

A multi-tiered waterfall cascading over rocks in a lush green forest. The water flows over several levels of rock, creating a series of small pools and rapids. The surrounding vegetation is dense and vibrant green, with a large tree trunk visible on the right side of the frame.

# **Species and Genotypes of Cryptosporidium**

RON FAYER

USDA

AGRICULTURAL RESEARCH SERVICE

# WHAT IS A SPECIES?

**It is a** basic unit of biological classification and a taxonomic rank. A species is often defined as a group of organisms capable of interbreeding and producing fertile offspring. More precise or differing measures can be used, such as similarity of DNA, morphology or ecological niche.

Species that are believed to have the same ancestors are grouped together, as a genus.

All species have two part name (a "binomial name"). The first part of a binomial name is the genus of the species. The second part is the specific name.

For example, *Boa constrictor* which is commonly called by its binomial name, and is one of four species of the *Boa* genus.

The first part of the name is capitalized, and the second part has a lower case. The two part name is written in italics.

A photograph of a multi-tiered waterfall cascading over rocks in a lush green forest. The water is white and frothy as it falls, creating a misty atmosphere. The surrounding vegetation is dense and vibrant green. The waterfall flows into a pool of water at the bottom.

**What are the sources of  
Cryptosporidium?**











WOODCHUCK

FIELD MOUSE



VOLE



BEAVER

SKUNK





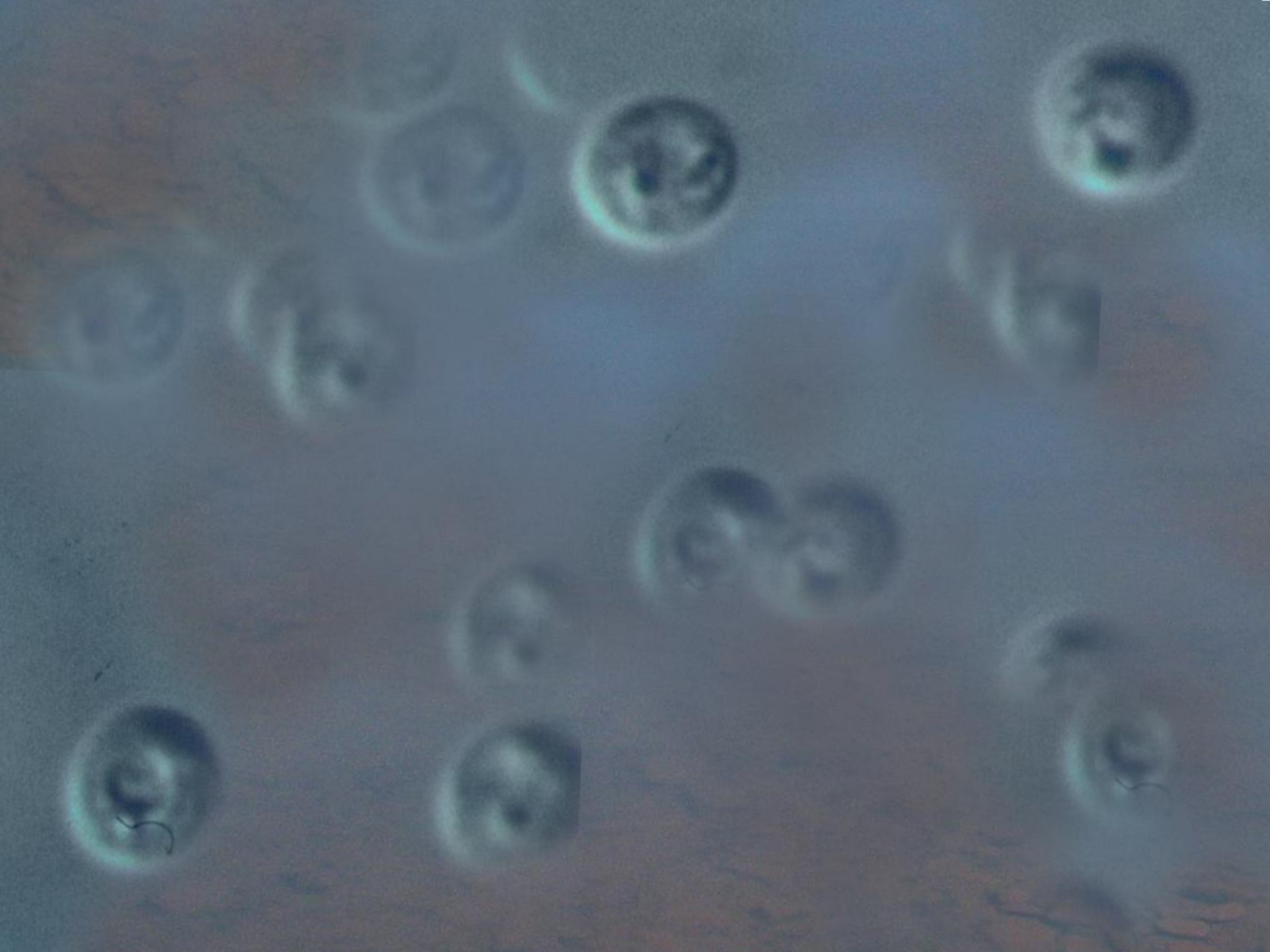












# More than 150 species of animals infected with *Cryptosporidium* spp.

## Order Artiodactyla

*Addax nasomaculatus* (Addax)

*Aepyceros melampus* (Impala)

*Ammotragus lervia* (Barbary sheep)

*Alces alces* (moose)

*Antidorcas marsupialis* (Springbok)

*Antilocapra americana* (Pronghorn)

*Antilope cervicapra* (Blackbuck)

*Axis axis* (Axis deer)

*Bison bison* (American bison)

*Bison bonasus* (European bison)

*Bos indicus* (Zebu)

*Bos taurus* (Ox)

*Boselaphus tragocamelus* (Nilgai)

*Bubalus bubalis* (Water buffalo)

*Bubalus depressicornis* (Lowland anoa)

*Camelus bactrianus* (Bactrian camel)

*Capra falconeri* (Turkomen markhor)

*Capra hircus* (Goat)

*Capreolus capreolus* (Roe deer)

*Cervus albirostris* (Thorold's deer)

*Cervus duvauceli* (Barasingha deer)

*Cervus elaphus* (Red deer/elk/wapiti)

*Cervus eldi* (Eld's deer)

*Cervus nippon* (Sika deer)

*Cervus unicolor* (Sambar)

*Connochaetes gnou* (Wildebeest)

*Connochaetes taurinus* (Blue-eared gnu)

*Dama dama* (Fallow deer)

*Elaphurus davidianus* (Pere David's deer)

*Gazella dama* (Addra gazelle)

*Gazella dorcas* (Dorca's gazelle)

*Gazella leptoceros* (Slender-horned gazelle)

*Gazella subgutterosa* (Persian gazelle)

*Gazella thomsoni* (Thomson's gazelle)

*Giraffa camelopardalis* (Giraffe)

*Hexaprotodom liberiensis* (Pygmy hippopotamus)

*Hippotragus niger* (Sable antelope)

*Kobus ellipsiprymnus* (Ellipsen waterbuck)

*Lama glama* (Llama)

*Lama guanicoe* (Guanaco)

*Muntiacus reevesi* (Muntjac deer)

*Odocoileus hemionus* (Mule deer)

*Odocoileus virginianus* (White-tailed deer)

*Oryx gazella callotys* (Fringe-eared oryx)

*Oryx gazella dammah* (Scimitar horned oryx)

*Ovis aries* (Sheep)

*Ovis musimon* (Mouflon)

*Ovis orientalis* (Urial)

*Sus scrofa* (Pig)

*Syncerus caffer* (African buffalo)

*Taurotragus oryx* (Eland)

*Tayassu tajacu* (Collared peccary)

*Tragelaphus eurycerus* (Bongo)

### **Order Carnivora**

*Acinonyx jubatus* (Cheetah)

*Canis familiaris* (Dog)

*Canis latrans* (Coyote)

*Felis catus* (Cat)

*Martes foina* (Beech marten)

*Meles meles* (Badger)

*Mephitis mephitis* (Striped skunk)

*Mustela putorius* (Ferret)

*Mustela vison* (American mink)

*Lontra canadensis* (river otter)

*Panthera pardus* (Leopard)

*Procyon lotor* (Raccoon)

*Urocyon cinereoargenteus* (Grey fox)

*Ursus americanus* (Black bear)

*Ursus arctos* (Brown bear)

*Ursus (Thalarctos) maritimus* (Polar bear)

*Vulpes vulpes* (Red fox)

*Zalophus californianus* (California sea lion)

### **Order Chiroptera**

*Eptesicus fuscus* (Big brown bat)

*Myotis adversus* (Large-footed mouse-eared bat)

### **Order Insectivora**

*Ateletrix albiventris* (African hedgehog)

*Crocidura russula* (Greater white-toothed shrew)

*Erinaceus europaeus* (European hedgehog)

*Sorex araneus* (Long-tailed shrew)

*Sorex minutus* (Pygmy shrew)

### **Order Lagomorpha**

*Oryctolagus cuniculus* (Rabbit)

*Sylvilagus floridanus* (Cottontail)



## **Order Marsupialia**

*Antechinus stuartii* (Brown antechinus)

*Didelphis virginiana* (Opossum)

*Isodon obesulus* (Southern brown bandicoot)

*Macropus giganteus* (Eastern grey kangaroo)

*Macropus rufogriseus* (Red neck wallaby)

*Macropus rufus* (Red kangaroo)

*Phascolarctos cinereus* (Koala)

*Thylogale billardierii* (Pademelon)

*Trichosurus vulpecula* (Brushtail possum)

## **Order Perissodactyla**

*Ceratotherium simum* (Southern white rhinoceros)

*Equus caballus* (Horse)

*Equus przewalski* (Miniature horse)

*Equus zebra* (Zebra)

*Rhinoceros unicornis* (Rhinoceros)

*Tapirus terrestris* (Brazilian tapir)

## **Order Primates**

*Ateles belzebuth* (Marimonda spider monkey)

*Calithrix jacchus* (Common marmoset)

*Cercopithecus campbelli* (Campbell's mona)

*Cercopithecus talapoin* (Talapoin monkey)

*Cercocebus albigena* (Mangabey)

*Cercocebus torquatus* (White-collared monkey)

*Cercopithecus aethiops* (Velvet monkey)

*Erythrocebus patas* (Patas monkey)

*Eulemur macaco* (Black lemur)

*Gorilla gorilla* (Gorilla)

*Homo sapiens* (Humans)

*Hylobates syndactylus syndactylus* (Siamang)

*Lemur catta* (Ring-tailed lemur)

*Lemur macacomayottensis* (Brown lemur)

*Lemur variegatus* (Ruffed lemur)

*Macaca fascicularis* (Long-tailed macaque)

*Macaca fuscata* (Japanese macaque)

*Macaca mulatta* (Rhesus monkey)

*Macaca nemestrina* (pigtail macaque)

*Macaca radiata* (Bonnet macaque)

*Macaca thibetana* (Pere David's macaque)

*Mandrillus leucophaeus* (Drill)

*Nycticebus pygmaeus* (Lesser slow loris)

*Papio anubis* (Olive baboon)

*Papio cynocephalus* (Baboon)

*Pithecia pithecia* (White-faced saki)

*Pongo pygmaeus* (Orangutan)

*Saguinus oedipus* (Cotton-topped tamarin)

*Saimiri sciureus* (Squirrel monkey)

*Varecia variegata* (Red-ruffed lemur)

## **Order Rodentia**

*Apodemus agrarius* (Field mouse)

*Apodemus flavicollis* (Field mouse)

*Apodemus sylvaticus* (Field mouse)

*Castor canadensis* (Beaver)

*Castor fiber* (European beaver)

*Cavia porcellus* (Guinea pig)

*Chinchilla laniger* (Chinchilla)

*Clethrionomys glareolus* (Red-backed vole)

*Coendou prehensilis* (ring tailed porcupine)

*Geomys bursarius* (Pocket gopher)

*Glaucomys volans* (Flying squirrel)

*Hystrix indica* (Indian porcupine)

*Marmota monax* (Woodchuck)

*Mesocricetus auratus* (Golden hamster)

*Microtus agrestis* (Field vole)

*Microtus arvalis* (Orkney vole)

*Mus musculus* (House mouse)

*Myocastor coypus* (Coypu)

*Ondatra zibethicus* (Muskrat)

*Rattus norvegicus* (Norwegian rat)

*Rattus rattus* (House rat)

*Sciurus carolinensis* (Gray squirrel)

*Sciurus niger* (Fox squirrel)

*Sigmodon hispidus* (Cotton rat)

*Spermophilus beecheyi* (California ground squirrel)

*Spermophilus tridecemlineatus*

(13-lined ground squirrel)

*Mus spretus* (Western Mediterranean mouse)

*Tamias sibiricus* (Siberian chipmunk)

*Tamias striatus* (Chipmunk)

## **Order Monotremata**

*Tacyglossus aculeatus* (Echidna)

## **Order Proboscidea**

*Elephas maximus* (Indian elephant)

*Loxodonta africana* (African elephant)

## **Order Sirenia**

*Dugong dugon* (Dugong)

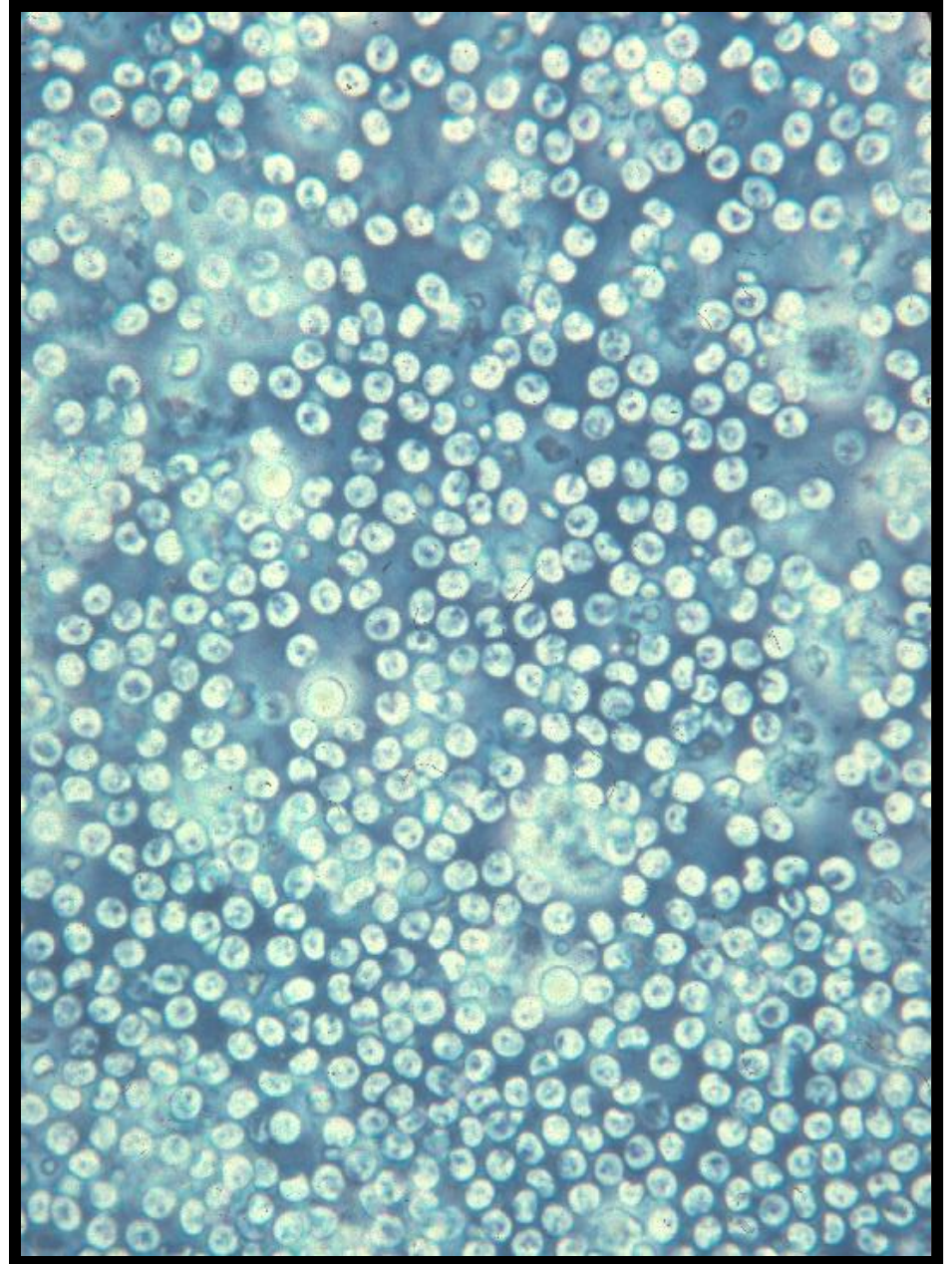
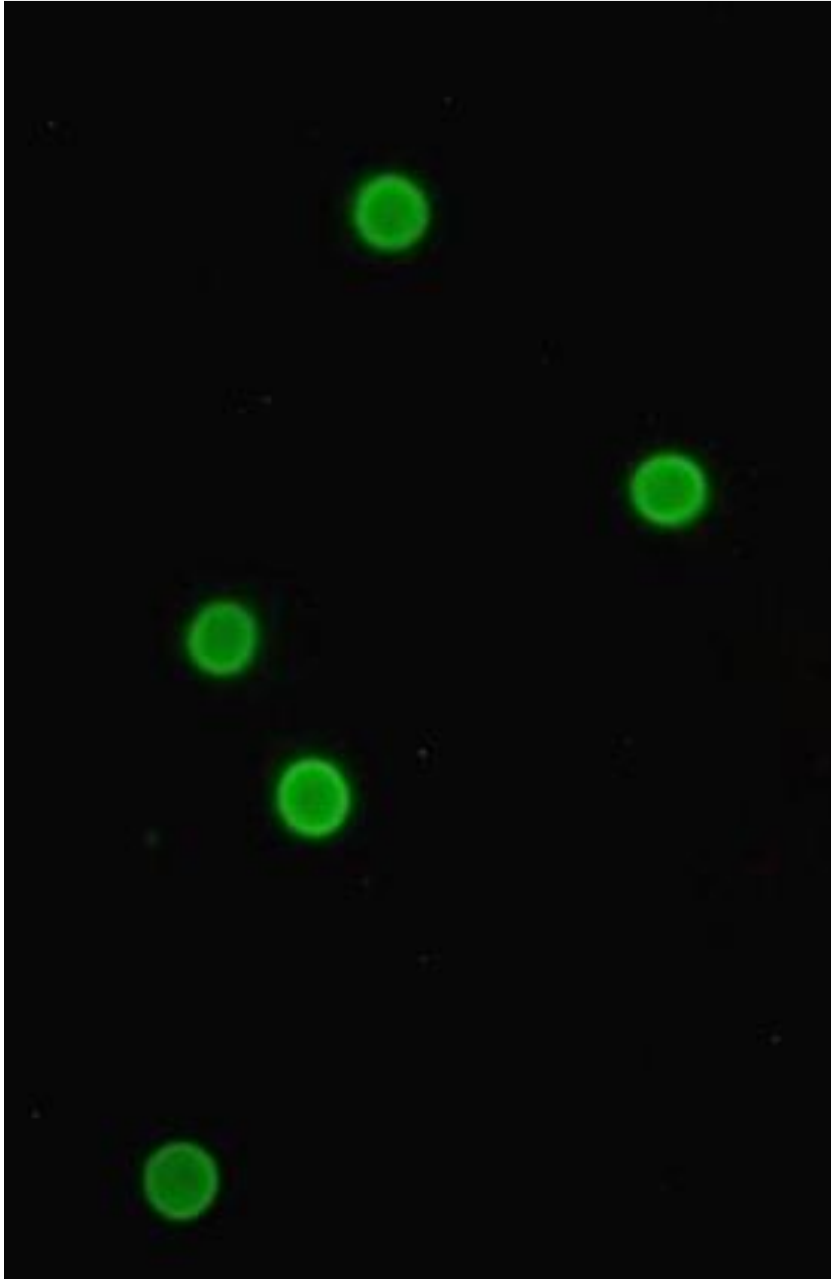
## **Order Pinnipedia**

*Mirounga leonina* (Southern elephant seal)

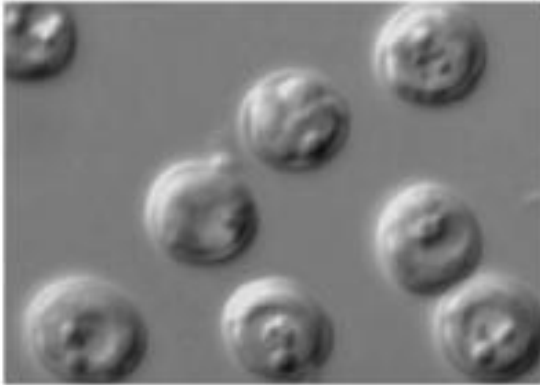
*Phoca hispida* (Ringed seal)

*Zalophus californianus* (California sea lion)

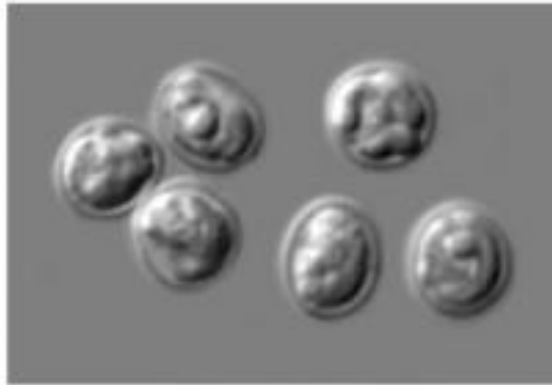
# MICROSCOPIC BASIS FOR DETECTION OF CRYPTOSPORIDIUM



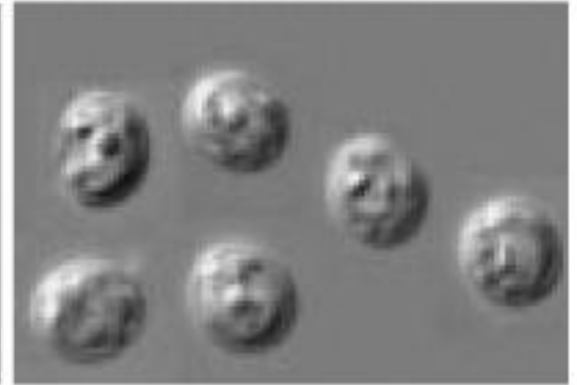
## SELECTED SPECIES OF CRYPTOSPORIDIUM



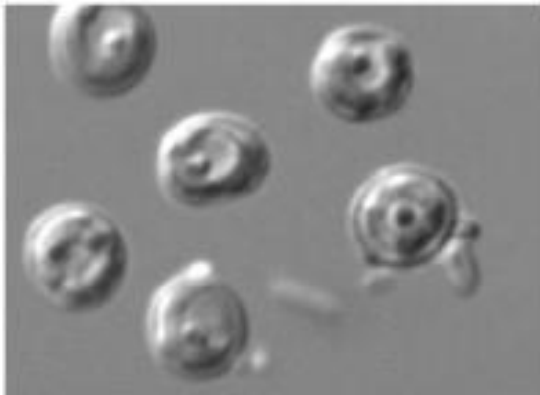
*C. parvum*



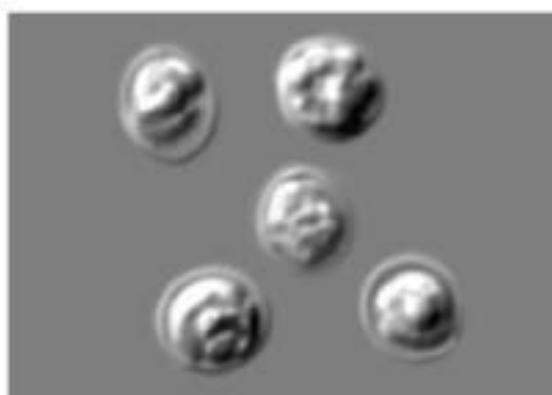
*C. hominis*



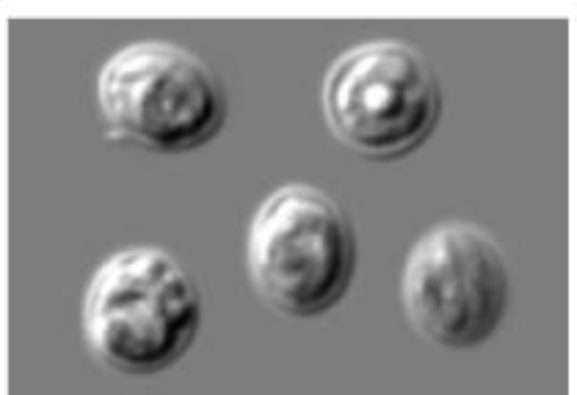
*C. meleagridis*



Pig genotype I



*C. saurophilum*



Opossum genotype I

*Modified from Xiao et al. (2004)*

Parasite	No. of oocysts measured	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )	L:W Ratio
		Mean	Mean	Mean
<i>C. parvum</i>	44	4.85	4.39	1.11
<i>C. hominis</i>	44	4.91	4.28	1.15
<i>C. meleagridis</i>	55	4.93	4.40	1.12
Pig genotype I	56	5.05	4.41	1.15
<i>C. saurophilum</i>	20	4.94	4.49	1.14
Opossum genotype I	55	5.26	4.38	1.20
Greatest Size Differences		0.41 $\mu\text{m}$	0.21 $\mu\text{m}$	0.09

**Modified from Xiao et al. (2004)**

# ***SPECIES OF CRYPTOSPORIDIUM***

*(based on oocyst morphology, molecular, and host specificity data)*

## **FISH**

*C. scophthalmi*

*C. molnari*

## **REPTILES/ AMPHIBIANS**

*C. serpentis*

*C. varanii*

*C. ducimari*

*C. fragile*

## **BIRDS**

*C. meleagridis*

*C. baileyi*

*C. galli*

## **MAMMALS**

*C. hominis*

*C. parvum*

*C. ubiquitum*

*C. felis*

*C. canis*

*C. muris*

*C. suis*

*C. cuniculus*

*C. andersoni*

*C. fayeri*

*C. macropodum*

*C. xiaoi*

*C. ryanae*

*C. bovis*

*C. wrairi*

*C. tyzzeri*

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*C. wrairi*

*C. tyzzeri*

# Genotypes of *Cryptosporidium*

## 39 selected genotypes

C. sp. Bear	C. sp. Pig II
C. sp. Deer	C. sp. Raccoon
C. sp. Deer mice	C. sp. Rat I, II, III
C. sp. Duck	C. sp. Seal 1 and 2
C. sp. Ferret C. sp. Goat	C. sp. Sheep novel genotype (Chalmers et al and Ryan et al)
C. sp. Fox and Fox II	C. sp. Chipmunk I, II, III
C. sp. Goose I and II	C. sp. Shrew
C. sp. Hamster	C. sp. Skunk
C. sp. Horse	C. sp. Snake
C. sp. Mongoose	C. sp. Caribou (gastric)
C. sp. Monkey	C. sp. Lizard (gastric)
C. sp. Muskrat I and II	C. sp. Tortoise (gastric)
C. sp. Opossum I and II	C. sp. Woodcock (gastric)
C. sp. Ostrich	C. muris Japanese field mouse



# Most human infections are caused by *C. hominis* and *C. parvum*

12 other species or genotypes also detected  
in immunocompetent and/or immunocompromised humans:

*C. meleagridis*

*C. felis*

*C. canis*

*C. suis*

*C. muris*

*C. andersoni*

*C. ubiquitum*

*C. cuniculus*

*C. fayeri*

and the horse, skunk, and monkey genotypes

## ***PROCESS OF NAMING A SPECIES OF CRYPTOSPORIDIUM***

- 1- Morphometric studies of oocysts
- 2- Genetic characterizations
- 3- Demonstration of natural and, when possible, at least some experimental host specificity
- 4- Compliance with ICZN

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# ***GENETIC CHARACTERISTICS***

**8 CHROMOSOMES**

**10.4 Mb**

**SSUrRNA** (Small sub unit ribosomal RNA)

**COWP** (Crypto oocyst wall protein)

**ACTIN**

**HSP** (heat shock proteins)

**TRAP C-1, C-2** (thrombospondin related adhesive proteins)

**$\beta$ -TUBULIN**

**GP60** (Glyco protein)

**GP40/15**

**ACETYL COA**

**DHFR** (dihydrate folate reductase)

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# SUBTYPING

Based on sequence analysis of the 60-kDa glycoprotein (gp60) gene

Used in tracking the transmission of six *Cryptosporidium* species and genotypes, including *C. hominis*, *C. parvum*, *C. meleagridis*, *C. fayeri*, and the rabbit and horse genotypes

There are at least 10 gp60 subtype families of *C. parvum*, two (IIa and IIId) of which are involved in zoonotic transmission

## THE WATERWORKS FLU

**A tiny parasite gets the blame for making thousands of Milwaukeeans miserable**

By J. MADELEINE NASH CHICAGO

ONLY THE MICROBIOLOGISTS WERE happy last week as Milwaukee turned into a huge laboratory. Anyone who

first outbreak of cryptosporidiosis in this country, nor is it likely to be the last. Indeed, Walter Jakubowski, a parasitology expert for the Environmental Protection Agency, believes that most surface water is now contaminated with the parasite. "It's so widespread," he says, "that you just can't keep your hands clean."

located about three miles away from the river's mouth. Possibly a major problem, experts say, is the lack of filtration.

any cryptosporidiosis (parasite versions of the pesky protozoan can be removed only through filtration. Unlike bacteria, they are not readily killed by chlorine. Furthermore, the tests that water-purification plants routinely rely on to

MILWAUKEE  
409,000 PEOPLE INFECTED  
*C. hominis*



Municipal water was taboo, so city residents lined up to fill jugs with clean well water



# *Cryptosporidium hominis*



Humans  
Baboons  
Cattle \*  
Sheep\*\*  
Pigs\*\*  
Dugong

\* natural and experimental

\*\* experimental

# *Cryptosporidium parvum*



## Humans

## Domesticated animals:

Cattle      Sheep      Mice

Rats      Rabbits

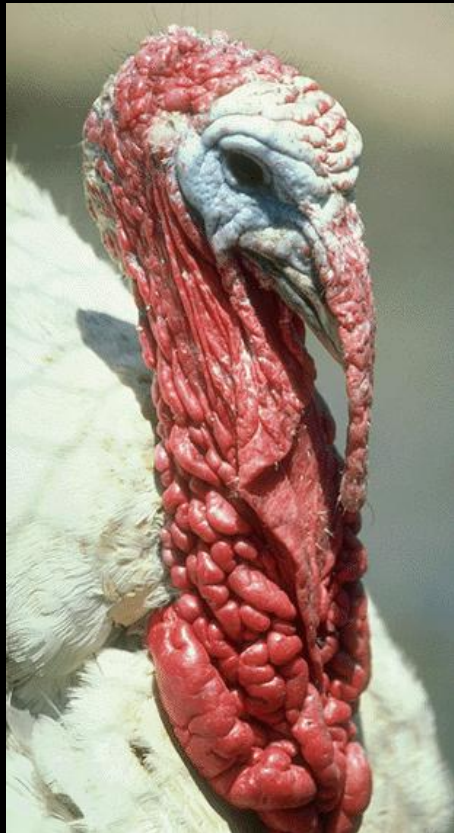
## Wild animals:

White tail deer      Mice

Wildebeest

# *Cryptosporidium meleagridis*

## HOSTS



Turkey

Human\*

Chicken

Parrots

Rats

Cattle

Cockatiels

Rabbits

Pigs

Mice

MOST OFTEN

\* 3<sup>rd</sup> most prevalent spp. in humans

\* IMMUNOCOMPETENT 36%

\* IMMUNOCOMPROMISED 64%

# *Cryptosporidium felis*



HOSTS:

CAT

HUMAN\* 97 cases

COW

\*Lucio-Forster et al. 2010 Trends in Parasitology 26:174

Estimated 70 million feral and homeless stray cats in the US

The Humane Society Jan 2011

# *Cryptosporidium canis*



HOSTS:

DOGS      COYOTES

FOXES      CATTLE

HUMANS\*      28 cases

\*Lucio-Forster et al. 2010  
Trends in Parasitology 26:174

~75 million dogs in US homes, no. of feral dogs unknown



# *Cryptosporidium muris*

MICE

RATS

RABBITS

GERBILS

GUINEA PIGS

DOGS

CAMEL

CALVES

HUMANS

(immunocompromised)

# *Cryptosporidium ubiquitum* (formerly: cervine genotype)



HUMANS\*

SHEEP

BLESBOK

MOUFLON

BEAVER

CHIPMUNK

RACCOON

SQUIRREL

LEMURS

CATTLE

IBEX

MICE

WHITE TAIL DEER

SIKA DEER

BOER GOAT

NYALA

GERBILS

WOODCHUCK

DEER MOUSE

COENDU

\* 9 immunocompetent

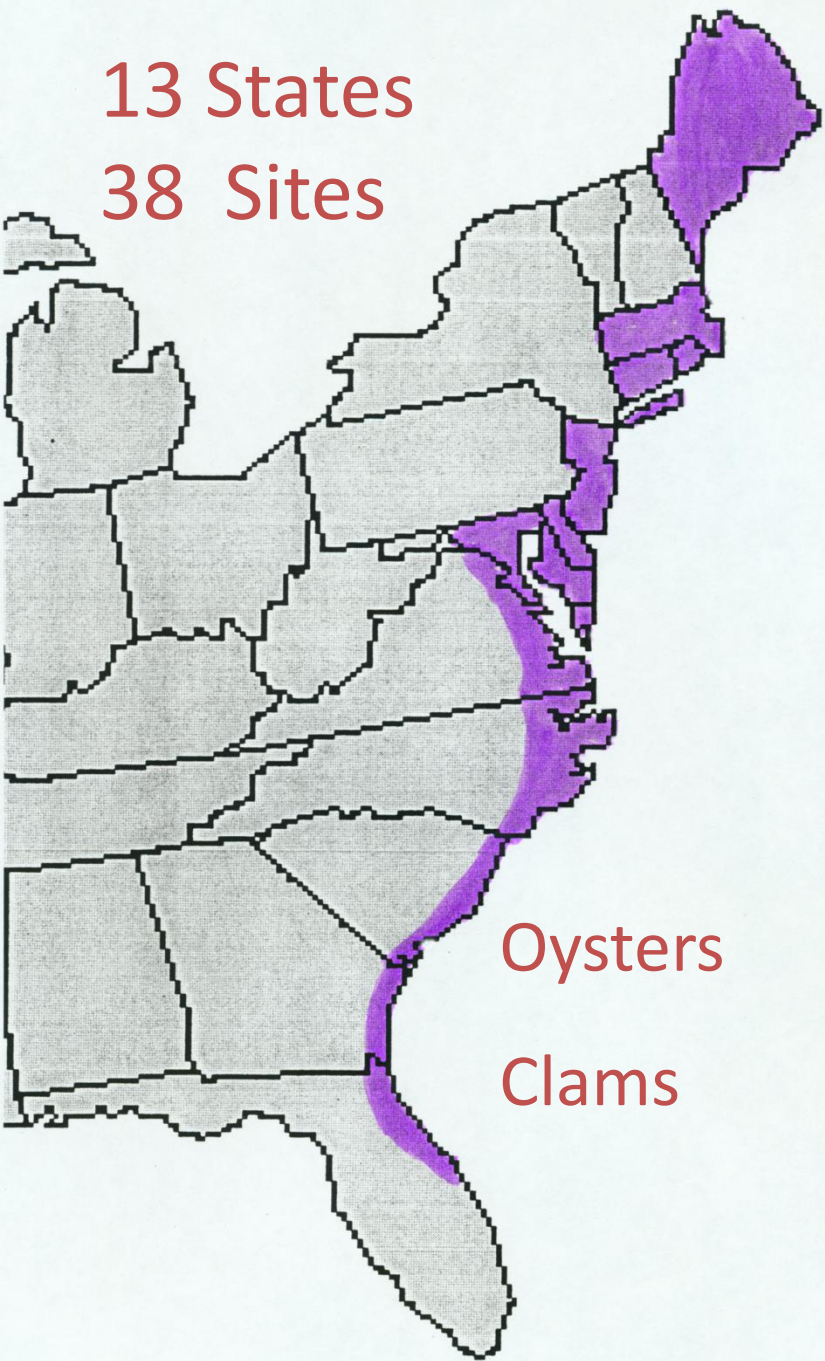
# > 500 Wild Animal Samples from Chesapeake Watershed

<u>Species</u>	<u>Crypto</u>	<u>Zoonotic</u>
Beaver	1%	
Muskrat	11%	
Otter	0%	
Fox	8%	<i>C. canis</i> (5)
Raccoon	4%	<i>C. sp.</i> skunk (2)
White-tailed Deer	58%	



13 States

38 Sites



Oysters

Clams

## SHELLFISH

	IFA	PCR
Maine	+	+
Massachusetts	+	+
Connecticut	+	+
Rhode Island	+	+
New York	+	-
New Jersey	+	+
Delaware	-	-
Maryland	+	+
Virginia	+	+
North Carolina	+	-
South Carolina	+	-
Georgia	-	-
Florida	+	+

Site	Province or State	Oyster or Clam	Collection Location	No. Positive		Species/genotype
				IFA	PCR	
1	New Brunswick	O	NW Gulf of St. Lawrence	3/25	1/5	<i>C. parvum</i>
3	Maine	O	Blue Hill Bay	1/25	2/5	<i>C. hominis</i>
4	Maine	O	Piscataqua River (Conn.)	1/25	1/5	<i>C. parvum</i>
5	Mass.	O	Cape Cod Bay	1/25	5/5	<i>C. parvum</i> <i>C. meleagridis</i>
6	Mass.	O	South Cape Cod	2/25	5/5	<i>C. parvum</i>
7	Mass.	C	South Cape Cod	0/25	5/5	<i>C. parvum</i> <i>C. meleagridis</i>
8	Mass.	C	South Cape Cod	0/25	5/5	<i>C. parvum</i>
9	Rhode Island	O	Upper Narragansett Bay	1/25	2/5	<i>C. parvum</i>
13	Connecticut	O	Long Island Sound, Norwalk	0/25	1/5	<i>C. hominis</i> <i>C. meleagridis</i>
14	Connecticut	C	Long Island Sound, Milford	0/25	1/5	<i>C. hominis</i> <i>C. meleagridis</i>
21	New Jersey	C	Great Egg Harbor	1/25	1/5	<i>C. parvum</i>
25	Maryland	O	Big Choptank River	0/25	1/5	<i>C. parvum</i>
26	Virginia	O	James River	0/25	1/5	<i>C. parvum</i>
37	Fla.	O	Inter Coastal Waterway, St. Augustine	0/25	1/5	<i>C. parvum</i>

CRYPTO  
IN U.S.  
COASTAL  
WATERS

Fayer et al 2003.  
Parasitol Res 89:141.

# SUMMARY

DEFINITION OF SPECIES

SOURCES OF WATERBORNE CRYPTOSPORIDIUM

➤ 150 HOSTS

NAMES OF CRYPTOSPORIDIUM SPECIES AND GENOTYPES

THE NAMING PROCESS

CRYPTO GENES USED FOR SPECIATION

7 SELECTED SPECIES AND THEIR HOST RANGES

WILDLIFE IN WETLAND AREAS DRAINING INTO CHESAPEAKE BAY

ATLANTIC COAST SHELLFISH CONTAMINATED WITH  
CRYPTOSPORIDIUM