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Drinking Water Annual,
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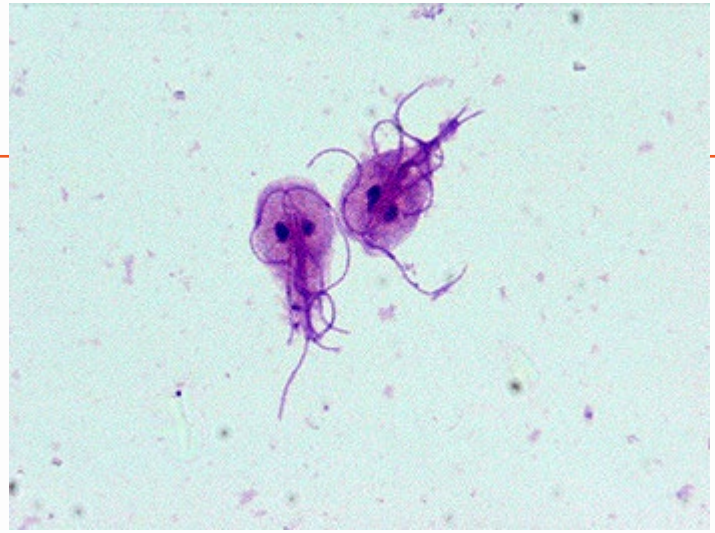
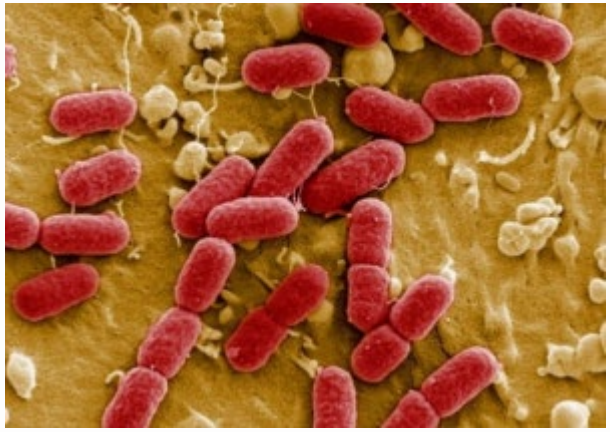
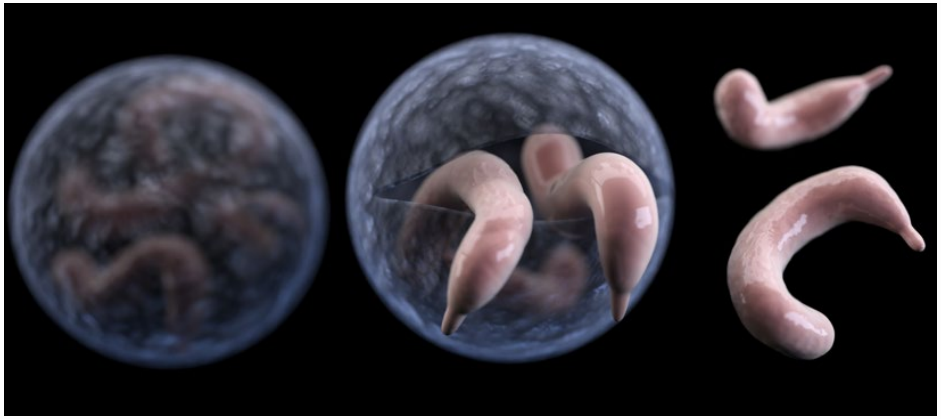
Waterborne Pathogens, Illnesses and Outbreaks

Agents

- Bacteria
- Viruses
- Parasites
- Noninfectious agents







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Clinical Presentation

- Gastrointestinal : abdominal cramps, vomiting, diarrhea
- Skin: hives, rashes
- Respiratory: sore throat, pneumonia
- Systemic illness
- Ear infections

Agents associated with Waterborne illness

- **Bacteria** include *Shigella*, shiga toxin-producing *E. coli* [e.g., *E. coli* O157:H7], *Campylobacter*, *Salmonella* Typhi as well as other *Salmonella* species, *Vibrio cholerae*, and other *Vibrio* species causing gastrointestinal symptoms as well as other uncommon agents such as *Francisella tularensis*, *Legionella*, *Leptospira*, and species of *Mycobacterium* and *Pseudomonas*.

- **Viruses** include hepatitis A virus and norovirus; historically poliovirus. Cases usually present with gastrointestinal symptoms.

- **Parasites** include *Cryptosporidium* and *Giardia* causing gastrointestinal symptoms, invasive amoeba (e.g., *Naeglaria* causing meningitis), Schistosoma (causing schistosomiasis), and trematodes causing cercarial dermatitis (swimmer's itch).

Reservoirs

- Humans: *Shigella* species, hepatitis A virus, typhoid, *Vibrio cholerae* (cholera), norovirus-like agents, and other viruses such as rotavirus and poliovirus.
  - Humans can also carry *E. coli*, *Cryptosporidium* and *Giardia*.

- Animals and birds: *Campylobacter jejuni*, *Cryptosporidium*, shiga toxin-producing *E. coli*, *Francisella tularensis*, *Giardia*, leptospires, schistosomes, and *Salmonella*

- Environmental: Algal toxins, *Legionella* species, non-cholera *Vibrio*, non-tuberculosis *Mycobacterium* species, schistosomes, amoeba

Oregon Reported Drinking Water Outbreaks by Agent

- *Campylobacter* (2: 1984, 2005) – surface water, well – Community and non Community
- *Cryptosporidium* (3:1992,1992,2013) – surface water - Community
- *E. coli* (2: 1975, 2005) – spring, river, Non community
- *Giardia (6: 1979, 1979, 1980,1982, 1984, 1997) – one well, others surface water*
  - –4 Community
  - –2 Non community
- Norovirus (1: 2006) – Non community, well, 2019 – vendor supplied water
- Oil (1:1974)
- *Shigella, 1978* – Community, well
- *Yersinia*, 1981– individual, Spring
- *Legionella*, 2011 – 2014 – shower, 2021 – 2 outbreaks

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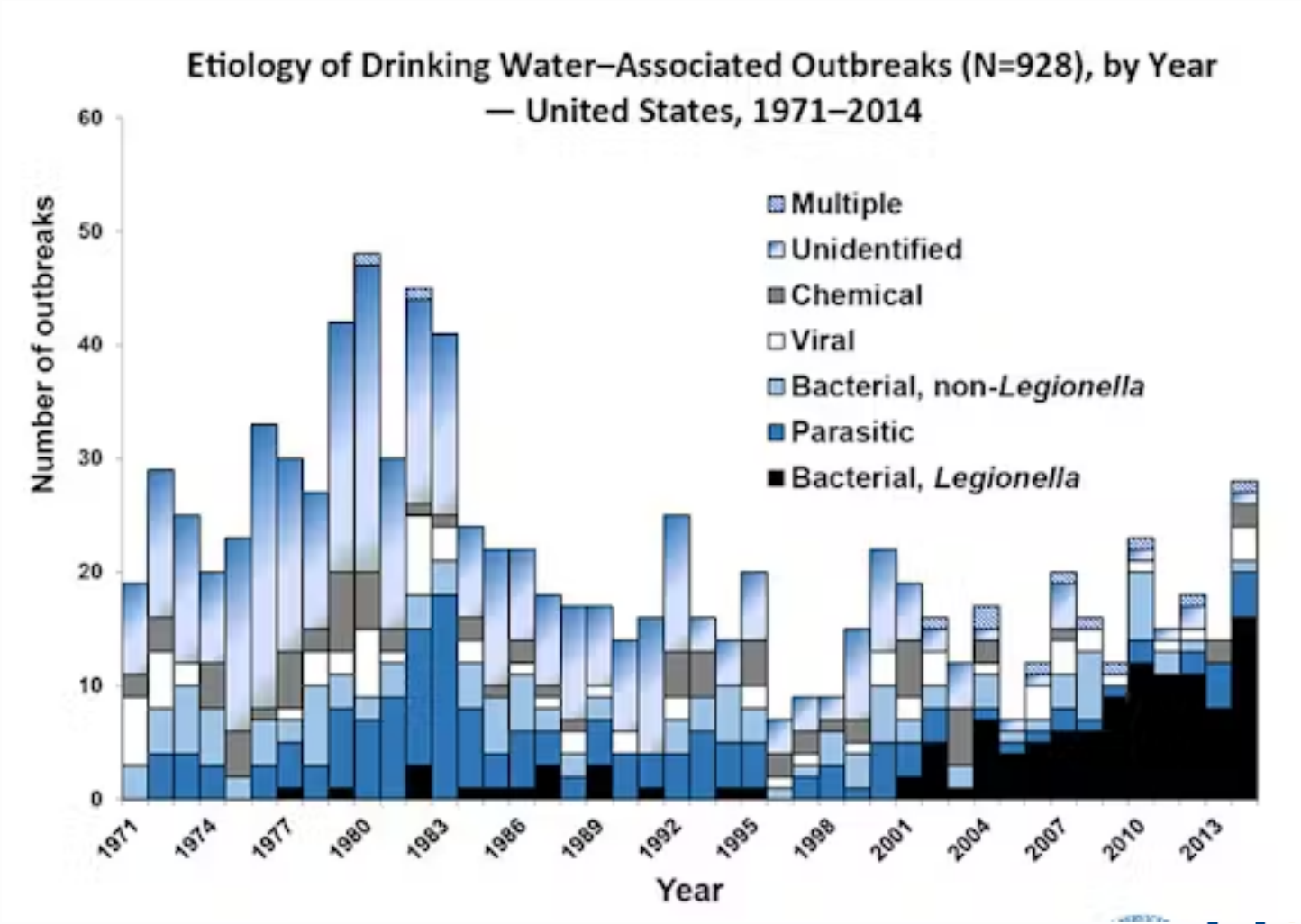
Waterborne disease outbreaks



Surveillance of Waterborne Disease Outbreaks Associated with Drinking Water — United States, 2015–2020

TABLE 7. Rank order (most common to least common) of etiology, water system, water source, and contributing factor types for drinking water–associated outbreaks and associated cases of illness — United States, 2015–2020

	Outbreaks*		Cases*	
Characteristic or rank	Category	No. (%)	Category	No. (%)
Etiology				
1	Bacterium (biofilm associated[†]), *Legionella*	184 (86.0)	Multiple (enteric)[§]	995 (46.5)
2	Virus	7 (3.3)	Bacterium (biofilm associated), *Legionella*	786 (36.7)
3	Bacterium (enteric)	7 (3.3)	Virus (enteric)	156 (7.3)
4	Multiple (enteric)	5 (2.3)	Bacterium (enteric)	93 (4.3)
5	Parasite (enteric)	5 (2.3)	Parasite (enteric)	55 (2.6)
6	Bacterium (biofilm associated), non-*Legionella*	3 (1.4)	Unknown	27 (1.3)
7	Unknown	2 (0.9)	Bacterium (biofilm associated), non-*Legionella*	23 (1.1)
8	Chemical or toxin	1 (0.5)	Chemical or toxin	5 (0.2)
Water system				
1	Community	169 (79.0)	Community	1,106 (51.7)
2	Unknown	22 (10.3)	Individual or private	944 (44.1)
3	Individual or private	17 (7.9)	Unknown	75 (3.5)
4	Noncommunity	3 (1.4)	Noncommunity	8 (0.4)
5	Other	2 (0.9)	Other	4 (0.2)
6	Not reported	1 (0.5)	Not reported	3 (0.1)

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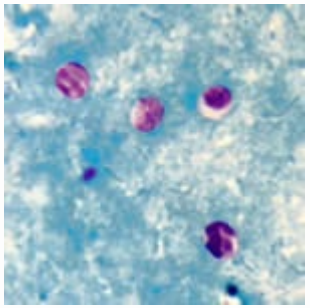
Water source				
1	Groundwater	82 (38.3)	Groundwater	1,348 (63.0)
2	Unknown	61 (28.5)	Surface water	384 (17.9)
3	Surface water	57 (26.6)	Unknown	309 (14.4)
4	Mixed	11 (5.1)	Mixed	89 (4.2)
5	Not reported	3 (1.4)	Not reported	10 (0.5)
Contributing factor type				
1	Premise point of use	85 (39.7)	Multiple	1,374 (64.2)
2	Not reported	70 (32.7)	Premise point of use	389 (18.2)
3	Multiple	46 (21.5)	Not reported	238 (11.1)
4	Source	7 (3.3)	Source	124 (5.8)
5	Distribution	6 (2.8)	Distribution	15 (0.7)

* N = 214 outbreaks; N = 2,140 cases.

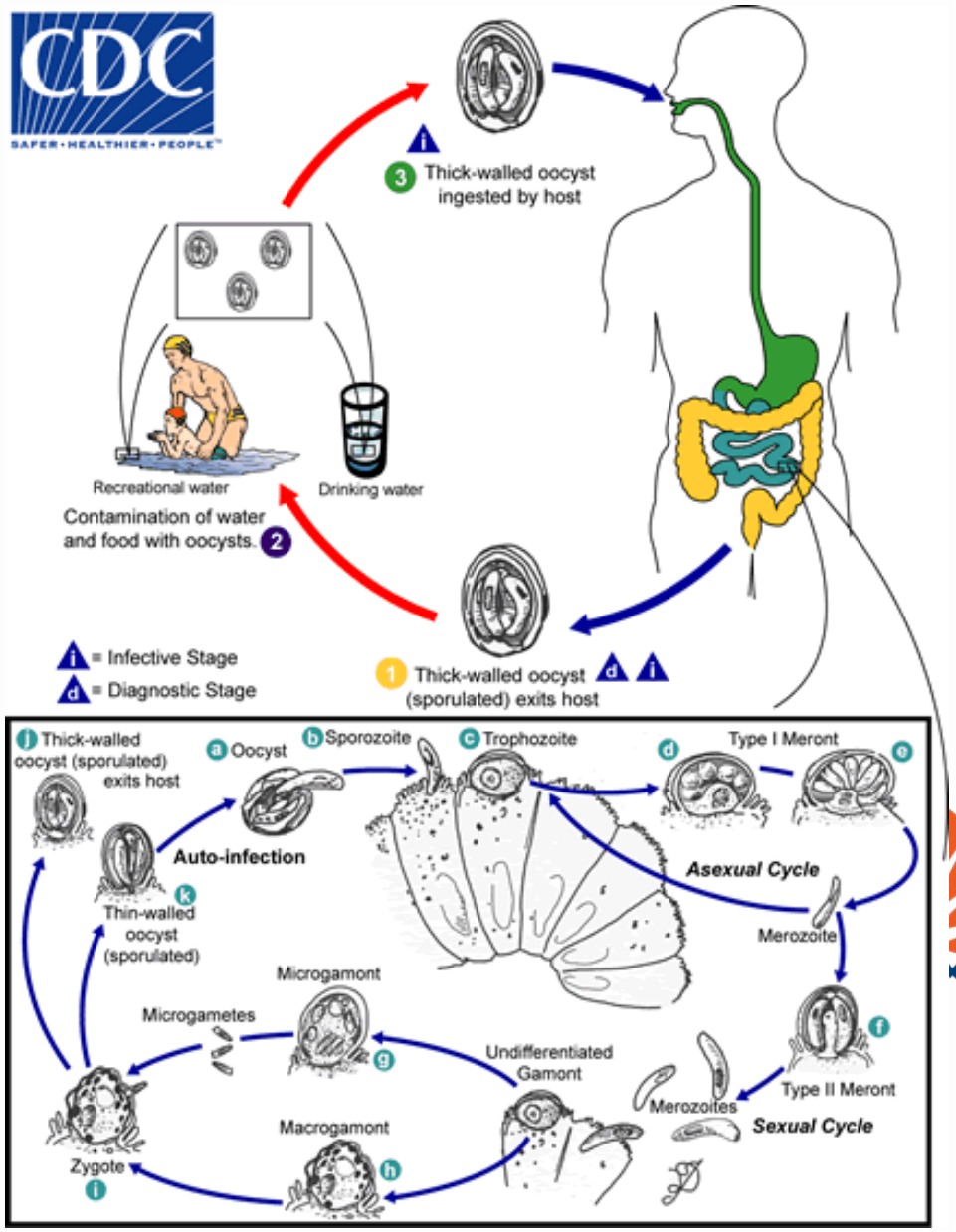
† Biofilm-associated drinking water outbreaks in this analysis include outbreaks caused by *Legionella* (n = 184), nontuberculous *Mycobacteria* (n = 2), and *Pseudomonas* (n = 1).

§ Multiple-etiology outbreaks include two enteric bacterial and parasitic; two enteric bacterial and viral; and one enteric bacterial, parasitic, or viral etiologic category.

Cryptosporidium



- Parasitic infection of both humans and animals
  - Some species thought not to cause human illness
  - Forms oocysts – tolerant to chlorine disinfection and increases survival time.
- Leading cause of waterborne illness (drinking and recreational)
  - Symptoms include watery diarrhea, abdominal pain/cramps, nausea, vomiting, fever, weight loss lasting 1-2 weeks in healthy persons
  - Intermittent illness – recommend three separate stool specimens on different days
  - Illness begins 2-10 days after exposure (average 7)
  - Some people are asymptomatic
  - Routine stool culture does NOT include Crypto testing
- Reportable nationally – routine interview and education
  - No bathing in communal facilities– 2 weeks



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Baker City Crypto Outbreak - 2013

- Five crypto cases reported 7/29-31
  - Final counts - 119 cryptosporidiosis cases
    - 23 confirmed
    - 96 presumptive
- Miner's Jubilee or Biker's rally?
  - Absence of plausible alternatives pointed to municipal water as source
- Boil water notice – 7/31
- Environmental samples – filtered reservoir water, goat, elk and cattle scat
- Survey results – 28% reported diarrheal illness - >2,700 cases
  - Four week lag from onset to diagnosis
- Test all water intakes twice weekly until two negatives
  - Boil water lifted August 20th

Location of water samples	# locations with oocysts detected / total locations tested
Raw watershed intakes	5/13 (38%)
City water faucets	6/9 (67%)

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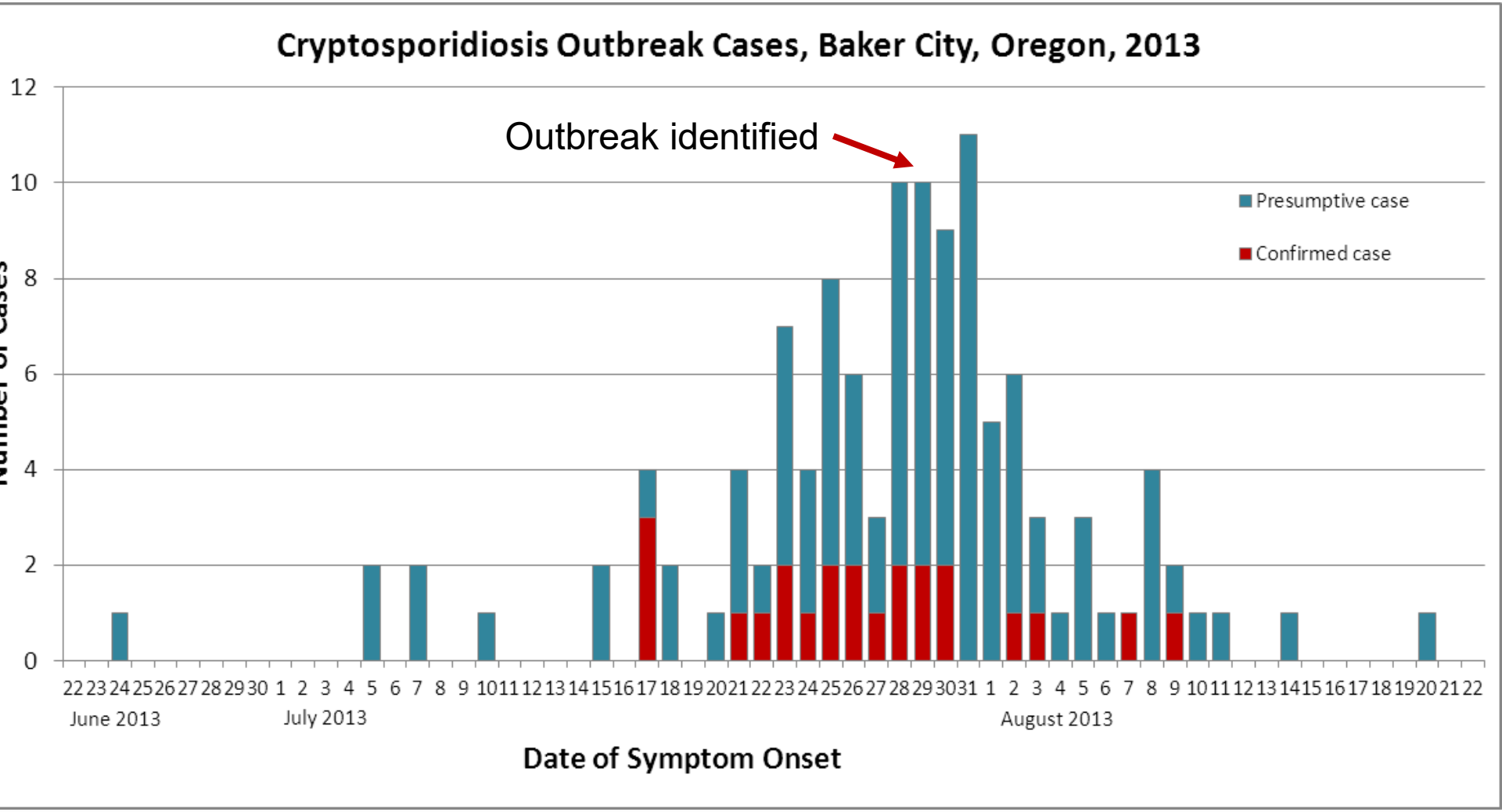
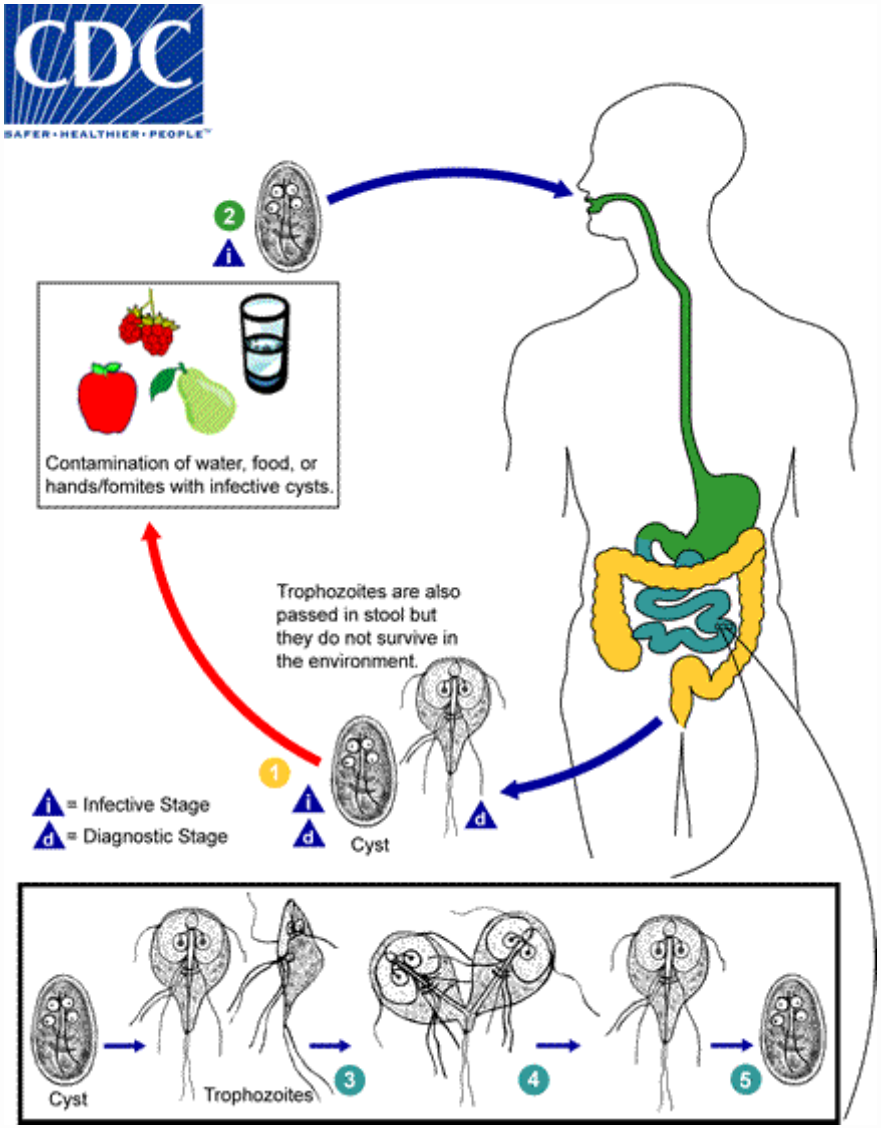

Cryptosporidiosis Outbreak Cases, Baker City, Oregon, 2013
Outbreak identified
Presumptive case
Confirmed case
Number of Cases
0
2
4
6
8
10
12
22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
June 2013
July 2013
August 2013
Date of Symptom Onset

Giardia

- Parasitic infection of both humans and animals, fecal oral transmission
  - Forms oocysts – can remain viable in environment for long period
- Most frequently diagnosed intestinal parasite in U.S.
  - Symptoms vary and come and go, asymptomatic infection common
  - include abrupt onset watery foul-smelling diarrhea, gas, greasy stools that float, nausea, vomiting, dehydration, weight loss lasting 1-2 weeks in healthy persons
  - Illness begins 3-15 days after exposure (median 7-10)
  - Some people are asymptomatic
- Human and animal reservoirs – humans most important source of human infections
- Reportable nationally – only require interview of children ≤3 in daycare
- Treatment – generally self limiting. Can use Metronidazole (Flagyl®), treatment failure in about 10% cases

Giardia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Contamination of water, food, or hands/fomites with infective cysts.
Trophozoites are also passed in stool but they do not survive in the environment.
i = Infective Stage
d = Diagnostic Stage
Cyst
Cyst
Trophozoites

Shigella

- Bacterial infection transmitted fecal-orally
- Symptoms appear 1-2 days post exposure – diarrhea (sometimes bloody), fever, abdominal pain asymptomatic infections possible
  - Usually last 5-7 days
  - Usually resolves without treatment, antibiotics are used with severe infections, reduces duration, however, often resistant
- Four species - *sonnei*, f*lexneri*, *boydii*, *dysenteriae*
  - *Sonnei* most common in Oregon
  - *Dysenteriae* associated with HUS
- Low infectious dose, humans are the only reservoir
  - Avoid recreational water for 1-2 weeks after symptoms resolve

Campylobacter

- Bacterial infection transmitted fecal-orally – one of the most common causes diarrheal illness
- Symptoms appear 2-5 days post exposure – diarrhea (sometimes bloody), fever, abdominal pain, headache, vomiting, asymptomatic infections possible
  - Usually last week
  - Usually resolves without treatment, antibiotics are used with severe infections, reduces duration, however, often resistant, susceptibility testing recommended
- Cases in Oregon are not routinely interviewed for exposures
- Many species –most common in humans – *jejuni*
  - *Jejuni* most common in Oregon
  - Organism is very fragile – lab handling especially important
- Many reservoirs – considered a zoonosis: poultry, cattle, birds, pigs, sheep, pets

Shiga toxin producing *Escherichia coli*

- Pathogenic *E. coli* – produces a shigatoxin
  - Toxin causes blood vessel damage – hemorrhagic colitis (bloody diarrhea)
  - O157 – leading cause hemolytic uremic Syndrome (HUS)
- Symptoms appear 3-4 days post exposure – diarrhea (often bloody), vomiting, abdominal cramps, low or no fever, asymptomatic infections can occur
  - Usually last 5-7 days
  - Usually resolves without treatment, antibiotics are not recommended.
- Human reservoir, but also other ruminant animals – cattle, deer
  - Keenism – "Where's the beef?"
- Low infectious dose
- Shedding decreases once symptoms resolve, however, person may continue shedding for weeks (especially children)
  - Two negative stools for high risk occupations

Outdoor School Outbreak

- May 24, 2005
  - EH manager of LHD notified by acquaintance of illness among 7th graders
- May 25th 2005
  - GI illness among 7th graders who attended outdoor school May 17-21 reported to appropriate LHD
  - A regional Oregon lab reports detecting shiga-toxin producing *E.coli* in a student who attended the camp
  - Camp activity director confirms that many campers have been ill

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The setting and the event

- 210 acre residential Christian camp in northern Oregon
- Sleeping capacity 300
- >10,000 visitors/yr
- Activities
  - –Summer camps
  - –Outdoor schools
  - –Special events
- May 17-21, Outdoor School
  - –5 Christian Academies in Oregon
    - 80 students
    - 17 outside staff
    - 20 parents
  - –Outdoor school
  - –Challenge Course
  - –Meals

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The Investigation

- May 26, 2005
  - –Site visit by epi, environmental health, food safety
  - –Water and sanitary survey
  - –Lab queries
  - –Questionnaire developed
- May 27, 2005
  - –Cohort study of campers, parents, staff
    - Telephone Questionnaire
      - –Meals
      - –Activities
      - –Symptom profiles
      - –Specimen requests
  - –Camp closed for weekend “voluntarily”

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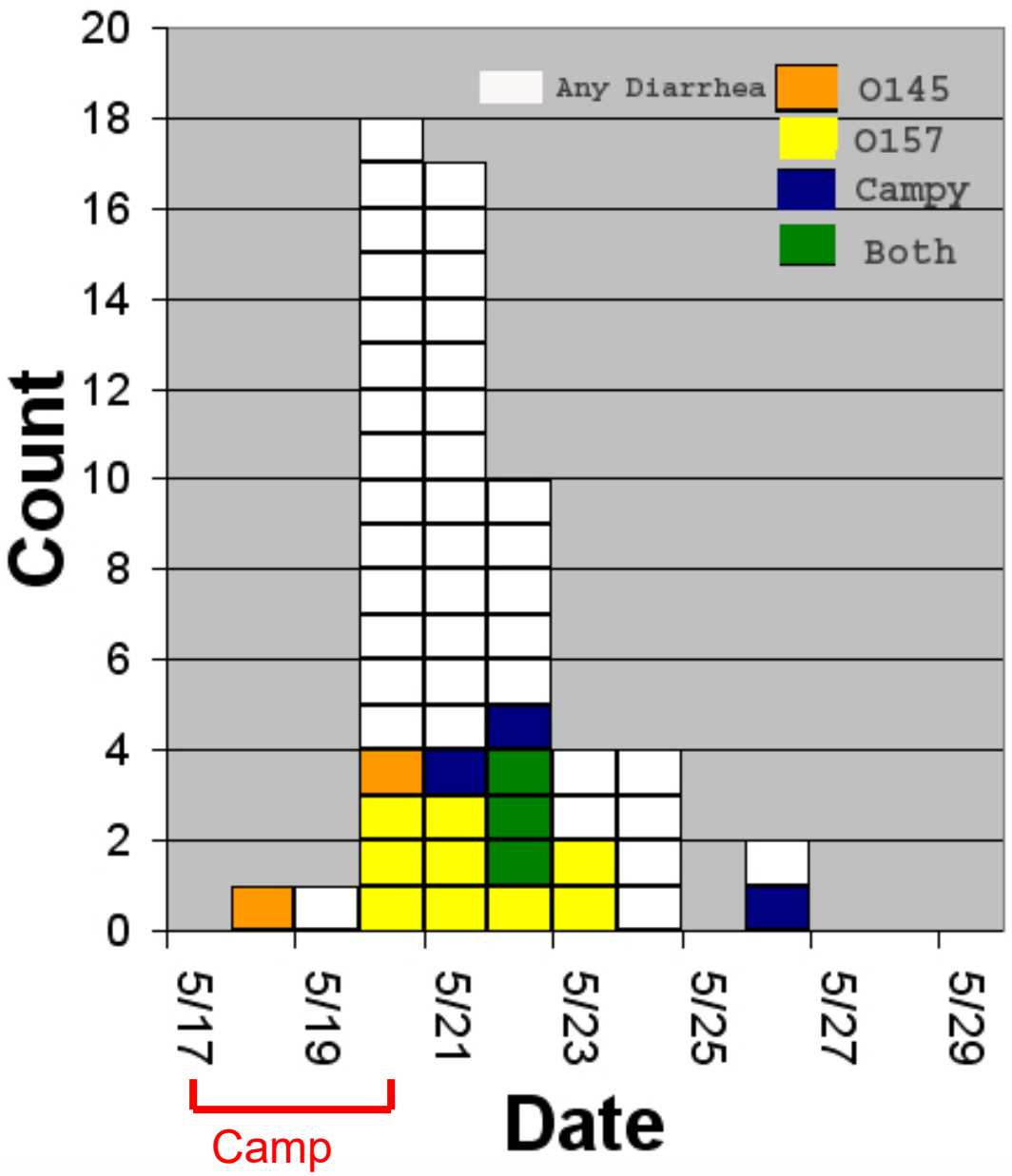
Onset of Illness, Camp Z



Enteric Pathogens

E.coli O157 =9

E.coli 0145=2

Campy sp=3

O157&*Campy*=3

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Environmental Microbiology

May 26, 2005, a sunny day, counts per 100 ml

Specimen	Coliforms	*E. coli*
Raw water	649	19
Treated water	absent	absent

Sanitary Survey

No water supply and sanitary drains cross connection

No leakage from drain fields

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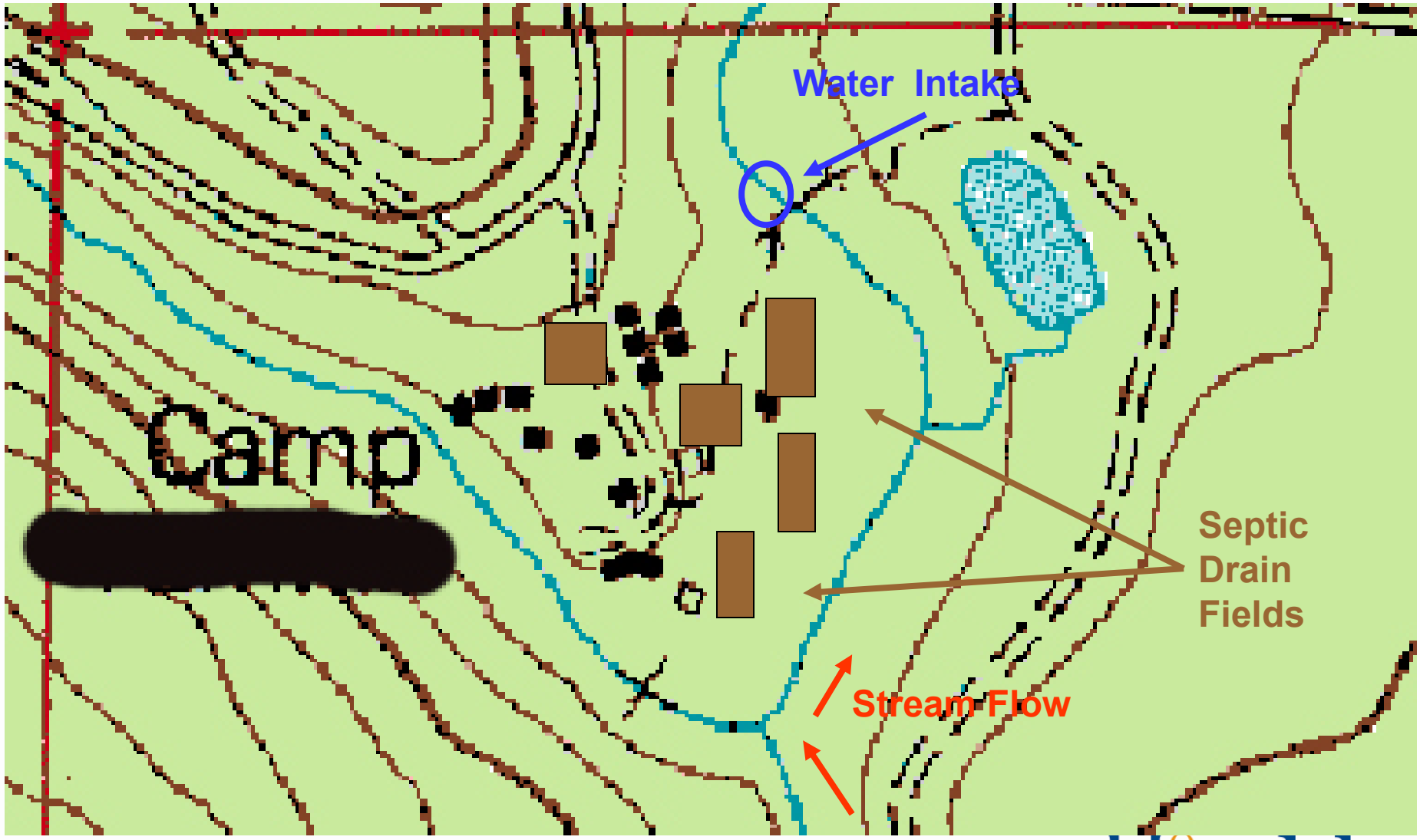
Food Safety Inspection

- Food supply
  - Prepackaged, minimal preparation
- No illness among full-time kitchen staff of 4
- Food served “family style” with assistance by students and parents
  - “Mandatory” glass of water for everyone before food could be eaten

Water Intake for Camp Treatment Plant



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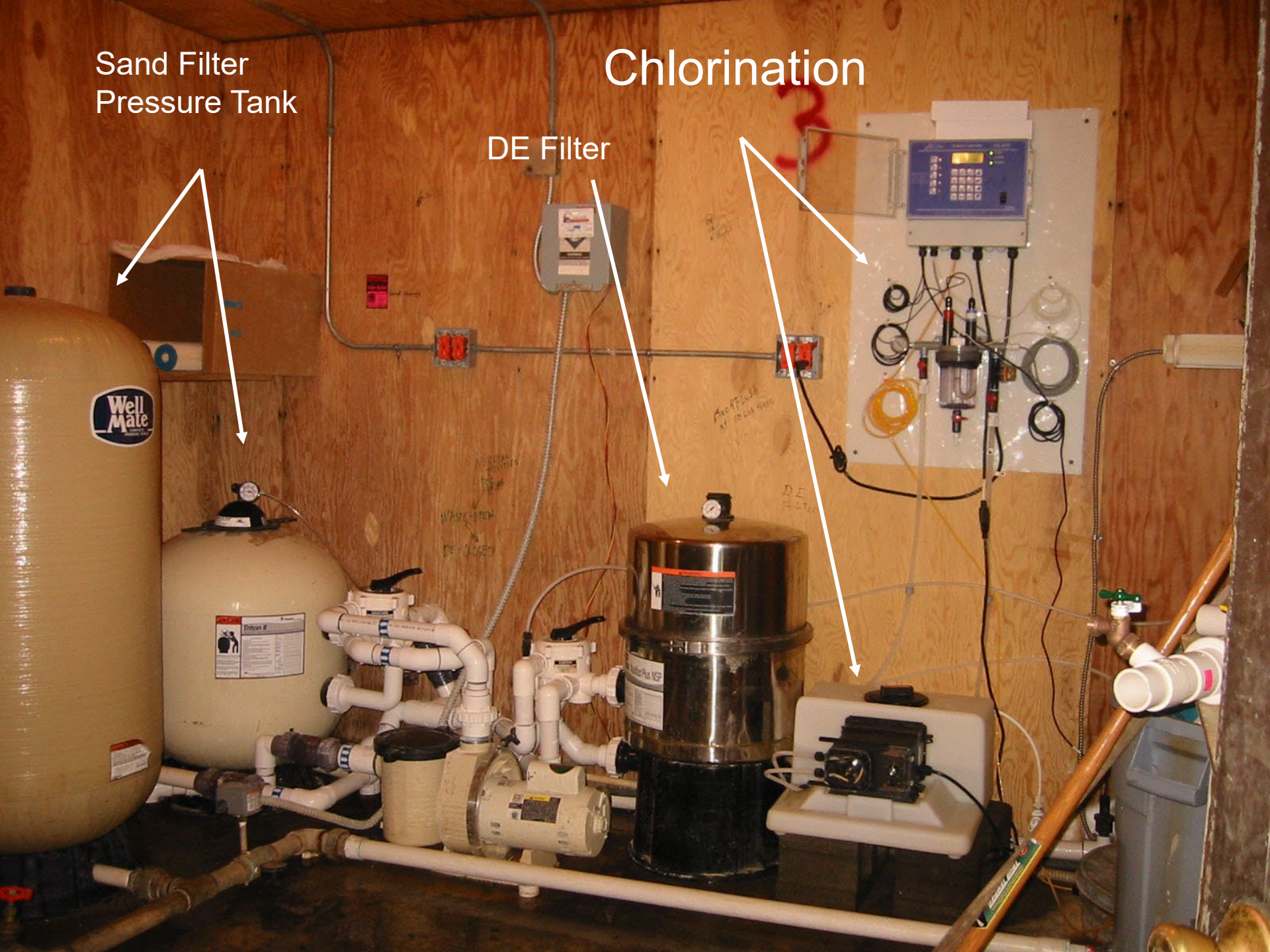
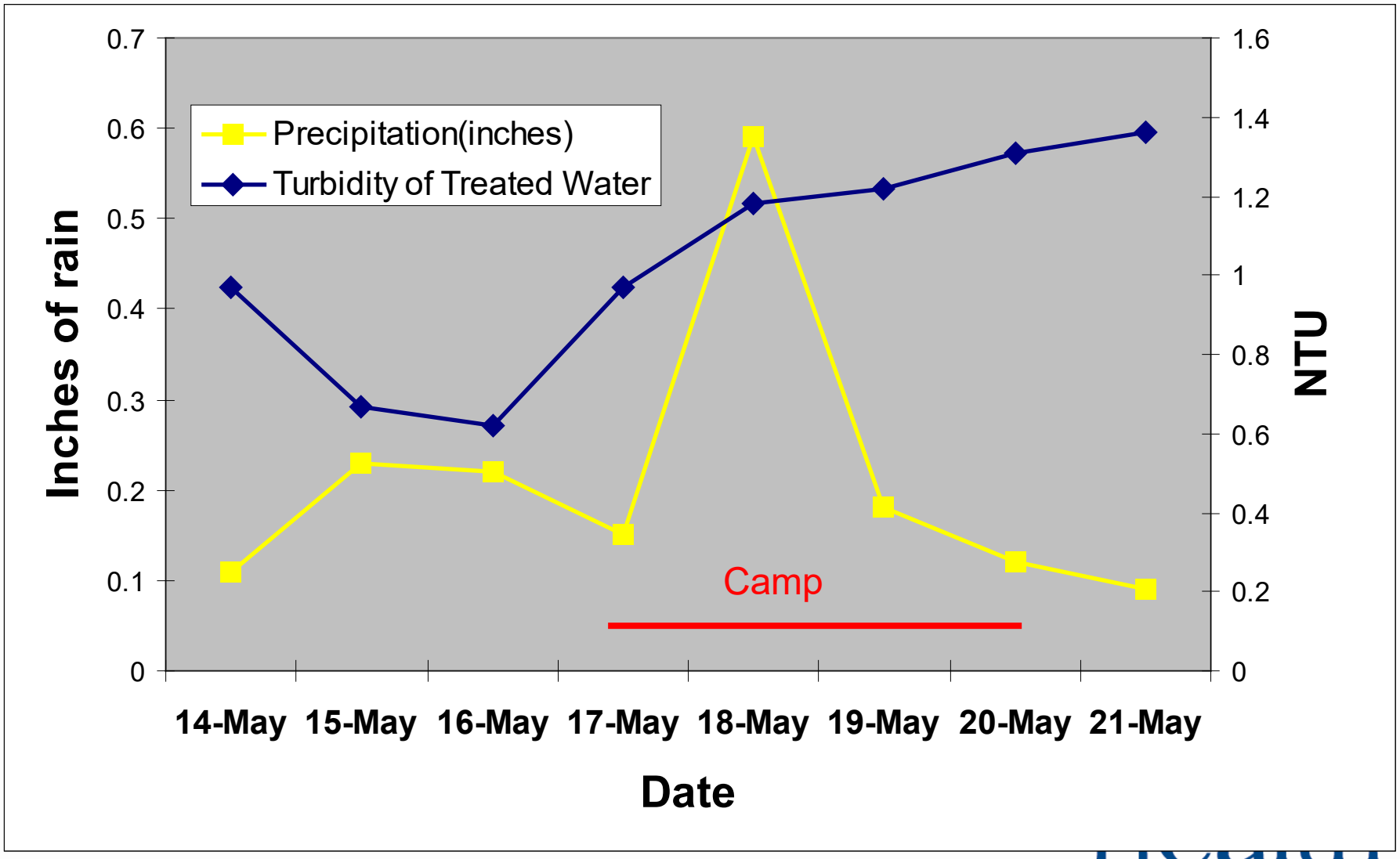

Sand Filter
Pressure Tank
Chlorination
DE Filter
Well Mate

Rainfall and Turbidity of treated water



Water disinfection variables

Factor	Best disinfection if:	On May 18
Temperature	higher	9.9 C°
pH	lower	6.42
Turbidity	lower	>1 NTU
Chlorine residual	higher	.32 ppm
Contact time	longer	~~175 min~~ 27 min

A direct link to stream water ?

- June 2005
  - ➢6 gallons raw water collected during rainstorm
  - ➢Many *E. coli* but no O157, O145, or C*ampylobacter* isolated

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Is the drinking water a plausible source?

- Surface water is a challenging source
  - ➢worse after rainfall
- Water treatment plant equipment was substandard, operator untrained
- Diatomaceous earth filtration ineffective
- Incorrect chlorine contact time estimate
- Multiple pathogens, high attack rate
- No other plausible risk factors identified

Surveillance of outbreaks of waterborne infectious disease: categorizing levels of evidence

Tillett, Louvois, Wall Epidemiol Infect 1998; 120:37-42

- A= pathogen found in water
- B=water quality failure, pathogen not found in water
- C=Analytic association of water an illness
- D=Descriptive epi suggests water is source and excludes other explanations

Level of Evidence

Strong: A+C or A+D or B+C

Probable: B+D or A only

Possible: B only or D only

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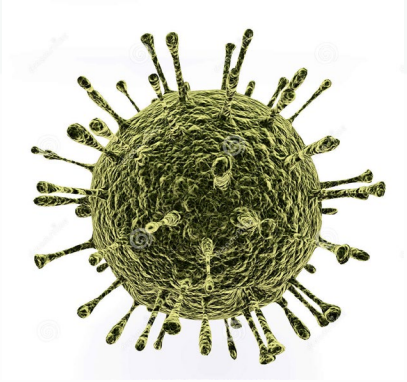
New Slow Sand Filters

Interventions

- Camp Closed briefly during investigation
- Re-opened next week using water trucked from nearby municipal source
- Slow sand filters installed
- Residual chlorine levels increased
- Contact time study done

Norovirus



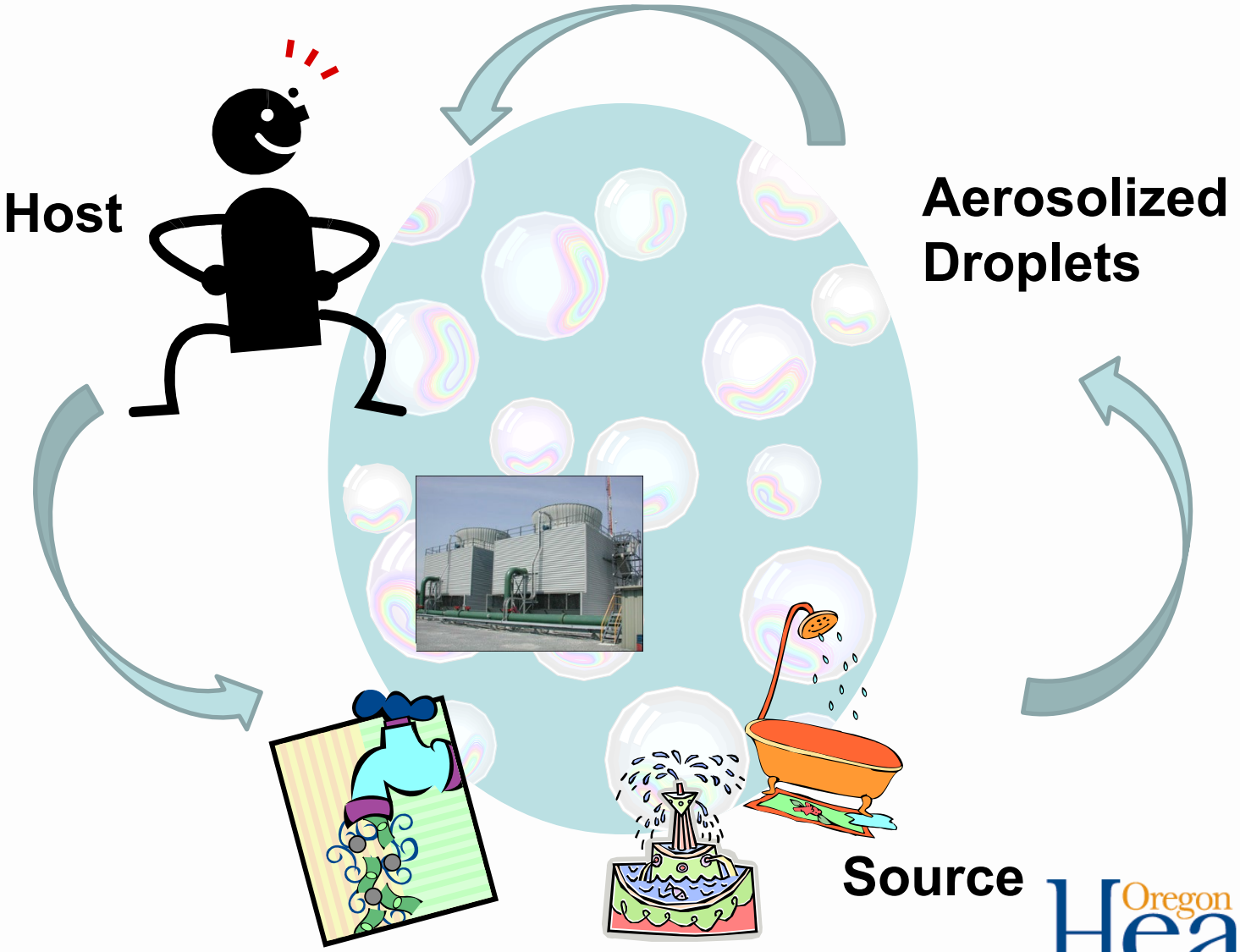
- RNA virus
  - Most common cause of epidemic gastroenteritis – extremely contagious
- Not reportable unless outbreak related.
- Symptoms- acute onset, vomiting, non bloody diarrhea and abdominal cramps, 12-48 hours post exposure. Typically resolve in 1-3 days. Asymptomatic infection is possible
- Shed in stool (or vomitus) for up to 4 weeks – unknown how

- Assume human fecal contamination

Legionella

- Gram negative bacilli
- More than 50 species, 70 serotypes
- L pneumophilia serotype 1 accounts for >90 % of known infections
- Ubiquitous, thrives in warm water
- Relatively resistant to chlorine and heat

Transmission



Slide courtesy WV Bureau of Public Health

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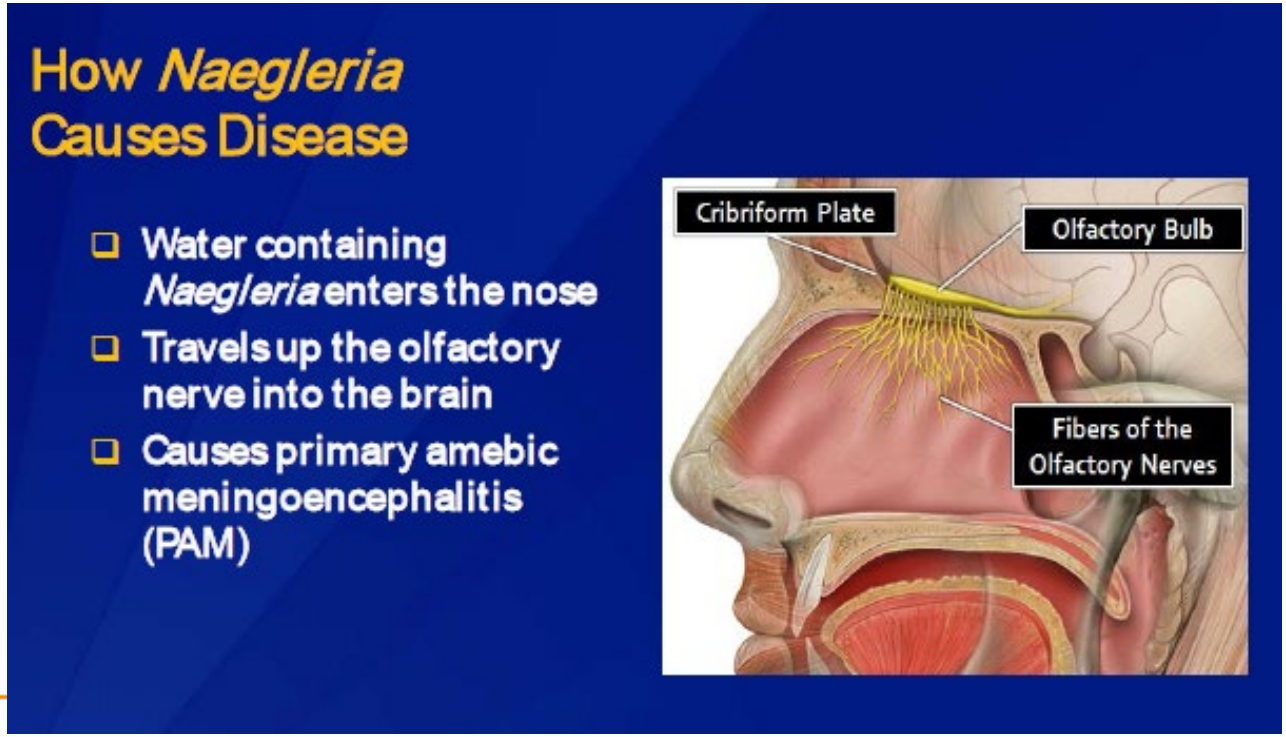
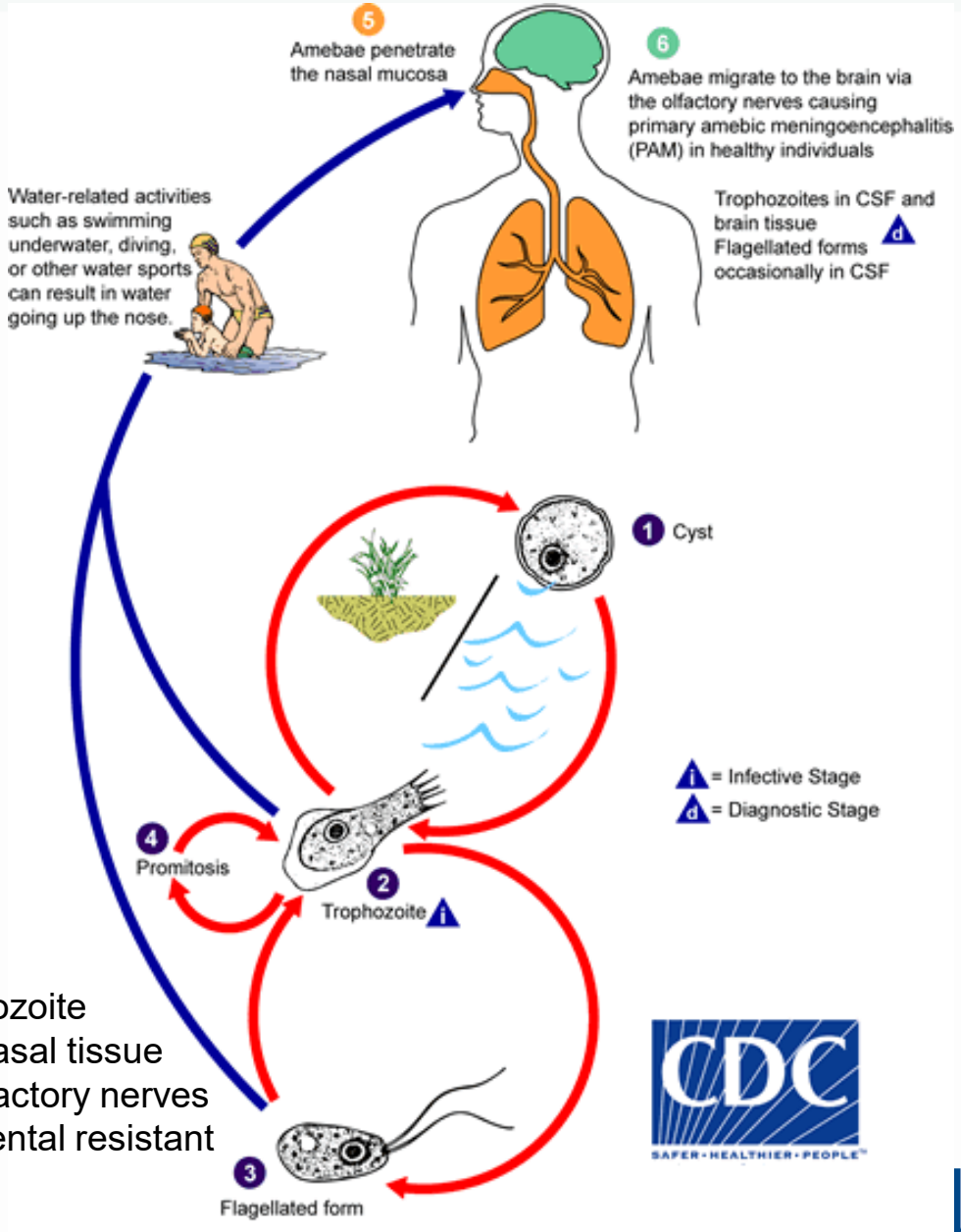
Primary Amebic Mengingoencephalitis (PAM)

- Rare, deadly brain infection – only three known survivors
- 138 cases in US since 1962, Southern US
- Diagnosis at CDC
- Acute exposure – exposure to death ~ 10 days
- *Naegleria fowleri*
- Thermophilic
- Also infects animals
- 2012 – 2 MN cases
- Became reportable in OR in 2015





Only infective stage is trophozoite
Infection by penetration of nasal tissue
and then brain through olfactory nerves
Can form a cyst – environmental resistant
Freezing and drying will

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Epidemiology

- Most common age group – children
- Males > females
- Study of 467 households in Ohio – 79% found free living *Amoeba* in premise plumbing, municipal water negative
- More recent studies –
  - Louisiana, 2013
    - No contact with lake, river, pond
    - Used slip and slide all day
    - *Naegleria* in residential plumbing, hot water heater, hoses to slip and slide
    - Municipal water positive

Suspected Waterborne Illness Investigation Steps

- Who is reporting illness: Age, Sex, address, occupation
- What is the symptom profile? Vomiting, diarrhea, fever, rash, abdominal cramps. How long is the illness lasting?
- Are there ≥ 2 individuals with the same symptoms and onset dates close in time? How many individuals appear to be infected?
- Collect specimens to Identify the infectious agent,
  - Consider the likely infectious agent based on symptoms and incubation period
  - Consider likely modes of transmission for that agent to focus the environmental investigation
  - Many pathogens should be removed by adequately functioning treatment and disinfection systems
- What are the common activities and water consumption history in the 7 days prior to illness?
- Does the individual have a history of travel in the last 30 days?

Oregon waterborne outbreak investigative guidelines

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Environmental and Epidemiological Investigation

- Is the suspected facility is licensed/regulated and by whom
- Were any staff ill during the incubation period of the suspect WBD agent? When, what do they do?
- Research any unusual circumstances just before the outbreak began:
  - Power outages or spa or pool chlorination
  - Air conditioning or other equip
  - Problems with water system treatment failures
  - Equipment updates or changes.
  - Heavy flooding or extreme weather events
- If legionellosis is suspected, work with EH to determine if all parts of the building are served by the same HVAC system. If not, obtain a diagram of which parts of the facility are served by each of the systems in place. Inspect shower heads, pipes and plumbing for obvious signs of biofilm.

Challenges & Limitations

- Pathogen loads will not be consistent. Clumping of pathogens will make infectious dose non uniform
- *Cryptosporidium* is chlorine tolerant
- Could be more than one pathogen if there is fecal contamination
- Monitoring methods and indicators are not sensitive nor specific
- Monitoring is not real time
- Viability and infectivity to humans is not directly interpreted from monitoring tests
- Communicable disease reporting – is insensitive to low level endemic disease
- Immunity of the local population – risk for visitors

Types of laboratory evidence

- Detection of a common agent in human cases with descriptive evidence of a common water exposure
- Detection of an agent in a water source and illnesses compatible with the agent in outbreak cases
- Detection of a common agent in human cases and in a water source

Outbreak classification

- *Confirmed*: Any outbreak of an infectious disease, chemical poisoning or toxin-mediated illness where water is indicated as the source by an epidemiological investigation.
- Drinking water, recreational water, water not intended for drinking or water of unknown intent. The route of exposure may be ingestion, inhalation, intranasal, or contact. Identification in water not required
  - Chemicals (including disinfection by products) in drinking or recreational water that cause health effects either through water exposure or by volatilization leading to poor air quality are included.
- Single cases of chemical exposure, wound infection (e.g., *Vibrio* skin infection) and other illnesses, (e.g., *Naegleria* infections) that are epidemiologically linked to water exposure as well as aquatic facility-related health events (e.g., chemical mixing accidents or air quality problems) are also of interest

Control Measures

- Implement immediate control measures based on the likely WBD agent and source.
- Depending on circumstances, immediate control measures may include a boil water order, hyperchlorination of a pool, flushing plumbing, posting warnings at a lake, closing a facility, recalling a commercial product like bottled water, or issuing a press release to advise citizens who may develop symptoms.
- Develop a fact sheets and a press release if transmission is expected to be widespread.
- Increase monitoring and revisit control measures as needed.
- Provide education to all partners as appropriate.