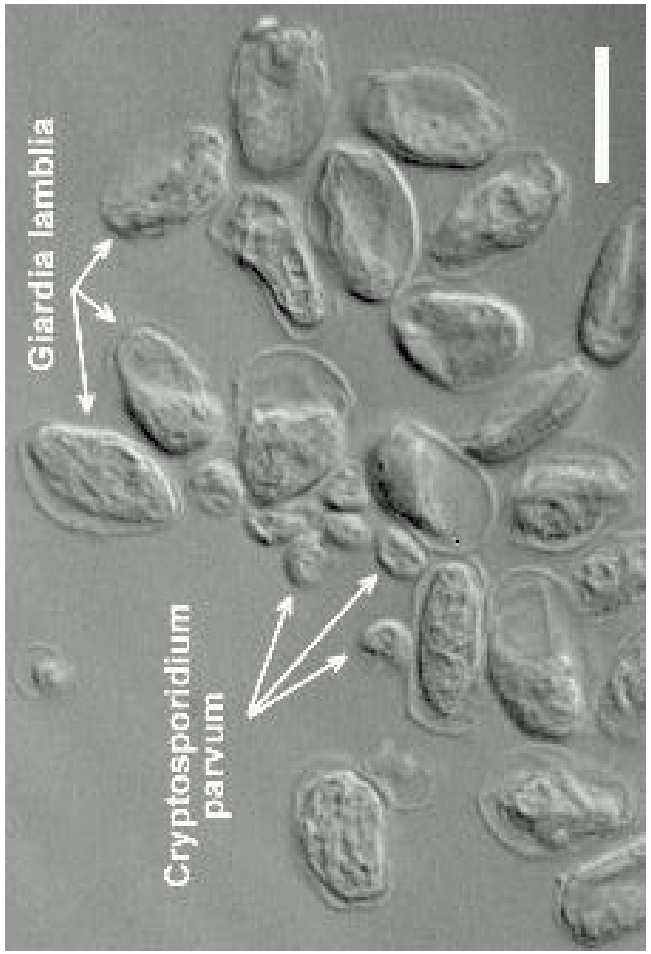
CRYPTOSPORIDIUM & GIARDIA

- What does this mean?
  - The Canadian Drinking Water Guidelines
    - Do not require analysis
  - Analysis is recommended
    - Human pathogen
      - Due Diligence
        - Important to assess the source water to determine the number of organisms present
    - Efficacy of treatment
    - Dictate treatment level
      - Spring runoff

CRYPTOSPORIDIUM & GIARDIA



USEPA

- Testing methods
  - USEPA method 1623.1
    - Filtration
    - Elution/Concentration
    - Immuno-magnetic separation (IMS)
    - Fluorescence staining
    - Enumeration
- Factors affecting recovery rates
  - Methodology
    - Previous methods → 10% recovery
    - New method → 50-60% recovery
  - Turbidity/Matrix interference
    - Addition of dispersants

Cyanobacterial Toxins – Microcystin-LR

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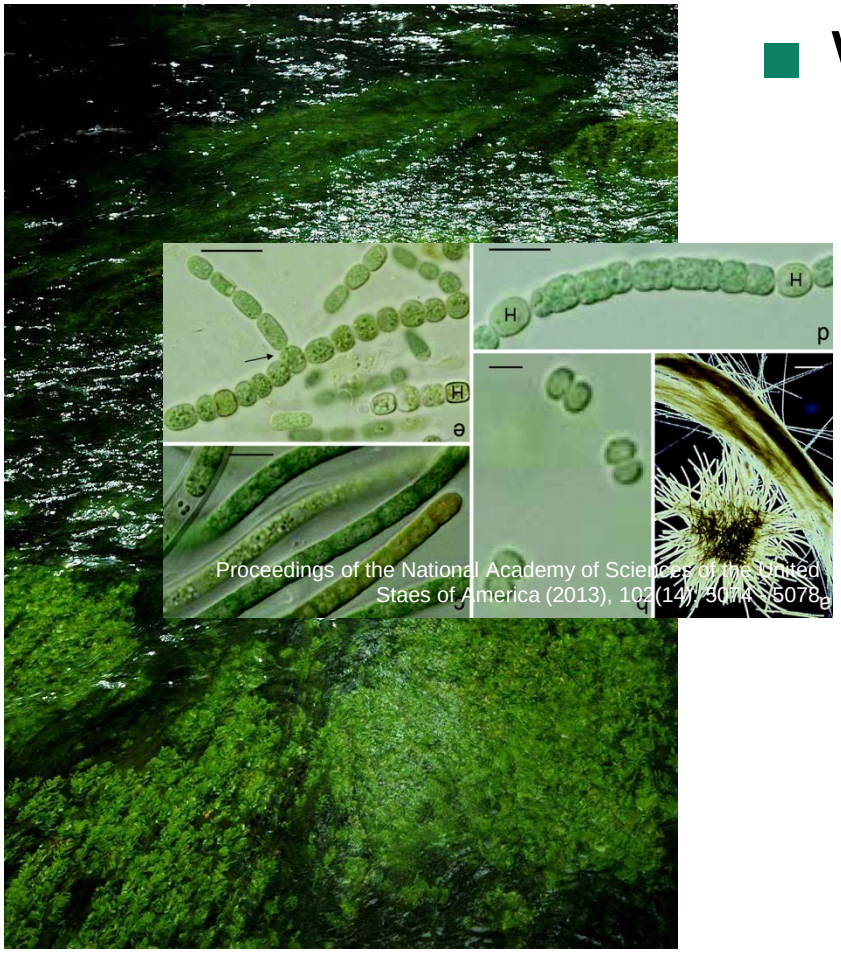
CYANOBACTERIA



Massachusetts Department of Environmental Protection

- What are they?
  - Blue-green algae
  - Form in shallow, warm slow moving or still water
  - Cells → cyanobacterial toxins
    - Neurotoxins → anatoxins
    - Hepatotoxins →microcystins
    - Skin irritants
    - Other toxins

CYANOBACTERIA

Massachusetts Department of Environmental Protection

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    - Neurotoxins → anatoxins
    - Hepatotoxins →microcystins
    - Skin irritants
    - Other toxins

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MICROCYSTIN

- Occurrence of Blooms
  - Hot summer Months
  - Prevalent in prairies
- Cyanobacterial bloom formation
  - physical (temperature, turbidity)
  - chemical (availability of macronutrients, e.g. phosphorous)
  - biological factors (competition for nutrients)
  - Year around

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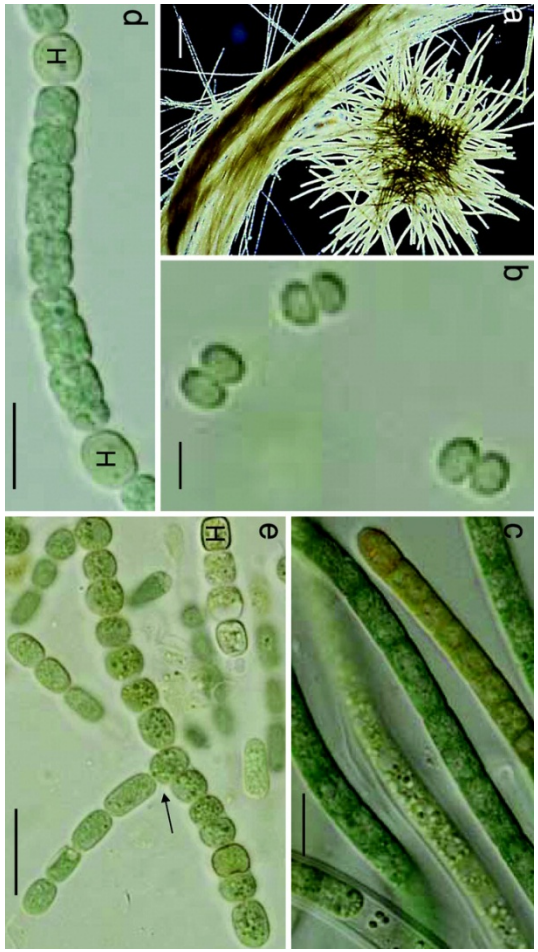
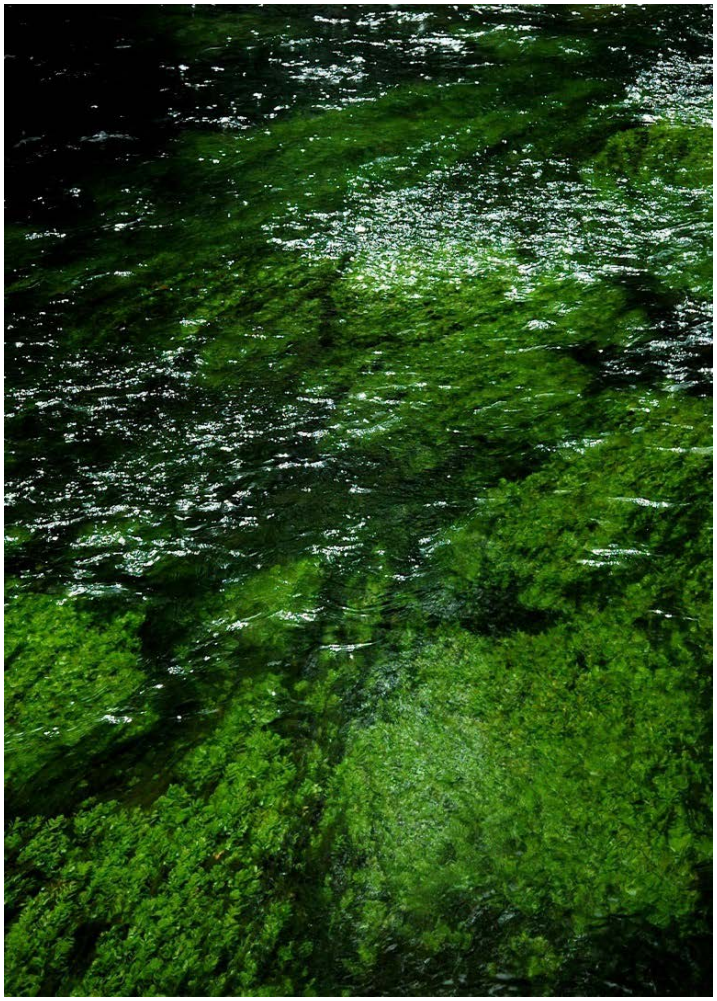
MICROCYSTIN - HEPATOTOXINS



Proceedings of the National Academy of Sciences of the United Staes of America (2013), 102(14): 5074 - 5078

- Common - Microcystin-LR
  - *Microcystis aeruginosa* and other blue-green algae.
  - Highly stable toxin → chemical structure
    - Water
    - Temperature fluctuations
    - Changes in water chemistry
  - Most toxic →LD_{50} of 50 µg/kg bodyweight.

MICROCYSTIN - HEPATOTOXINS



Massachusetts Department of Environmental Protection

- The Canadian Drinking Water Guideline
  - The maximum acceptable concentration (MAC) for the cyanobacterial toxin microcystin-LR in drinking water is 0.0015 mg/L (1.5 ug/L).
- World Health Organization
  - 1.0 ug/L

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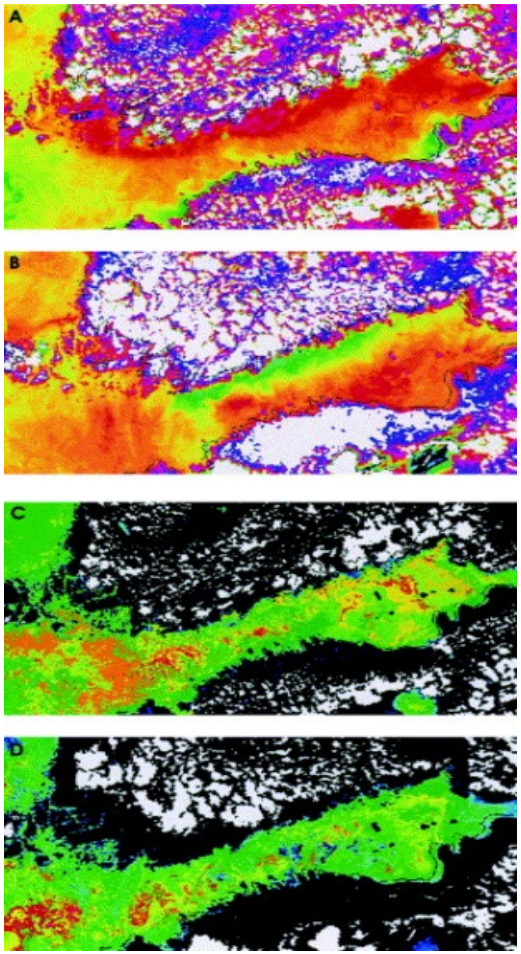
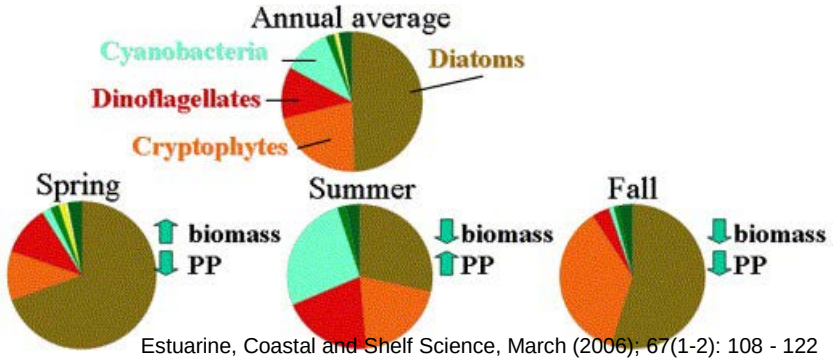
MICROCYSTIN - HEPATOTOXINS



Finnish Institute of Marine Research

- Occurrence - Cyanobacterial
  - Most common genera in Canada
    - *Anabaena*, *Aphanizomenon, Microcystis, Oscillatoria* and *Nodularia*
  - Toxicity
    - Temporal
    - Spatial
  - 50-75 % of bloom isolates → Toxins
  - No obvious way of determining bloom toxicity



Estuarine, Coastal and Shelf Science, March (2006); 67(1-2): 108 - 122

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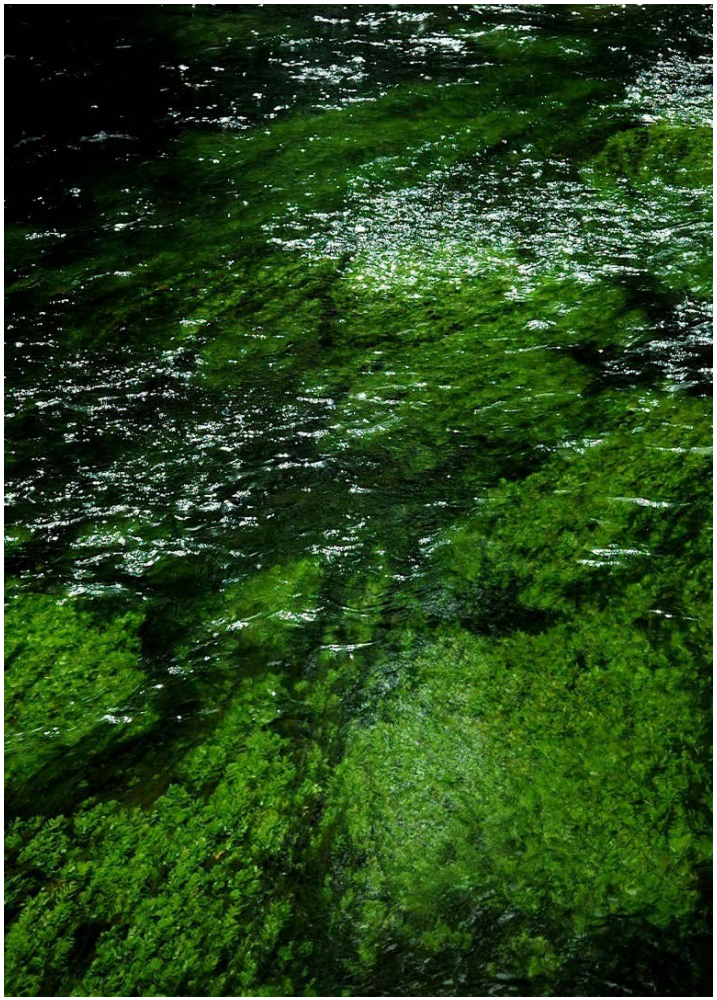
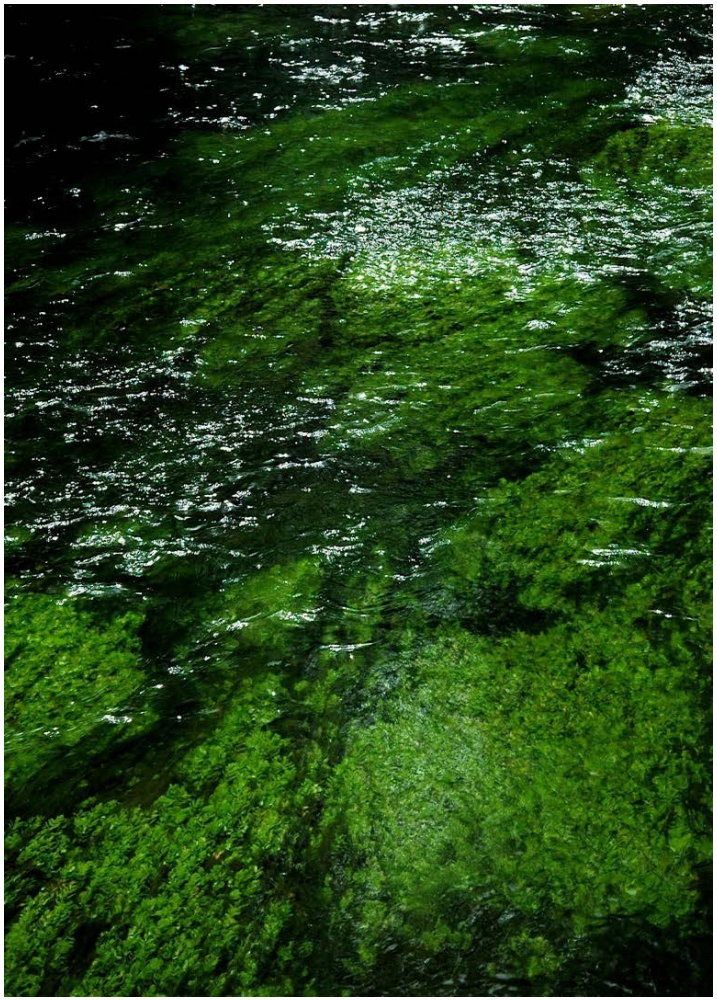
MICROCYSTIN



Massachusetts Department of Environmental Protection

- Prevention
  - **What to do**
    - Nutrient deprivation through good watershed management.
    - Addition of chemicals to reduce nutrient availability (e.g. ferric sulphate to precipitate phosphorous).
  - **What not to do**
    - Addition of an algicide (copper sulphate - blue stone)

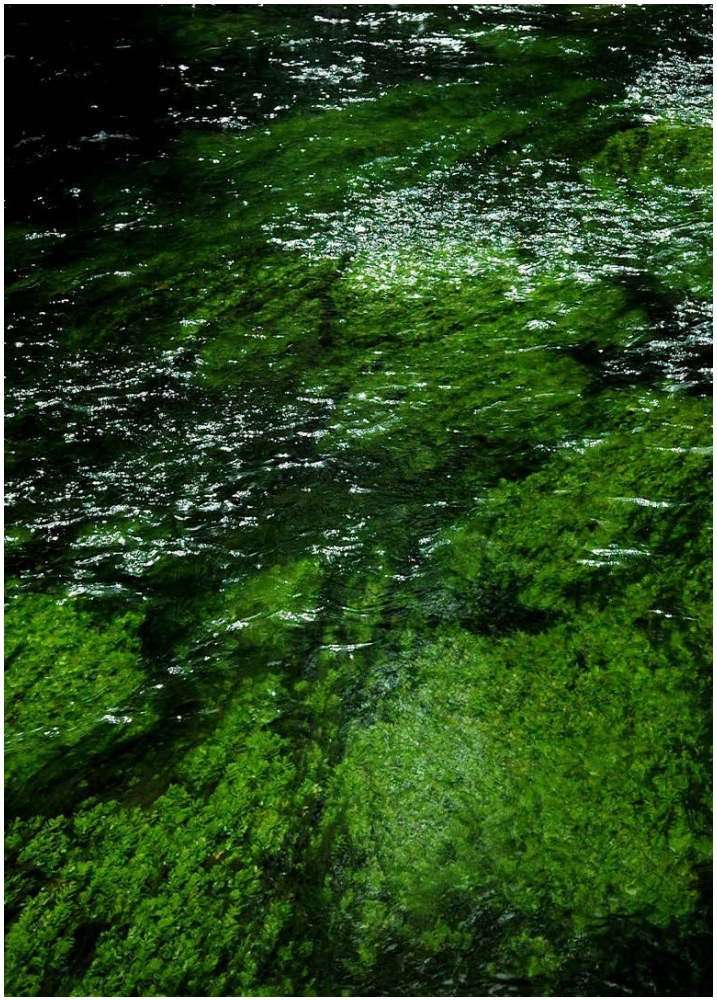
MICROCYSTIN



Massachusetts Department of Environmental Protection

- Prevention
  - Monitoring
    - Drinking water supplies suspected or known to be susceptible to blooms should be routinely monitored for presence of cyanobacteria (identification or enumeration) and their toxins

MICROCYSTIN



Massachusetts Department of Environmental Protection

- Prevention
  - Treatment Technology
    - Conventional water treatment processes
      - Successful → Removing cells
      - Partially successful → Removing/destroying toxins.
    - Combination treatment → Preferred
      - Conventional treatment + oxidant + biologically activated GAC

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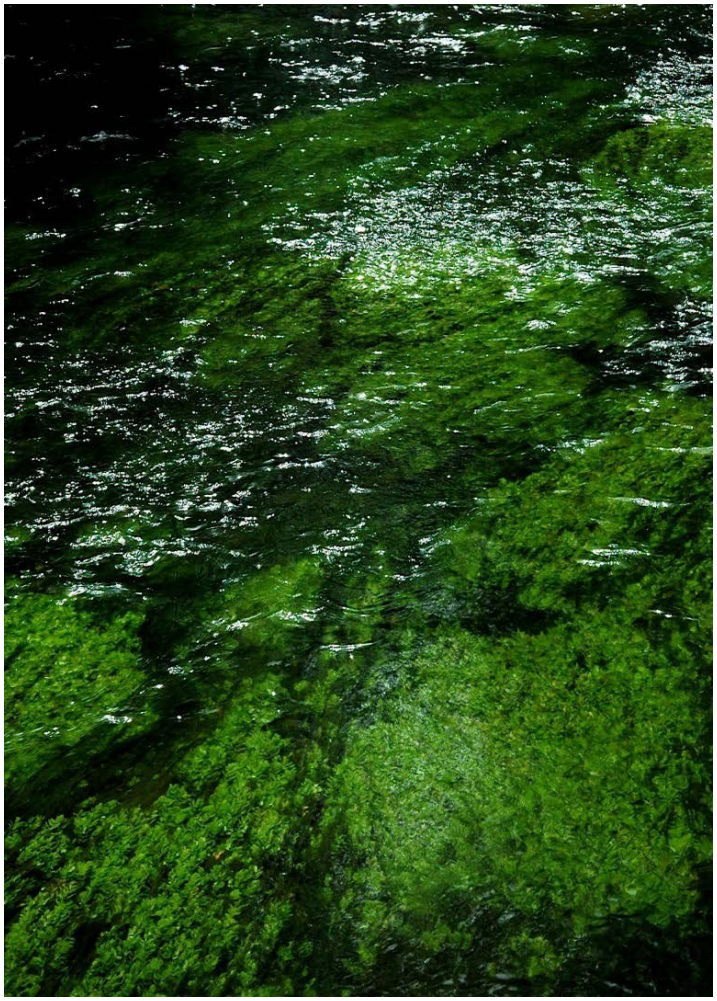
MICROCYSTIN - TESTING



Massachusetts Department of Environmental Protection

- Protein Phosphatase Inhibition (PPI)
  - Highly sensitive
  - Not Specific
  - Screening tools
- Liquid chromatography mass spectroscopy (LC-MS)
  - Sensitive
  - Specific → identification of variants
  - Screening/Confirmatory tool
  - Expensive

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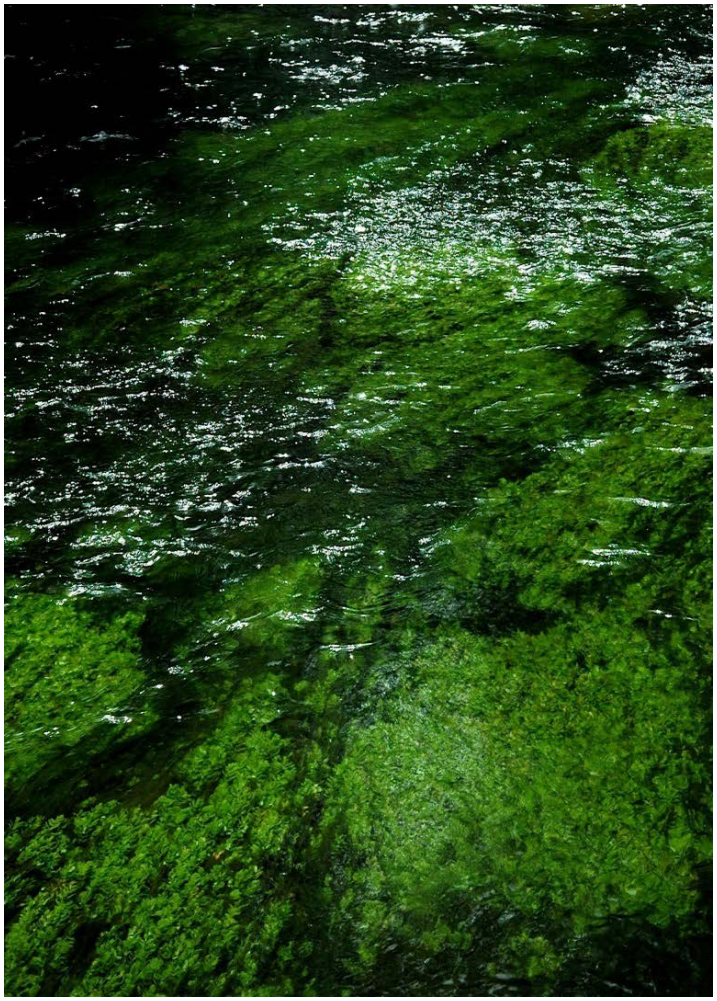
MICROCYSTIN - TESTING



Massachusetts Department of Environmental Protection

- ELISA based method
  - Highly sensitive
  - Not Specific
  - Rapid (3 hours)
  - Screening tool
- Positive Drinking water results
  - Confirmation with LC-MS

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Legionella

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LEGIONELLA

- Gram negative bacterium
  - Water sources
  - 25°C - 45°C
- Human pathogens
  - Respiratory illness --> immunocompromised
- American Legion outbreak – 1976
  - 221 Infected → 34 deaths

LEGIONELLA – Legionnaires' Disease

- Legionnaires' disease
  - Inhalation
    - Droplets
    - Mist
    - Steam
  - Symptoms
    - Fever
    - Chills
    - Headache
    - muscle pain
    - Respiratory
    - Vomiting
    - altered mental status
  - 10-15% mortality rate

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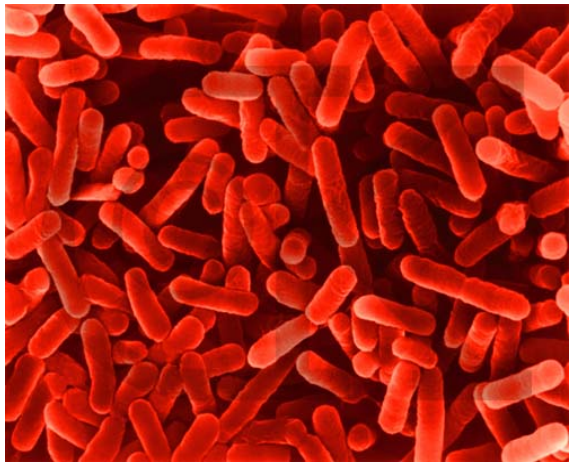
LEGIONELLA – Pontiac fever



- Pontiac fever causes a flu-like illness.
- Caused by inhalation of *Legionella pneumophila*
- The symptoms include fever, lack of appetite, headache, and aching muscles.
- Pontiac fever is not associated with pneumonia. In most cases no treatment is required, and you will recover within two to five days.
- 50-80% attack rate after exposure

Where is *Legionella* found?

- Ubiquitous
- Ground and surface water
- Plumbing systems
- Respiratory therapy
- whirlpool baths and hot tubs,
- humidifiers
- cooling towers of large air-conditioning systems → IDEAL

Legionella - Ecology

- Survival
  - tap water
  - chlorinated and untreated water
  - stagnant water areas (water heaters, tanks, reservoirs)
  - Sediment, sludge and organic materials can harbor and promote growth

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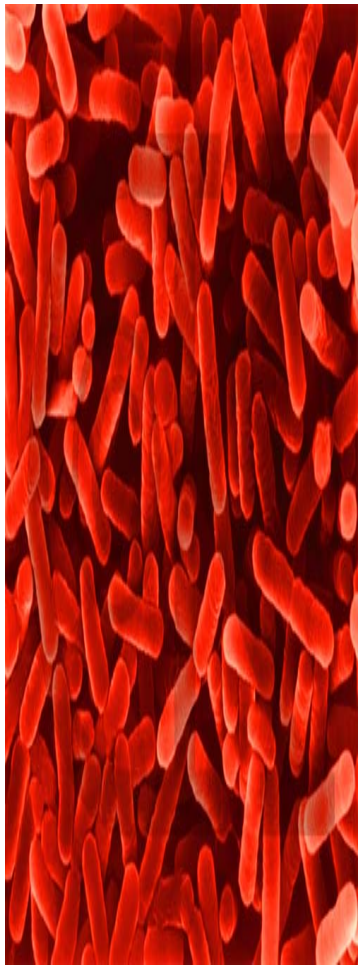
Legionella - Ecology



70-100ºC	Killed	
60-70ºC	Killed in time	Hot water, Warm water
20-55ºC	Multiplication	Warm water, Spa pool, Heated pool, Cooling tower, Cold water
0-20ºC	Dormant	Cold water, Evaporative air cooler, Spray humidifier, Cold water main, Air cooling coil condensate

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Legionella - Ecology

- Biofilms → difficult to remove
- Biofilms form as a thin layer of slime on surfaces in contact with water
- Able to grow in iron rich, oxygen low environments
- Incorporate other bacteria and protozoa that act as a shield to protect the *Legionella* from biocides

How do you test for *Legionella?*

- Swabs
  - Sludge, sediment, scale, shower heads, etc

- Water Samples
  - 1L sample needed in sterile/DNA free bottles

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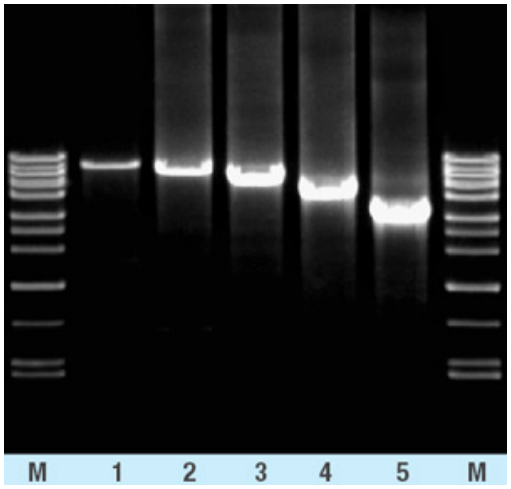
What test methods does HydroQual offer?



- DNA methods
  - Polymerase chain reaction (PCR)
    - Quick turn around time
- Culture methods
  - Viable *Legionella*
  - Identify serotype
    - 15 serotypes-type
      - 1,3 and 6 most severe

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Legionella

- Prevention
  - Source Water maintenance (e.g. Water Safety Plan)
  - System design (i.e. dead legs)
  - Maintaining disinfection levels (i.e. 0.5 mg/L throughout the system)

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Legionella

- Monitoring
  - Investigation of an outbreak
  - Validation of the effectiveness of control measures
  - Verification of the effectiveness of decontamination.
  - Recommended for cooling towers, hot tubs and water distribution systems (e.g. health care facilities)

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THANK YOU

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