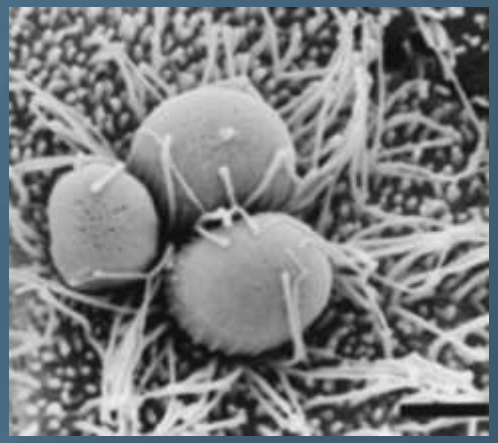
# Cryptosporidium

- Protozoan
- Phylum: Apicomplexa
- Class: Sporozoasida
- Order: Eucoccidiida
- Family Cryptosporiidae
- Genus: *Criptosporidium*
- Species: ***parvum***, *muris, meleagridis, felis, etc.*

waterfilterreview.com

# Cryptosporidium

- Cryptosporidium is a spore producing parasite found in the intestine of infected people and animals.
- Cryptosporidium spp. is the most common cause of Cryptosporidiosis.



landesbioscience.com

# Cryptosporidium History

- Recognized in mice in 1907
- Reported in humans in 1976
  - Immunocompetent child
  - Immunosuppressed adult
- Recognized globally in 1980s and 1990s
  - AIDS patients
  - Outbreak among veterinary students

www.nap.edu

Ernest Edward Tyzzer

Cryptosporidium is a microscopic parasite that causes the diarrheal disease cryptosporidiosis.

Both the parasite and the disease are commonly known as “ Crypto.”

There are many species of Cryptosporidium that infect animals, some of which also infect humans. The parasite is protected by an outer shell that allows it to survive outside the body for long periods of time and makes it very tolerant to chlorine disinfection.

While this parasite can be spread in several different ways, water (drinking water and recreational water) is the most common way to spread the parasite.

Cryptosporidium is a leading cause of waterborne disease among humans in different parts of world

There are at least 32 'valid' *Cryptosporidium* species, some of which cause disease in humans, livestock, poultry and game birds, and companion animals.

*Cryptosporidium* species and subtypes as many of the oocyst sizes are similar (Table 1) and there are few species - distinguishing antigens.

In livestock, poultry and game birds, *C. parvum, C. andersoni, C. baileyi and C. meleagridis* have been reported to cause morbidity and outbreaks of disease. In humans, *C. parvum, C. hominis, C. meleagridis and C. cuniculus* are considered the main pathogenic species, causing sporadic cases and outbreaks (Table 1). Most cases of cryptosporidiosis in young mammalian livestock are likely to be caused by *C. parvum*, which is also the most significant zoonotic threat for humans. In addition, over 40 *Cryptosporidium* 'genotypes' have been identified in animals on the basis of DNA sequencing.

***Table 1.*** *Some differences among species within the genus* Cryptosporidium

| ***Cryptosporidium* species** | **Mean oocyst dimensions (µm)[a]** | **Major host(s)** | **Usual site of infection** | **Infections reported in humans** |
|---|---|---|---|---|
| *C. andersoni* | 7.4 × 5.5 | Cattle | Stomach | Yes, but only rarely |
| *C. baileyi* | 6.2 × 4.6 | Poultry | Upper respiratory tract, | No |
| *C. bovis* (previously bovine B genotype) | 4.9 × 4.6 | Cattle | Small intestine | Yes, but only rarely |
| *C. canis* (previously dog genotype) | 5.0 × 4.7 | Dog | Small intestine | Yes, occasionally |
| *C. cichlidis* (previously piscine genotype 1 or *C. molnari*-like) | 4.6 × 4.4 | Tilapia | Stomach | No |
| *C. cuniculus* (previously rabbit genotype) | 5.6 × 5.4 | Rabbit, humans | Small intestine | Yes, occasionally. One waterborne outbreak |
| *C. ducismarci* | | Tortoises | Intestine | No |
| *C. erinacei* | 4.9 x 4.4 | Hedgehog | Small intestine | Yes, but only rarely |
| *C. fayeri* (previously marsupial genotype I) | 4.9 × 4.3 | Marsupials | Intestine | Yes, but only rarely |
| *C. felis* | 4.6 × 4.0 | Cat | Small intestine | Yes, occasionally |
| *C. fragile* | 6.2 × 5.5 | Black spined toad | Stomach | No |
| *C. galli* | 8.3 × 6.3 | Chicken | Proventriculus | No |
| *C. hominis* (previously referred to as *C. parvum* human genotype, genotype 1, and genotype H) | 4.9 × 5.2 | Humans | Small intestine | Yes, commonly. Outbreaks are reported frequently |

| *Cryptosporidium* species | Mean oocyst dimensions (μm)[a] | Major host(s) | Usual site of infection | Infections reported in humans |
|---|---|---|---|---|
| *C. huwi* | 4.6 × 4.4 | Guppy | Stomach | No |
| *C. macropodum* (previously marsupial genotype II) | 5.4 × 4.9 | Eastern grey kangaroo | Intestine | No |
| *C. meleagridis* | 5.2 × 4.6 | Birds, mammals | Intestine | Yes, frequency depends on setting. One farm-related and one school-related outbreak |
| *C. molnari* | 4.7 × 4.5 | Sea bream | Intestine | No |
| *C. muris* | 7.0 × 5.0 | Rodents | Stomach | Yes, but only rarely |
| *C. parvum* (also sometimes previously called bovine genotype, genotype II, and genotype B) | 5.0 × 4.5 | Humans, pre-weaned mammalian livestock | Small intestine | Yes, commonly and outbreaks are reported frequently |
| *C. proliferans* | 7.7 × 5.3 | Rodents | Stomach | No |
| *C. ryanae* (previously deer-like genotype) | 3.7 × 3.2 | Cattle | | No |
| *C. reichenbachklinkei* (previously piscine genotype 2) | 3.4 × 3.4 | Gourami | Stomach | No |
| *C. rubeyi* | 4.7 × 4.3 | Ground squirrels | | No |
| *C. scrofarum* (previously pig genotype II) | 5.2 × 4.8 | Pig | Small intestine | Yes, but only rarely |
| *C. serpentis* | 6.2 × 5.3 | Reptiles | Stomach | No |
| *C. suis* (previously pig genotype I) | 4.6 × 4.2 | Pig | Small intestine | Yes, but only rarely |
| *C. tyzzeri* (previously mouse genotype I) | 4.6 × 4.2 | Mice | Small intestine | Yes, but only rarely |
| *C. ubiquitum* (previously cervine genotype) | 5.0 × 4.7 | Various mammals | Small intestine | Yes, occasionally |
| *C. viatorum* | 5.4 × 4.7 | Humans | | Yes, occasionally |
| *C. varanii* (syn. *C. saurophilum*) | 4.8 × 4.7 | Reptiles | Intestine | No |
| *C. wrairi* | 5.4 × 4.6 | Guinea pig | Small intestine | No |
| *C. xiaoi* (previously *C. bovis*-like genotype or *C. bovis* from sheep or *C. agni*) | 3.9 × 3.4 | Sheep, goat | | No |

Among many *Crptosporidium spp Cryptosporidium parvum* is most important due to its zoonotic value.

It is an important cause of scour in young , unweaned farmed livestock including calves , lambs , goat kids , alpaca and foals showing adverse consequences for productivity . Healthy and adult animals can also shed oocysts , often in large numbers , providing a potential reservoir of infection and environmental contamination.

Its infection to cattle are considered endemic globally . Prevalence and severity of disease peak in the second week of life.

Clinical signs can range from a mild to inapparent infection in older animals to severe scouring in young animals , varying degrees of dehydration , dullness , anorexia , fever and loss of condition . Mortality is generally low but concurrent infection with *Escherichia coli* or rotavirus show high mortality.

In small ruminants causes neonatal diarrhoea sometimes associated with high morbidity and mortality especially with concurrent infections or deficiencies in nutrition and husbandry . In ewes , a periparturient rise in oocyst shedding has been observed.

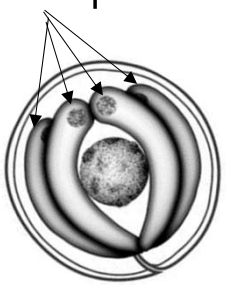
*C. parvum* appears to be pathogenic to piglets , causing inappetence , depression, vomiting or diarrhoea


# *Cryptosporidium parvum*

- **Intestinal pathogen of calves**
- *C. parvum* has very low host specificity!
- There are many *Cryptosporidium* spp. that are more host specific (*C. ryanae, C. bovis, C. canis, C. felis* etc)

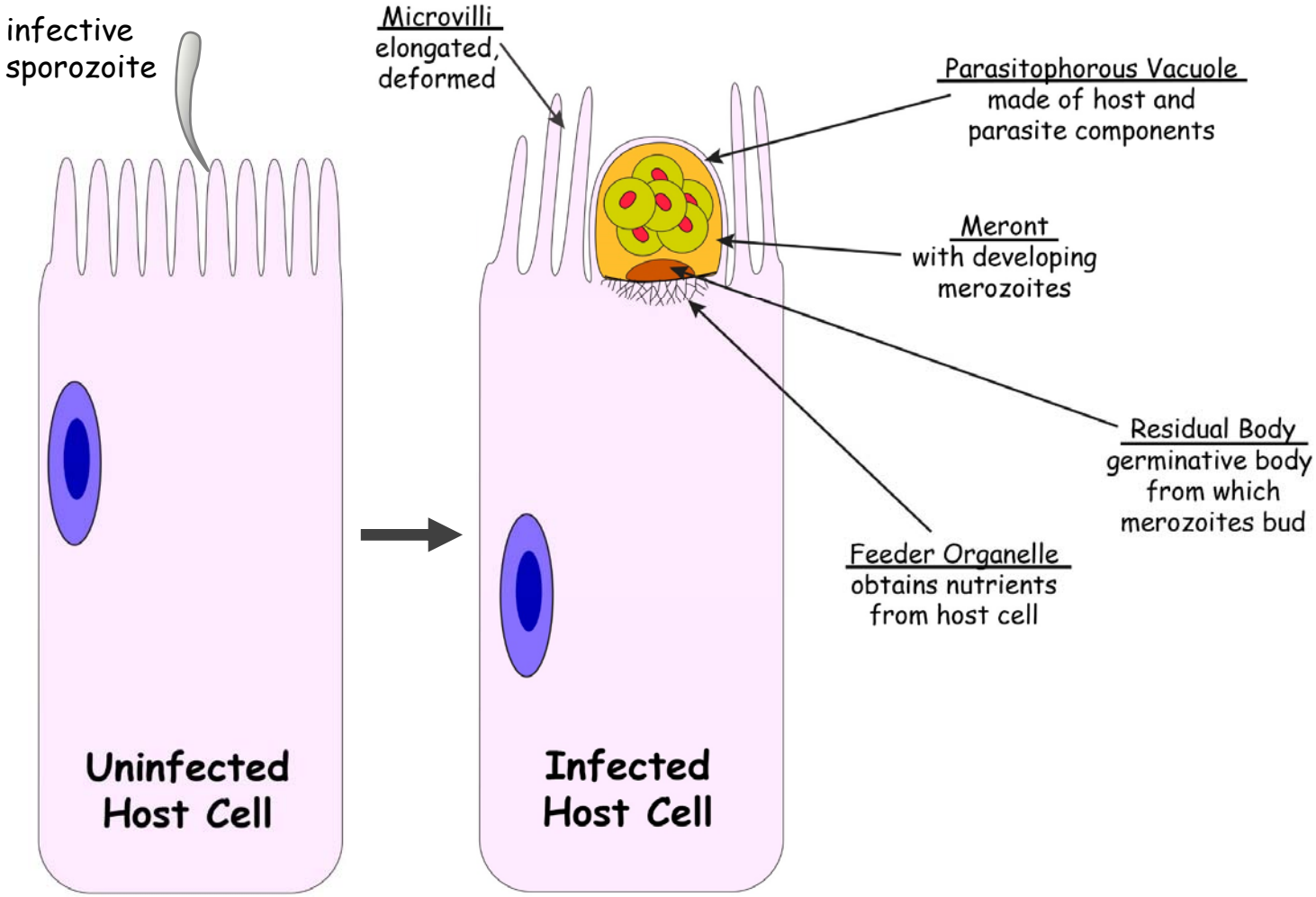
# **Morphology**: *C. parvum*

**Oocyte**
w/ 4 sporozoites



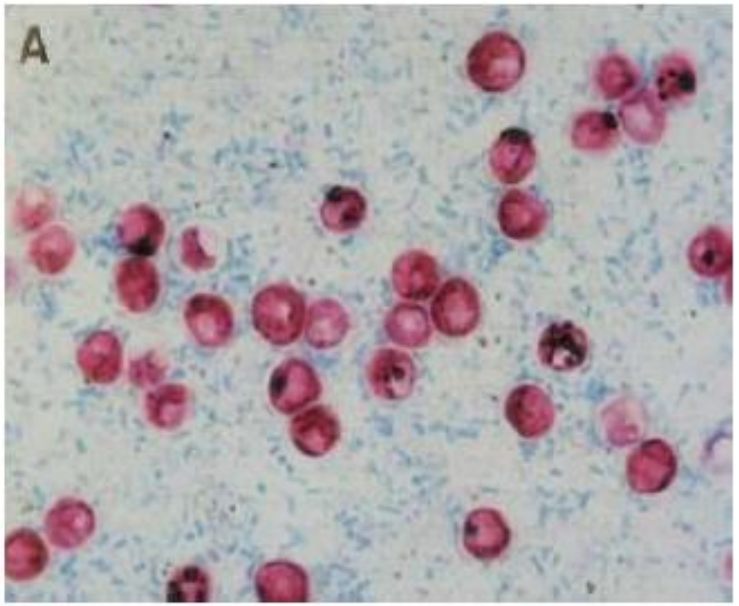
5-8 um (very small)

**thick** or thin walls



# Morphology

- Infective form- **oocyst**
- Spherical, oval, 5$\mu$m in diameter
- Does not stain with iodine and is acid fast
- Thick walled but 20%thin walled- autoinfection
- 4 crescent shaped sporozoites
- Very hard and resistant. Temperature-60°C
- Sequential application of ozone and chlorine – eliminate cyst



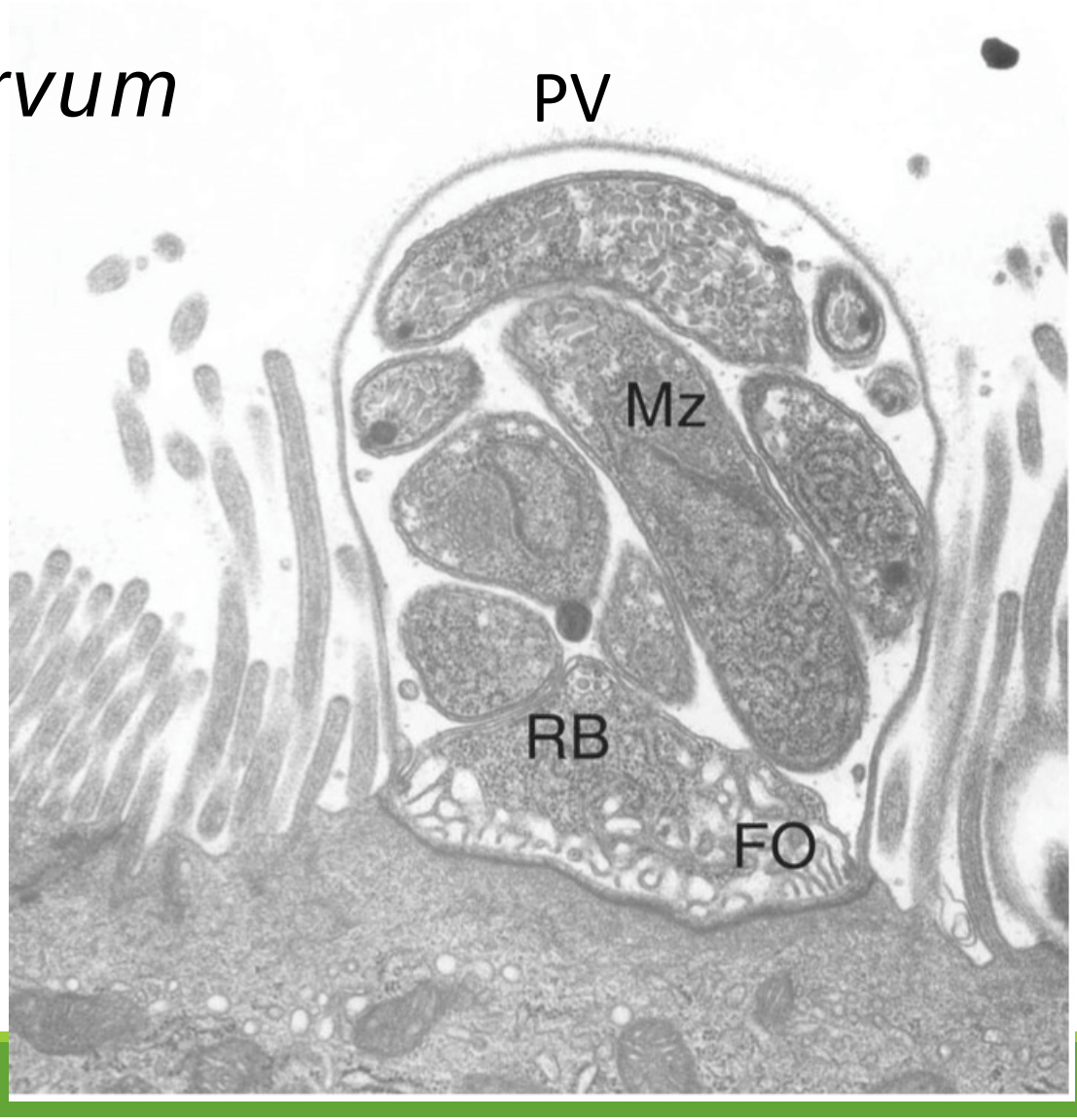
# Oocyst

- Double walled
  - Resistant to chlorine, drying, progressive freezing, salt water
- Only stage in life cycle that can live ex vivo
- Imbeds itself in gut epithelium and releases sporozoites
- Reproduction continues sexually and asexually

# **Morphology**: *C. parvum*

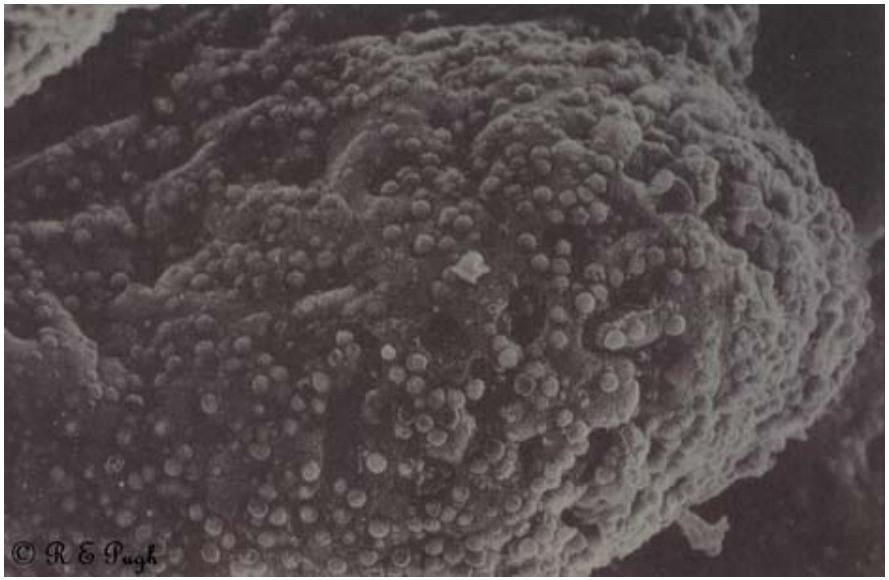
**parasitophorous vacuole (PV)**
**feeder organelle (FO)**
**residual body (RB)**
**merozoites (Mz)**

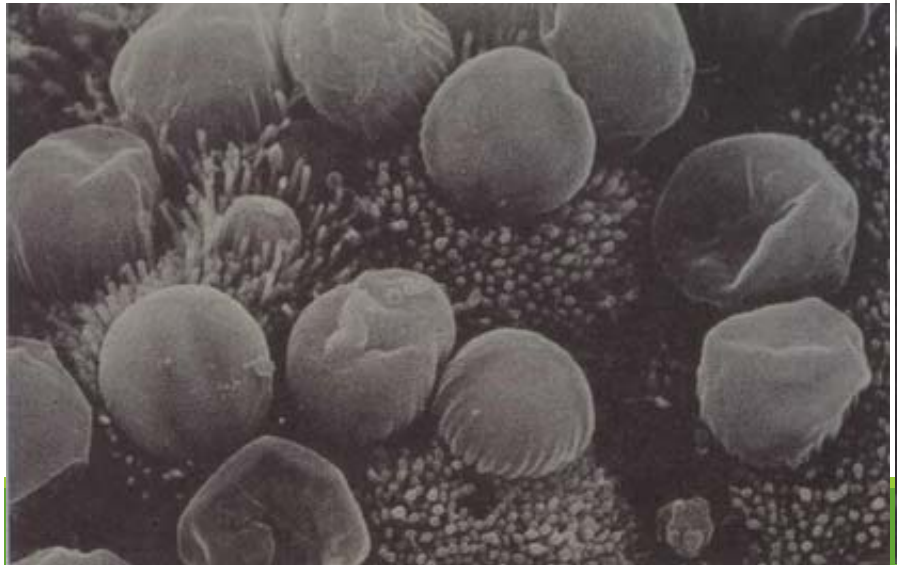
The enterocyte brush border microvilli immediately adjacent to the parasite are typically elongated.




https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3368497/

# SEM's of Crypto



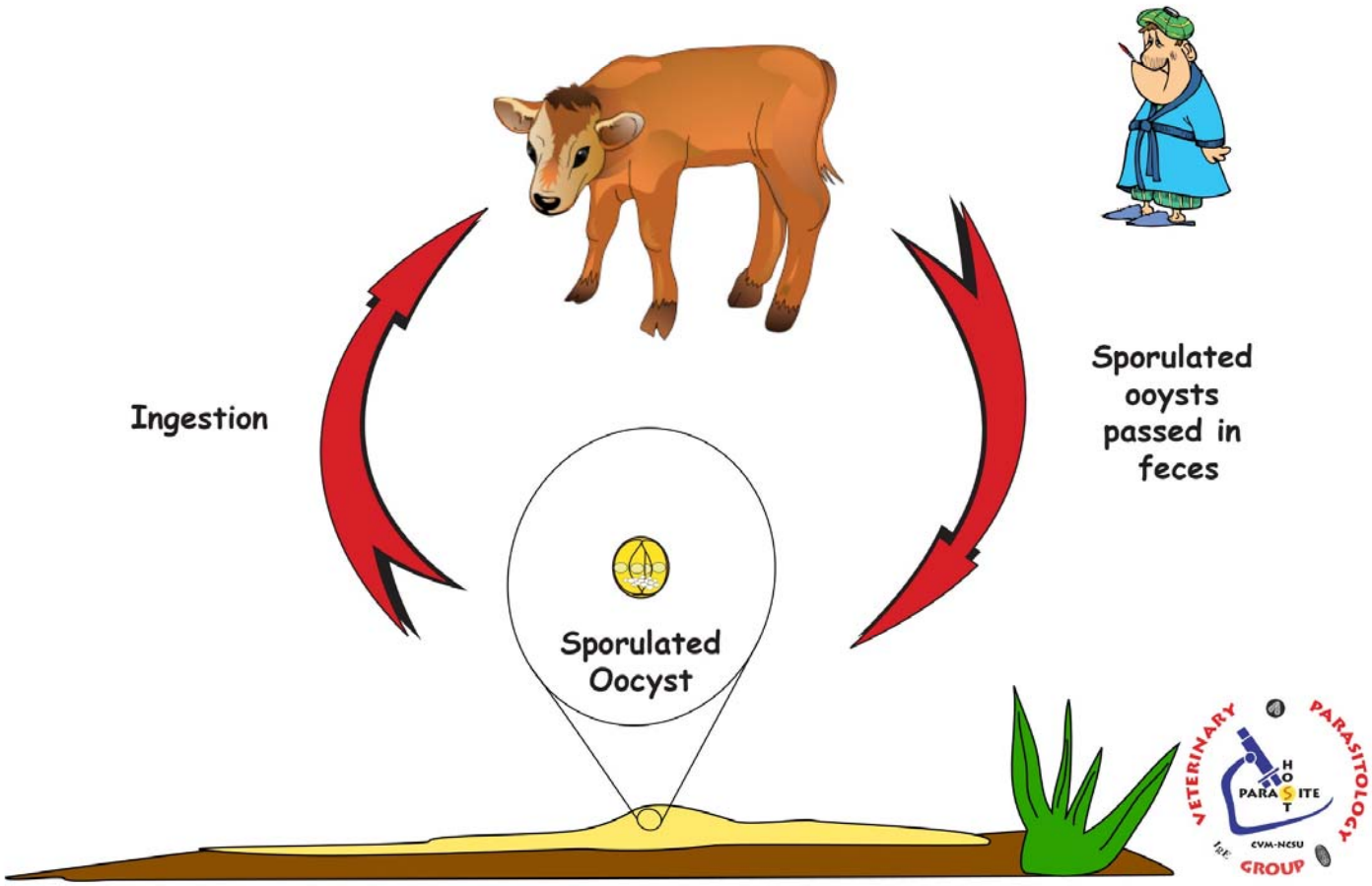



http://parasite.org.au/pugh-collection/

NC STATE UNIVERSITY

# Direct life cycle

## Cryptosporidium parvum



# **Life Cycle**: *C. parvum*

**Transmission**

- Direct life cycle – fecal-oral, ingestion of oocyst

**Invasion**

- Sporocysts excyst from oocyst and invade microvillus border of enterocyte

**Asexual reproduction** (small intestines: Ileum, less in cecum & colon)

- Merogony (schizogony)
  - [multi-nuclear division followed by cytoplasmic division]
- Merozoites exit the enterocyte and infect the microvillus border of other enterocytes and goes through merogony again.
- Number of asexual cycles: unknown, (probably variable depending on host response.)

# **Life Cycle**: *C. parvum*

**Sexual reproduction**

- Final generation of merozoites exit the enterocyte and infect the microvillus border of other enterocytes undergo **gametogony** (production of gametes)
- Macrogamete (egg)
  - Some final merozoites remain a single cell and become a macrogamete (egg) within a macrogamont.
- Microgametes (sperm)
  - Other final merozoites go through gametogony thus forming a microgamont
  - Exflagellation –microgametes exit the microgamont in search of a macrogamete.
- Fertilization – a microgamete fuses with a macrogamete forming a zygote
- A cyst wall forms around the zygote = immature oocyst. The oocyst exits the host cell into the lumen of the host's gut and begins **sporogony** (sporulation).

# **Life Cycle**: *C. parvum*

**Sporogony (= Sporulation)**

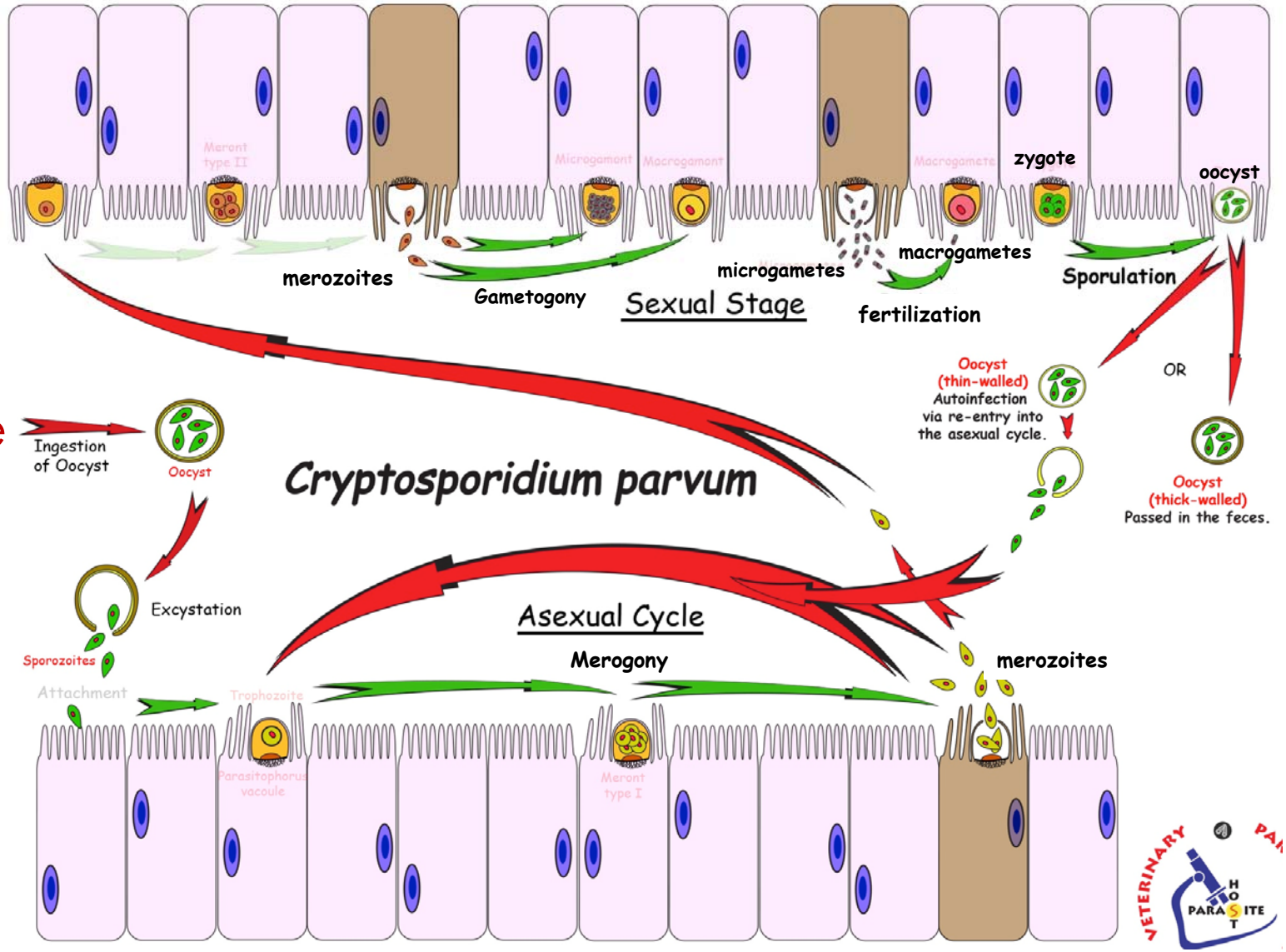
- The zygote, within the oocyst, goes through sporogony, forming 4 sporozoites
- Sporulation occurs within the lumen of the host gut, thus making the oocyst immediately infectious.

**Dissemination**

- Thin-walled Oocysts
  - **Autoinfection:** oocysts have thin cyst walls and excyst within the same host
    - **Normal immune system → low grade chronic pathology** (diarrhea)
    - **Immunocompromised → hyperinfection / severe pathology / mortality**.
- Thick-walled Oocysts
  - Some oocysts have **thick cyst walls** and exit the host in the feces
    - contamination of the **environment and transmission to the next host**.
    - infectious when passed.

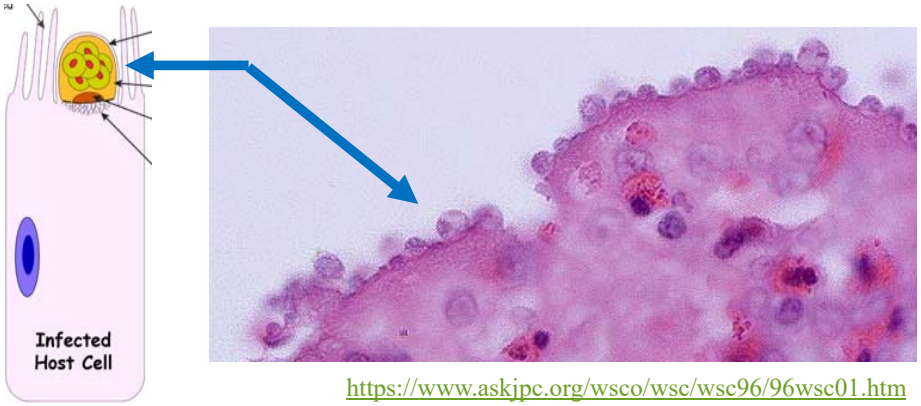
# Life Cycle:
*C. parvum*

start here




small intestines

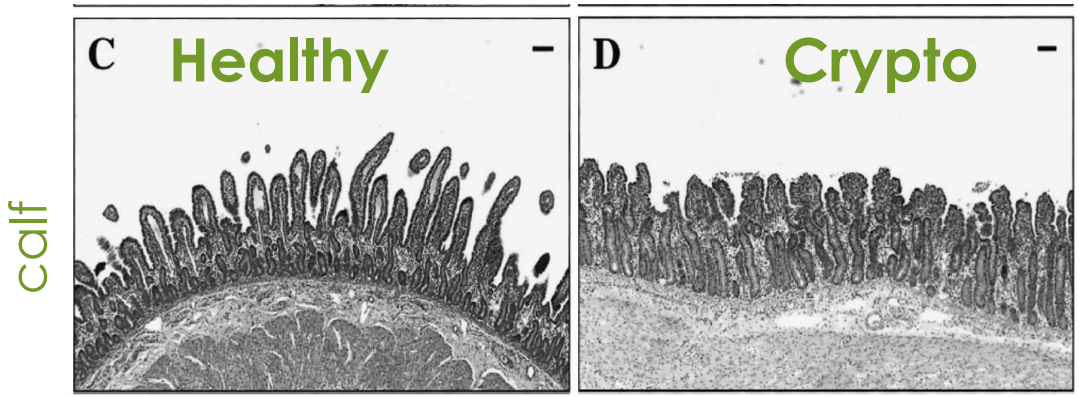
# *C. parvum* Pathogenesis → Watery Diarrhea




https://www.askjpc.org/wsco/wsc/wsc96/96wsc01.htm

Direct damage (inside microvilli)

- SI **villus atrophy** and dysfunction of absorptive enterocytes,
  - ↓ surface area
  - ↓ absorption
- Crypt hyperplasia causes ↑ secretory activity




Indirect damage

- Inflammation ↑ permeability, with **loss of fluids into the gut lumen**.

Image: Gookin, Jody L., Shila K. Nordone, and Robert A. Argenzio. "Host responses to Cryptosporidium infection." *Journal of veterinary internal medicine* 16.1 (2002): 12-21.

# **Clinical Disease**: *C. parvum*

http://www.vetserviceswairarapa.co.nz/news/article/16/calf-scours-feeder-calf-rearing/

Main complaint: **Mild to severe diarrhea**

- usually in neonatal calves
- **"Calf Scours"**
- most often reported in calves from 5 -15 days of age.
- Most cases are self-limiting after several days
- Persistent infection may cause marked dehydration, weight loss, and emaciation.

# Clinical Disease:

*C. parvum*

*"Calf Scours"*

http://calfcare.ca/calf-care-corner/feeding-to-fight-disease/

http://coloradodisasterhelp.colostate.edu/prefair/disease/dz/Cryptosporidiosis.html

## **Clinical Disease**: *C. parvum*

Pathological Findings

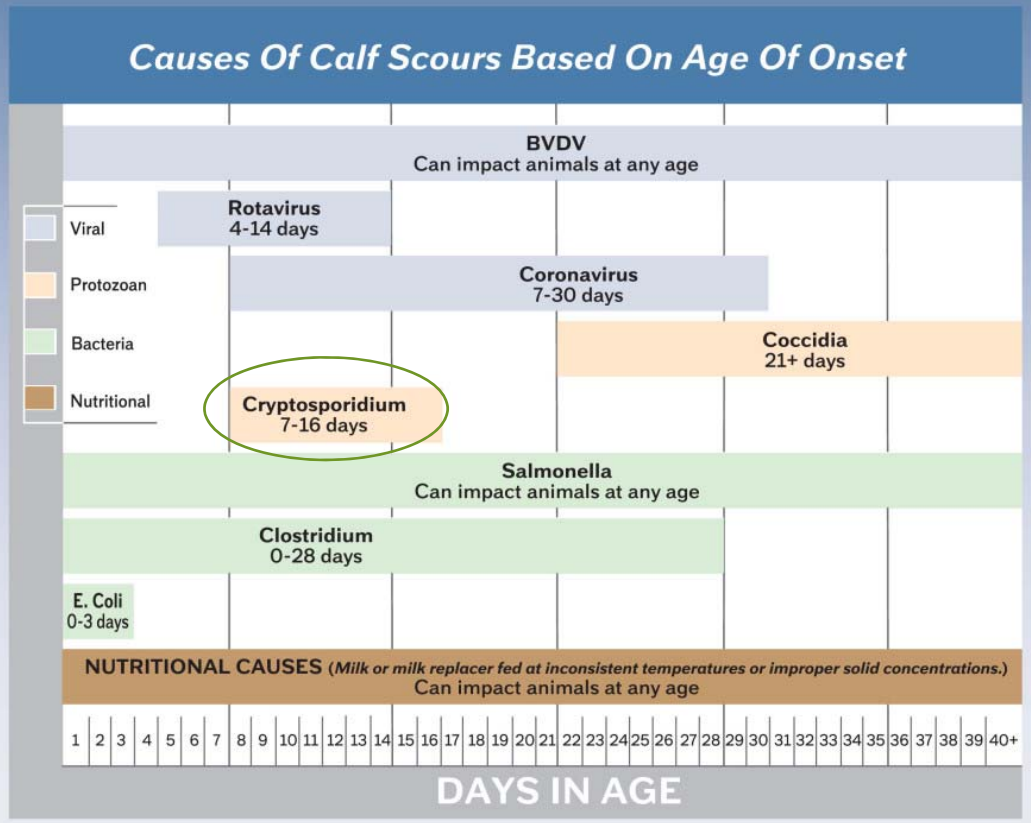
- Large amounts of watery diarrhea
- feces yellow or pale, watery, may contain mucus.
- subsequent severe dehydration, anorexia, debilitation

Usually self-limiting in immunocompetent hosts

Severe and lethal in immunodeficient hosts

# Differential Diagnoses "Calf Scours"

***Cryptosporidium* 7-16 days**
**Coccidia (e.g. *Emeria*) 21+ days**
Rotavirus
Coronavirus
Bovine viral diarrhea virus (BVDV)
*Salmonella*
*Clostridium*
*E.coli*
Nutritional causes




**GOALS WHEN TREATING SCOURS**

1. Maintain caloric intake. Keep the calf on its normal feeding schedule.
2. Restore hydration status.
3. Stabilize the intestinal tract.

http://crystalcreeknatural.com/causes-of-calf-scours-based-on-age-of-onset/

FYI: this chart

# **Diagnosis**: *C. parvum*

Fecal Float Centrifugation

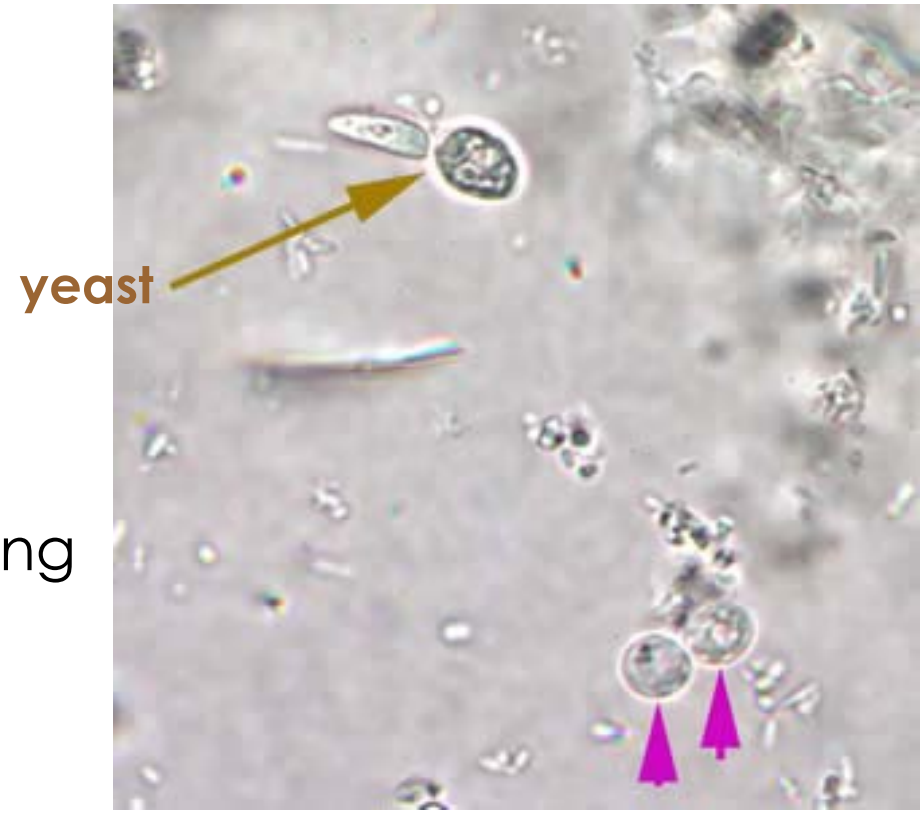
- very small oocysts
  - focus on the thin layer of fluid above bubbles
- don't confuse with yeast

Thin fecal smear with special staining

- acid fast stains

Molecular diagnostics

- Fluorescent antibodies bind oocysts, ELISA, PCR



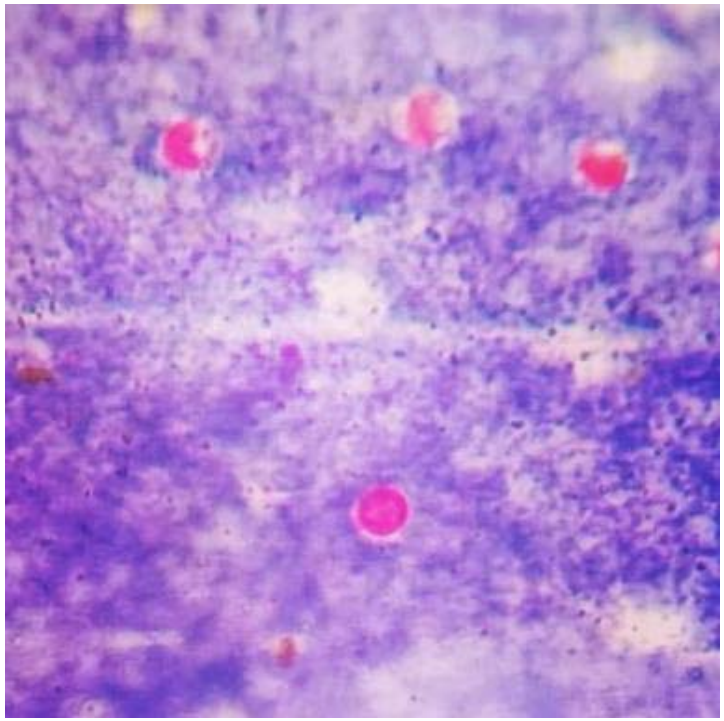

***C. parvum***

**FYI:** concentrated sucrose for fecal float

https://mcdinternational.org

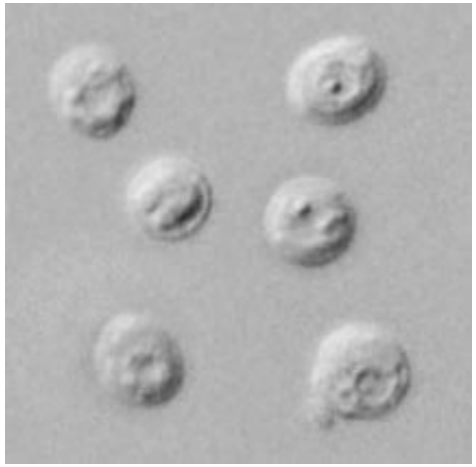
# **Diagnosis**: *C. parvum*

Acid-fast Stain



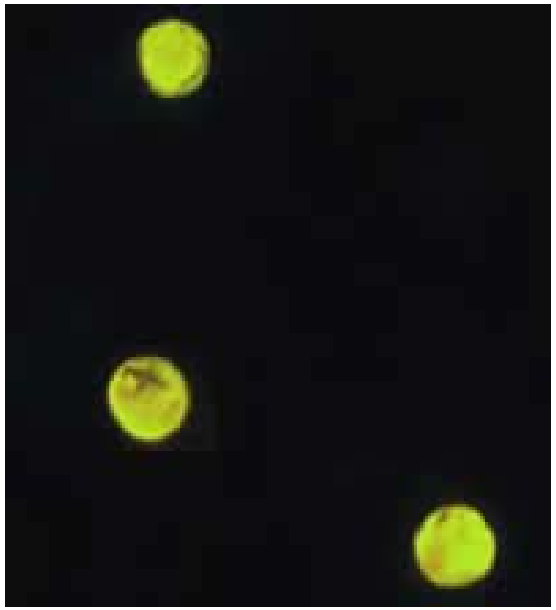
http://www.imgrum.org/media/1000074980669288494_423165795

Wet Mounts



https://mcdinternational.org

Fluorescent stain



# **Treatment**: *C. parvum*

Some drugs are only suppressive (Paromomycin, Azithromycin, etc.)

Coccidiostats don't work

Fluid-replacement therapy for the dehydration caused by the diarrhea.

Electrolyte solution

Allow calf to feed on milk

**Risk factors for calf scours:**

1. Dirty or contaminated environments

2. Failure of newborn calf to receive an appropriate amount or quality of colostrum

3. Housing sick calves with healthy calves

# **Control**: *C. parvum*

- Sanitation for young calves
  - Hutch system for dairy calves
- Provide adequate amounts of colostrum
- Sanitation & hygiene for humans & others
- Oocysts are viable for months unless exposed:
  - to extreme temps (0°C or <65 °C), drying
  - disinfectants (5% ammonia, 10% formalin)
- No Vaccines Available

# Calf hutches

# **Epidemiology**: *C. parvum*

*C. parvum* in Calves

- **Primarily in neonatal calves**, but also in lambs, kids, foals, and piglets, as well as in **humans** (zoonotic ?)
- Calves 9-14 days old most likely source of oocysts.
- A concurrent infection with rotavirus and coronavirus tends to make disease worse, than with *Crypto* alone.

# **Zoonosis**: *C. parvum*

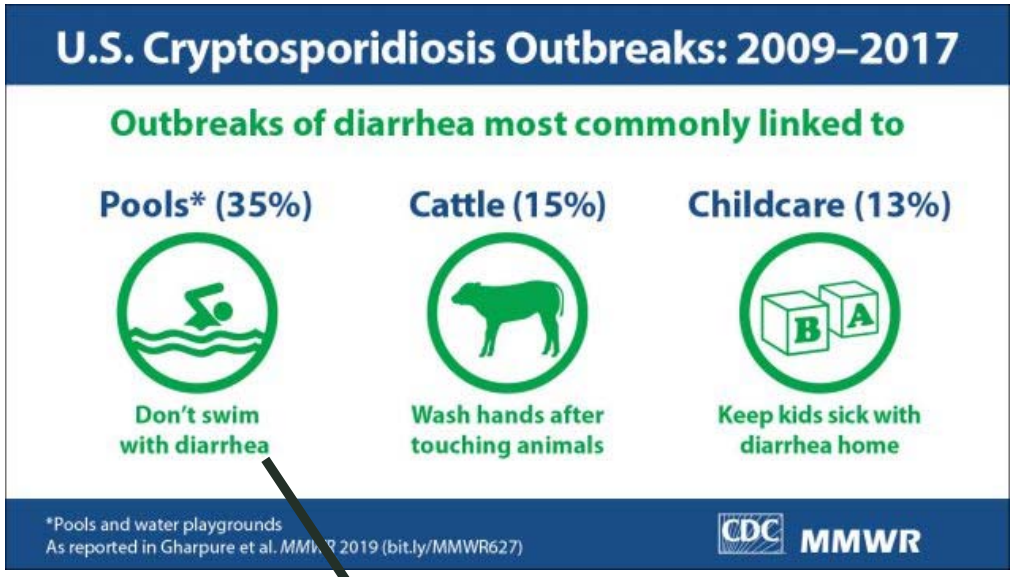
human outbreaks are more likely from human to human transmission than contamination from animals.

Highly zoonotic

Transmitted to humans

- predominantly human-to-human
- direct contact with animals
- water-borne from contamination of water sources with animal feces
- Food-borne outbreaks
- Farm workers at high risk

Highly dangerous for immunocompromised patients.




*Resistant to chlorine*

# **Zoonosis**: *C. parvum*

17 Water-borne -- 1990 to 2015 -- Municipal water, drinking fountains, public recreational swimming pools, interactive recreational water fountains, etc.

- 1993 Milwaukee outbreak most famous

6 Food-borne outbreaks – 1993-2005 -- Fresh apple cider, unpasteurized milk, chicken salad, raw vegetables, etc.

9 Human to Human or animal to human outbreaks -- 1984 to 2015 Children day care, Summer camps, Zoos, wildlife center, State fairs, VETERINARY STUDENTS.

**FYI**

# **Zoonosis**: *C. parvum*

Levine, Levy, Walker, Crittenden. 1988.

**Cryptosporidiosis in veterinary students.**

JAVMA. 193: 1413-1414.

**Abstract:** Cryptosporidiosis was diagnosed in 10 veterinary students. Exposure to the pathogen was associated with direct contact with infected calves and contact with contaminated materials. Affected students had fever (50%), headache (50%), nausea (70%), diarrhea (80%), and vomiting (40%). Clinical signs persisted for 30 hours to 16 days after the onset of clinical signs of disease. Although one student required hospitalization, the remaining students recovered without treatment.

**FYI**

# Prevalence

- Found in most parts of the world
- Most prevalent in Asia, Africa, Australia, South America
- Antibody prevalence in Peru and Venezuela – 64%
- 32% in Peace Corps workers
- More prevalent in rural areas of U.S.
  - More animal contact

# Cryptosporidiosis Infection

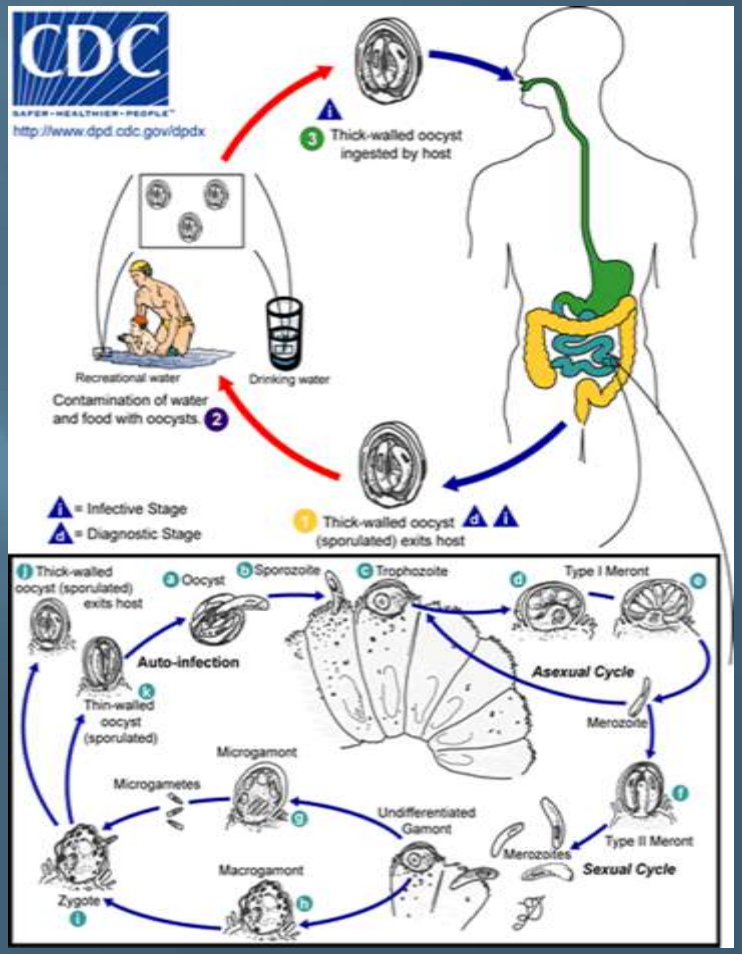
- Infection
  - Ingesting food or drinks contaminated with fecal material
  - Swallowing recreational water contaminated with Cryptosporidium
  - Not washing hands
  - Sexual practices leading to oral exposure with fecal material

secretsofsoa.com


victorystore.com

# Etiology

- Buries into intestinal lining of the gut
  - Goes through Life Cycle
- Alters osmotic pressure
  - Diarrhea
- Atrophy of intestinal villi
  - Alters uptake of fluids, electrolytes, and nutrients
  - Malabsorption syndrome

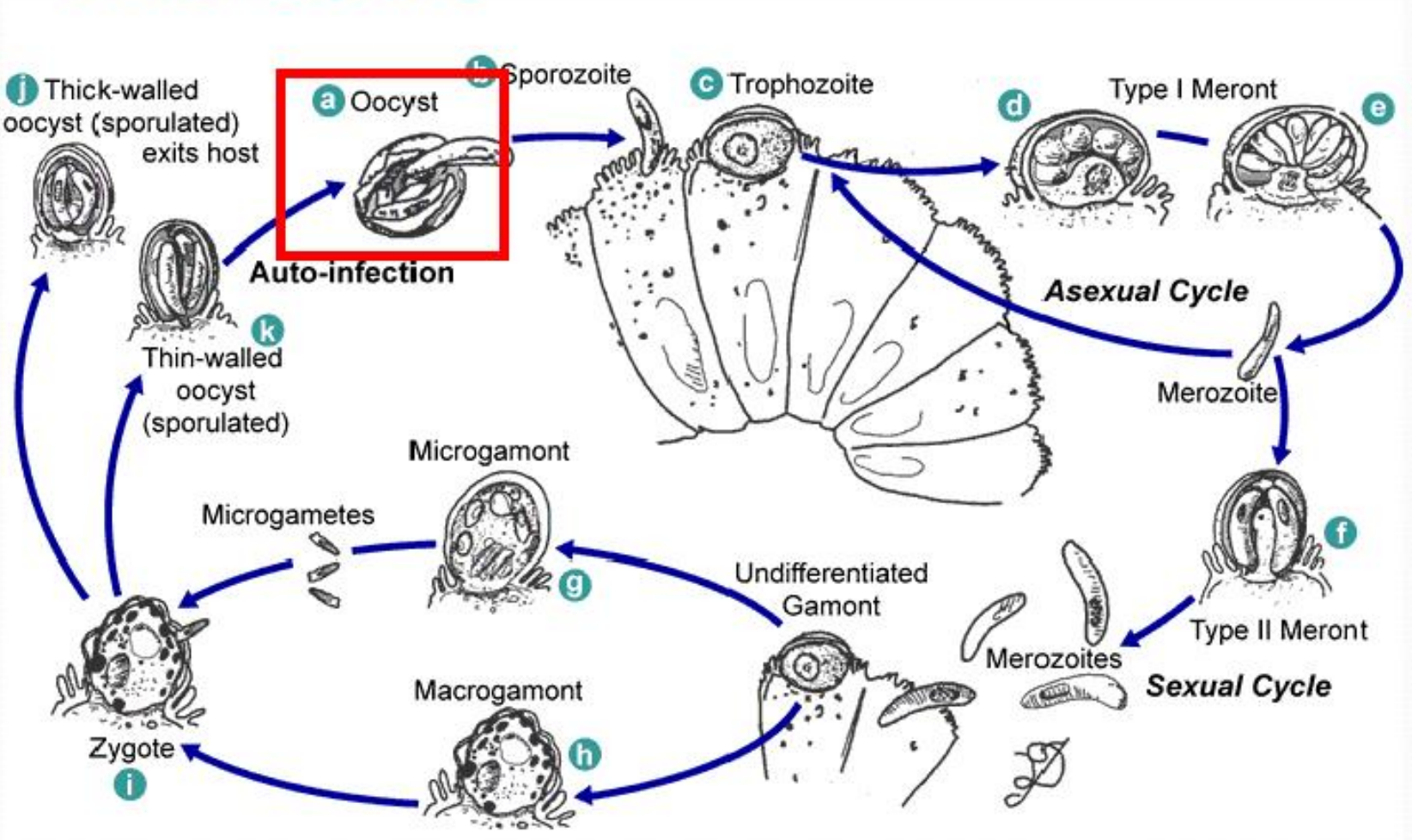



CDC DPDx Library

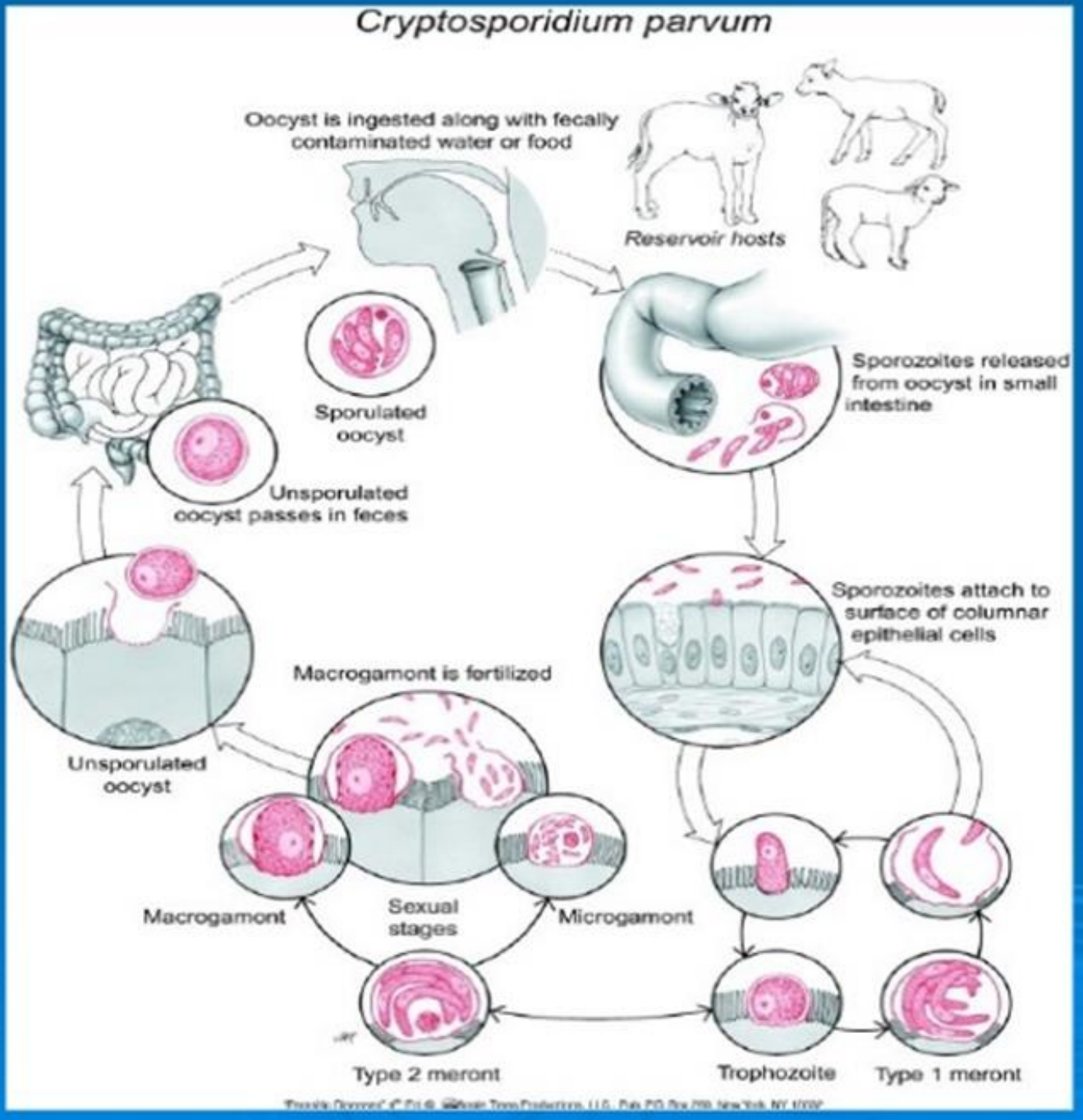
# Infectivity

- *C. parvum* has a low $ID_{50}$ (9-1000 oocysts)
- Can be infected by just one oocyst
- 10 billion oocysts per gram infected feces

# Life Cycle




http://www.dpd.cdc.gov/dpdx/HTML/Cryptosporidiosis.asp?body=Frames/A-F/Cryptos


Cryptosporidium parvum
Oocyst is ingested along with fecally contaminated water or food
Reservoir hosts
Sporulated oocyst
Sporozoites released from oocyst in small intestine
Unsporulated oocyst passes in feces
Sporozoites attach to surface of columnar epithelial cells
Macrogamont is fertilized
Unsporulated oocyst
Macrogamont
Sexual stages
Microgamont
Type 2 meront
Trophozoite
Type 1 meront

# Transmission

- Reservoir: Humans, cattle, other domestic animals
- Food and water contaminated by livestock mammal or human feces containing cysts
- Outbreaks -drinking water from lakes and rivers, swimming pools, untreated groundwater, well water
- Cysts survive water chlorination

# Pathogenesis

- Sporozoites adhere to the intestinal mucosa
- Cells release cytokines
- Increased intestinal secretion of sodium and chloride, water absorption is inhibited
- Epithelial cells damaged by:
  - Parasite invasion and multiplication
  - T cell-mediated-villus atrophy
- May produce up to 10-20 liters of watery stools per day

# Symptoms

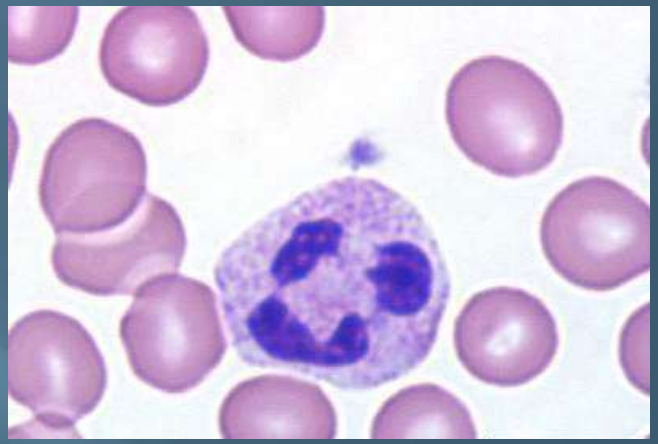
- Symptoms (2 to 10 days after infection and can last up to 30 days)
  - Diarrhea
  - Stomach cramps
  - Dehydration
  - Nausea
  - Vomiting
  - Fever
  - Weight loss
  - Sometimes no symptoms are seen

treehugger.com


bathroomscalereview.com

# Innate Immune Response

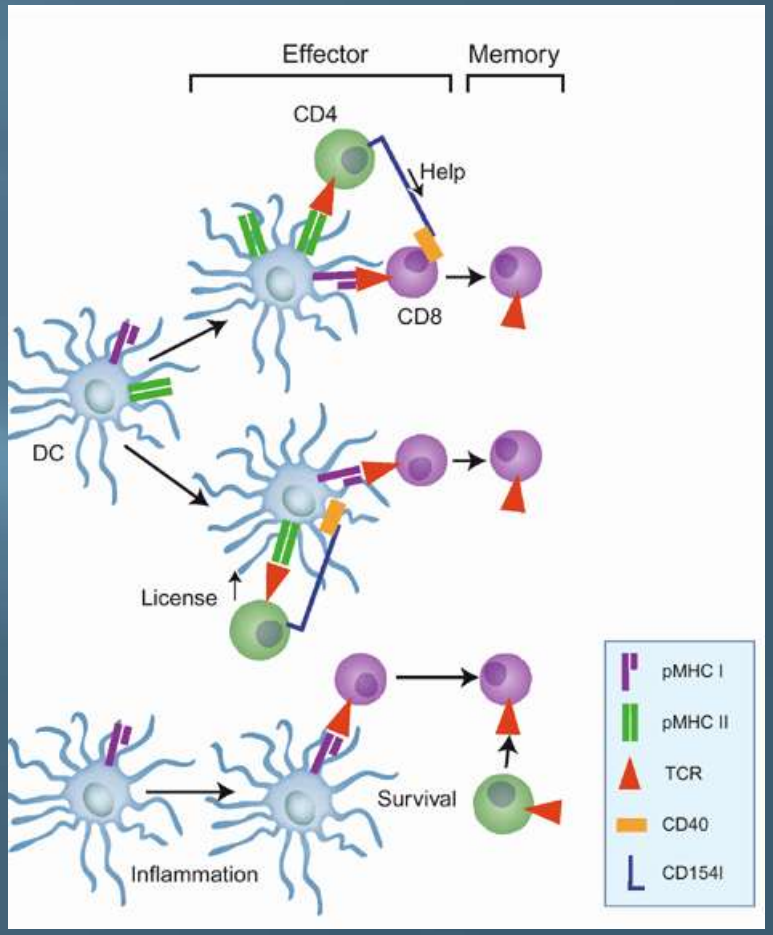
- White Blood Cells Phagocytize Parasites
  - Segmented neutrophils
  - Macrophages
  - Lymphocytes
  - Eosinophils



labmed.hallym.ac.kr

# Cell Mediated Immune Response

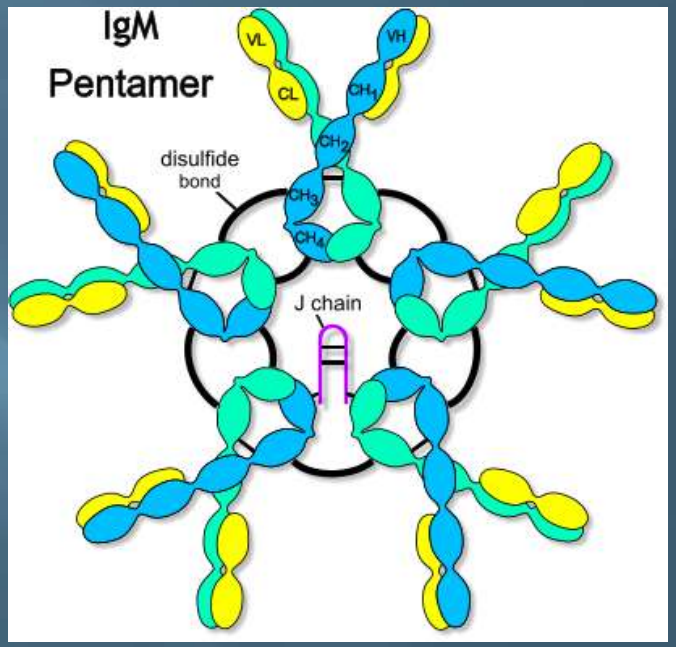
- CD4+ T cells
  - Early infection
- CD8+ T cells
  - Elimination
- CD154 and CD40
  - Stimulate nitric oxide
  - IFN-γ, IL-12
  - T cell response
  - Apoptosis
- Other Cytokines
- TNF-α, IL-1β, IL-2, IL-4, IL-10, IL-15, etc.
- Patients with AIDS
  - Decreased CD4+ count




Ashton-Rickardt, 2004

# Humoral Immune Response

- IgM
- IgG
- IgA
- X-linked immunodefiencey
  - Mutations in CD154 gene
  - Defected IgM cannot mount immune response




allerresponz.com

# Laboratory Diagnosis

- Specimen Source
  - Multiple Stool Specimens
- Diagnostic Techniques
  - Wet Mount
  - Modified Acid Fast Stain
  - Direct Fluorescent Antibody (DFA) Assay
- Detection Methods
  - Safranin Stain
  - Trichrome Stain
  - Enzyme Immunoassay (EIA)
  - Polymerase Chain Reaction (PCR)
  - Rapid Immunochromatographic cartridge Assays

savethecanyoncall.com

# Post Mortem Lesions

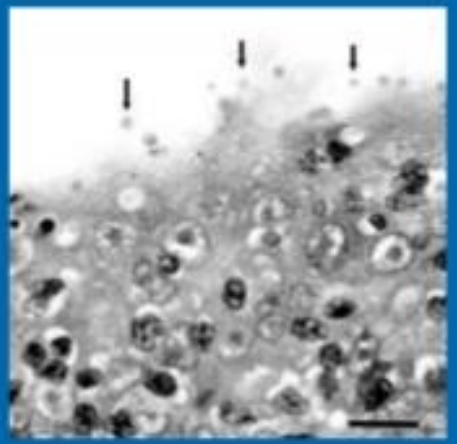
- Gross lesions

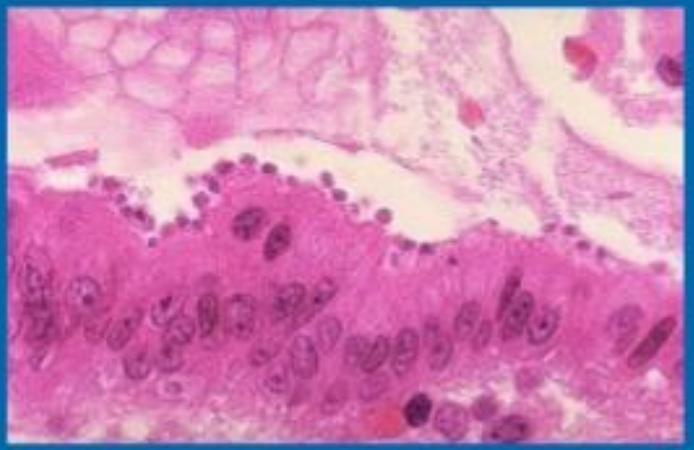
  (not common)

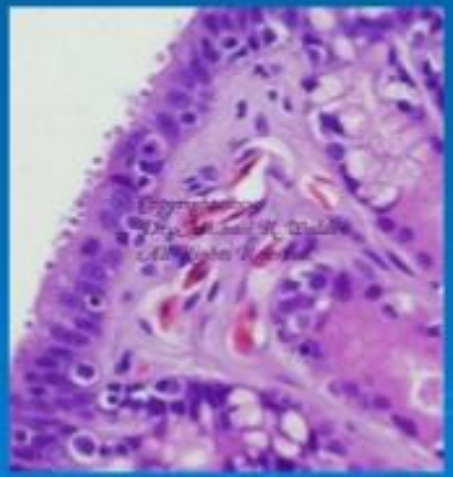
  - Hyperemia of intestinal mucosaThe mucosal folds are markedly thickened, and there are numerous pinpoint foci of hyperemia.

- Microscopic lesions
  - Mild to severe villous atrophy
  - Spherical organisms in the brush border

# Histopathology







# Wet Mount

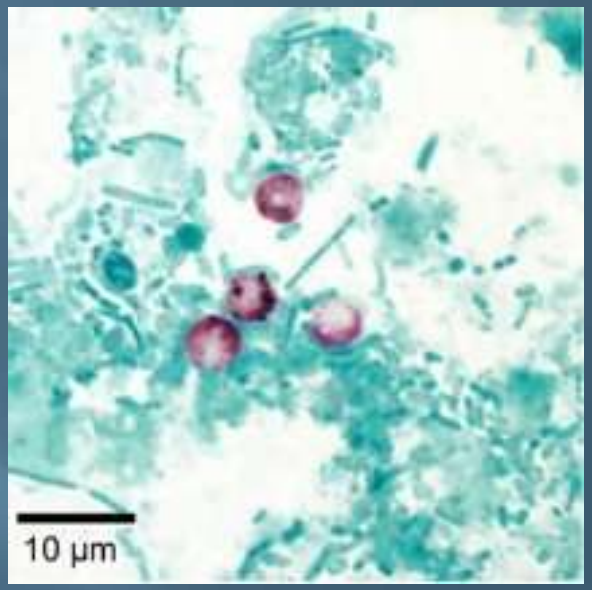
- Visualization of Oocysts
  - 4 to 6 µm
- Bight-Field Microscopy
- Differential Interference contrast (DIC)
- High Sensitivity and Specificity

CDC DPDx Library

Wet Mount Slide

# Modified Acid-Fast Stain

- Visualization of Oocytes
  - Light pink to dark red
  - Can also visualize sporozoites
- Relatively High Sensitivity and Specificity
- Irregular Staining
  - cause "ghost" oocysts




CDC DPDx Library

Modified Acid Fast Stain

# Direct Fluorescent Antibody (DFA) Assay

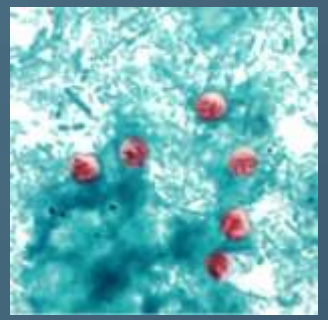
- Fluorescence microscope
- "Gold Standard"
  - High sensitivity and specificity
- Does not provide archievable stained slide
- Requires special equipment

CDC DPDx Library

Fluorescent Stain
Auramine Rhodamine

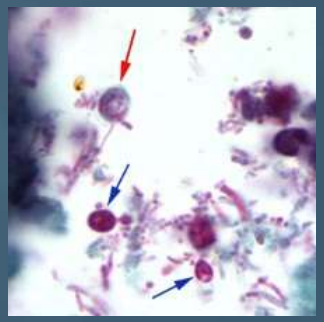
# Safranin and Trichrome Stains

- Safranin stain
  - Oocysts stain a bright red orange
  - Not widely used because oocysts may not stain properly
- Trichrome Stain
  - Oocysts may appear unstained
- Lowest sensitivity and specificity among all tests
- Can detect Oocysts, but Cryptosporidium should be confirmed by diagnostic techniques



CDC DPDx Library

Safranin Stain



CDC DPDx Library

Trichrome Stain

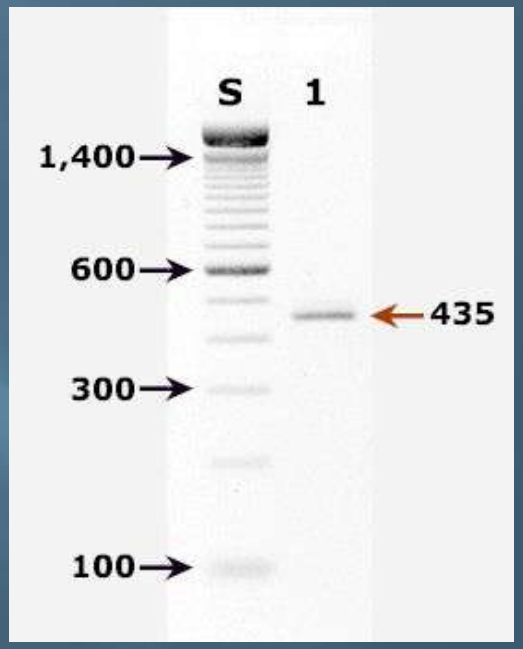
# Enzyme Immunoassay (EIA)

- Detects isolated antigens from a patients sample using antibodies that are tagged with a color changing enzyme.
- Relatively high Sensitivity and Specificity
- Does not involve microscopy
- Screens large numbers of specimens

techlab.com

# Polymerase Chain Reaction

- Separates DNA fragments based on size
- 435 bp
- High Sensitivity and Specificity




CDC DPDx Library

# Rapid Immunochromatographic Cartridge Assays

- Detects isolated antigens from sample using antibodies. A positive test is indicated by a colored bar.
- Variable Sensitivity and Specificity
- Some Assays Have Been Recalled


alibaba.com

# Treatment

- Nitazoxanide
- Paromomycin
- Azithroycin
- Individuals with AIDS
  - anti-retroviral therapy


generecsmed.com

# Treatment

- Nitazoxanide
  - Interferes with folate production
  - Prevents parasite replication
- Immunocompetent
  - *C. parvum* will usually pass on its own
- Immunocompromised
  - AIDS patients: treat with antiretrovirals and strengthen immune system, no cure
  - Others: would not benefit from antiretrovirals; keep hydrated

# Prevention

- Boiling and microfiltration of drinking water
- Micro filtration removes oocysts from the water supply
- Low levels of chlorine does not kill cysts
  - *C. parvum* 240,000 times resistant to chlorination than Giardia
  - Chlorine dioxide -ineffective for oocysts

# Waterborne Prevention

- Do not swallow recreational water
  - Lakes, rivers, streams, untested wells
- Do not drink untreated water
  - Travelers and hikers
  - Boil water for 15 minutes or use filter rated for “cyst removal”
  - Don’t rely on chemical treatments
- Do not swim with GI infection

# Foodborne Prevention

- Wash vegetables with detergent soap
- Proper human/animal waste disposal
- No bare hand contact of ready-to-eat foods
- No food workers with GI illness
  - Until 2 weeks after end of diarrhea
- Handwashing-handwashing-handwashing

# Bottled Waters
# "not all are created equal"

- **Water so labeled has been processed by method effective against crypto**
  - Reverse osmosis treated
  - Distilled
  - Micro-filtered
  - Filtered through an *absolute* 1 micron or smaller filter
  - "One micron absolute"

- **Water so labeled may not have been processed by method effective against crypto**
  - Carbon-filtered
  - Filtered
  - Particle-filtered
  - Multimedia-filtered
  - Ozonated
  - Ozone-treated
  - Ultraviolet light-treated
  - Activated carbon-treated
  - Carbon dioxide-treated
  - Ion exchange-treated
  - Deionized
  - Purified
  - Chlorinated

http://www.cdc.gov/NCIDOD/DPD/parasites/cryptosporidiosis/factsht_crypto_prevent_water.htm

# Outbreaks

- Milwaukee, WI 1993; 400,000 people
- Gainesville, FL  1995; day camp
- New York 1996; unpasteurized apple cider

## Other Cryptosporidium species infecting livestock and companion animals.

C. bovis and C. ryanae are generally more common than C. parvum in post-weaned calves, host-adapted cattle species have not yet been associated with illness and there are no histological or pathological reports.

C. ubiquitum and C. xiaoi infect lambs and kids. C ubiquitum is prevalent in postweaned lambs. C xiaoi infection has been associated with outbreaks of neonatal diarrhoea in goats.

C. canis is the most frequently reported species in dogs and although usually asymptomatic, C. felis is the most frequently reported species in cats, often in the absence of clinical signs,

Three species infect poultry: C. baileyi, C. meleagridis and C. galli

C. baileyi most commonly infects the upper respiratory tract, although other sites include the renal tract, bursa of Fabricius and cloaca, while the trachea and the conjunctiva are lesser sites of infection

C. meleagridis infects turkeys other poults and humans. Villous atrophy, crypt hyperplasia and shortening of microvilli are major pathological changes

C. galli produces a disease in adult hens and some wild and exotic birds. Unlike the life cycle stages of either C. meleagridis or C. baileyi, infection with C. galli is limited to the epithelial cells of the proventriculus.