

Cyclospora

(protist: apicomplexan)

Overview

Protists are single-celled organisms with membrane-bound nuclei (eukaryotes). One protistan supergroup known as SAR comprises the Stramenopiles (with heterokont flagella), Alveolata (with cortical alveoli) and Rhizaria (with fine pseudopodia). Three major alveolate groups are recognized: ciliates, apicomplexans and dinoflagellates. Apicomplexan cells possess a distinctive apical complex of organelles, comprising a conoid, polar ring, rhoptries, micronemes and subpellicular microtubules, which facilitate entry into host cells as they are obligate intracellular parasites for most of their life-cycles. There are three main apicomplexan groups: gregarines, coccidia and haematozoa. Coccidia form non-motile resistant oocysts that contain infective sporozoites usually confined within secondary spores (sporocysts). Enteric coccidia are monoxenous (1-host) parasites in the digestive tracts of vertebrates. They undergo three sequential developmental stages: endogenous multiplication by asexual merogony (= schizogony) followed by sexual gamogony (male microgametes fertilize female macrogametes) producing oocysts which undergo asexual sporogony (sporozoite formation). *Cyclospora* oocysts contain two sporocysts each with two sporozoites (1:2:2 configuration). Infections have been reported in various animals, with one species infecting humans and causing acute diarrhoeal disease.

Classification:

Domain: Eukaryota (membrane-bound nucleus)
Supergroup: SAR (Stramenopiles + Alveolata + Rhizaria)
Group: Alveolata (with cortical alveoli)
Phylum: Apicomplexa (with apical complex, all parasitic, sexual development (gamogony))
Class: Coccidiomorpha [Coccidiasida] (with conoid)
Subclass: Coccidia [Coccidiasina] (small intracellular gamonts)
Order: Eucoccidiorida (cyclic merogony (schizogony), gamogony, sporogony)
Suborder: Eimeriorina (no syzygy, many microgametes)
Family: Eimeriidae (monoxenous, endogenous intracellular merogony and gamogony, exogenous sporogony)
Genus: *Cyclospora* (parasitic in gut of mammals and reptiles)
Species: *C. cayetanensis* (causes diarrhoea in humans)

Parasite biodiversity and host range: Protists are unicellular eukaryotes that move using undulipodia (flagella or cilia), pseudopodia (false-feet) or a unique gliding motion. Cells with different modes of locomotion do not form separate monophyletic assemblages as previously thought, but rather are distributed across several disparate supergroups (as evidenced by recent molecular phylogenetic analyses). One protistan supergroup known as SAR comprises the Stramenopiles (with heterokont flagella), Alveolata (with cortical alveoli) and Rhizaria (with fine pseudopodia). Three diverse alveolate groups are recognized: Ciliophora (with cilia), Dinoflagellata (with flagella) and Apicomplexa (with gliding motion, some also with flagellated microgametes). Over 4,000 species of Apicomplexa have been described as obligate parasites from vertebrate and invertebrate hosts. At some stage in their development, these possess unique cytoskeletal and membrane-bound organelles (conoid, rhoptries, micronemes, subpellicular microtubules) forming an apical complex that facilitates host cell invasion. Apicomplexans undergo cyclic development involving up to three different divisional processes: asexual merogony (schizogony) either by fission (splitting of maternal cell) or endogony (internal formation of daughter cells); gamogony involving formation of gametes (macrogametes = female, microgametes = male) which undergo fertilization to recombine by fusion (syngamy) with or without paired alignment (syzygy); and sporogony (formation of infective sporozoites).

Three main apicomplexan groups are recognized: haematozoa, gregarines, and coccidia. Haematozoa are small blood-borne parasites in vertebrates which complete their development in blood-sucking invertebrate vectors; with pleomorphic haemosporidia being transmitted by insects and pear-shaped piroplasms being transmitted by ticks. Gregarines are lumen-dwelling parasites that form large extracellular (sometimes septate) gamonts with an anterior holdfast organelle (mucron or epimerite) used to attach to the gut or body cavity of invertebrates. Coccidia are tissue-invading parasites that form small intracellular gamonts (lacking a mucron or epimerite) and most species undergo sexual reproduction by anisogamous fusion without syzygy forming non-motile resistant spores (oocysts) containing infective sporozoites usually confined within secondary spores (sporocysts). Three groups of coccidia are recognized: coelotrophiid coccidia in marine annelids; adeleid coccidia in marine and terrestrial animals (including blood parasites paradoxically known as 'haemogregarines' in reptiles and amphibians with leech or arthropod vectors); and eimeriid coccidia in vertebrates. Many eimeriid coccidia are monoxenous gut parasites undergoing faecal-oral transmission, but some are heteroxenous alternating between enteric stages in predators and encysted stages in prey (there are also a few enigmatic 'haemococcidia' in the blood of reptiles and birds).

Higher taxonomy	Family	Genera	Hosts	Site	Transmission*
Class: Gregarinomorpha (gregarines, trophonts with specialized attachment epimerite or mucron, syzygy)					
Subclass: Cryptogregaria (epicellular parasites of vertebrates with feeder organelle but lacking apicoplast)					
	Cryptosporidiidae (naked sporozoites)	<i>Cryptosporidium</i>	vertebrates	gut, lungs	direct (f-o)
Class: Coccidiomorpha [Conoidasida] (with conoid)					
Subclass: Coccidia [Coccidiasina] (small intracellular gamonts)					
Order: Eucoccidiorida (cyclic merogony (schizogony), gamogony, sporogony)					
Suborder: Adeleina (syzygy, 1-4 microgametes)	Haemogregarinidae (ookinete, gamonts in blood cells, invertebrate vectors)	<i>Haemogregarina</i>	reptiles, amphibia, fish	tissues, blood	indirect (v-b)
		<i>Hepatozoon</i>	mammals, reptiles	tissues, blood	indirect (v-b)
	Klossiellidae (sporocysts)	<i>Klossiella</i>	mammals	kidney	direct (f-o)
Suborder: Eimeriorina (no syzygy, >4 microgametes)	Eimeriidae (monoxenous, endogenous merogony and gamogony, exogenous sporogony)	<i>Caryospora</i>	birds, reptiles	gut	direct (f-o)
		<i>Cyclospora</i>	mammals, reptiles	gut	direct (f-o)
		<i>Isospora</i>	birds, reptiles	gut	direct (f-o)
		<i>Eimeria</i>	vertebrates	gut, tissues	direct (f-o)
		<i>Epieimeria</i>	fish	gut	direct (f-o)
		<i>Goussia</i>	fish	gut	direct (f-o)
	Sarcocystidae (heteroxenous, 1:2:4 oocyst:sporocyst:sporozoite configuration)				
subfamily Cystoisosporinae (monozoic cysts)	<i>Cystoisospora</i> (no Stieda bodies)	carnivores, omnivores	gut, tissues	direct (f-o), indirect (p-p)	
subfamily: Sarcocystinae (thick-walls, metrocytes)	<i>Sarcocystis</i> (<i>Frenkelia</i>)	mammals, birds, reptiles	gut, muscles	indirect (p-p)	
subfamily: Toxoplasmatinae (thin-walled cysts without metrocytes)	<i>Besnoita</i>	mammals, reptiles	gut, tissues	indirect (p-p)	
	<i>Hammondia</i>	mammals	gut, tissues	indirect (p-p)	
	<i>Neospora</i>	herbivores, dogs	gut, tissues	indirect (p-p)	
	<i>Toxoplasma</i>	vertebrates, cats	gut, tissues	indirect (p-p)	
Class: Aconoidasida (asexual stages without conoid)					
Subclass: Haematozoa (clade of vector-borne spore-forming haemo-protozoa)					
Order: Haemosporida (pleomorphic blood stages, insect vectors, motile ookinete)	Plasmodiidae (schizogony in tissues then blood cells, haemozoin pigment)	<i>Plasmodium</i>	mammals, birds, reptiles	liver, erythrocytes	indirect (v-b)
	Haemoproteidae (schizogony in tissues, haemozoin pigment)	<i>Haemoproteus</i>	birds	endothelia, erythrocytes	indirect (v-b)
	Leucocytozoidae (schizogony in tissues, no haemozoin pigment)	<i>Leucocytozoon</i> (<i>Akiba</i>)	birds	tissues, leucocytes	indirect (v-b)
Order: Piroplasmorida (pear-shaped blood stages, tick vectors)	Babesiidae (merogony in erythrocytes, trans-stadial + trans-ovarian transmission)	<i>Babesia</i>	mammals	erythrocytes	indirect (v-b)
	Theileriidae (merogony in leucocytes, trans-stadial transmission in ticks)	<i>Theileria</i>	ruminants	leucocytes, erythrocytes	indirect (v-b)

* f-o = faecal-oral transmission; p-p = predator-prey transmission; v-b = vector-borne transmission.

Numerous species of eimeriid coccidia have been described from a wide range of vertebrate and invertebrate hosts. Some 50 genera have been classified in 11 families in the suborder Eimeriorina, including 21 genera in the family Eimeriidae. Most genera are characterized by the formation of oocysts with unique configurations in terms of the numbers of contained sporocysts and sporozoites. The genus *Cyclospora* forms oocysts with a 1:2:2 configuration; that is, oocysts are disporocystic (contain 2 sporocysts) and each sporocyst is disporozoic (contains 2 sporozoites).

Parasite genera	No. spp.	Life-cycle	Hosts	Oocyst configuration
Family: EIMERIIDAE				
<i>Diaspora</i>	1	monoxenous	invertebrates (arthropods)	0:1:1
<i>Tyzzeria</i>	12	monoxenous	vertebrates (birds, reptiles)	1:0:8
<i>Pfeifferinella</i>	6	monoxenous	invertebrates (molluscs, priapulids)	1:0:8-14
<i>Alveocystis</i>	4	monoxenous	invertebrates (molluscs, priapulids)	1:0:8-14
<i>Mantonella</i>	5	monoxenous	invertebrates (panarthropods), vertebrates (turtles, rodents, birds, some possibly pseudoparasites)	1:1:4
<i>Caryospora</i>	70	monoxenous	vertebrates (birds, reptiles)	1:1:8
<i>Cyclospora</i>	19	monoxenous	vertebrates (mammals)	1:2:2
<i>Dorisa</i>	13	monoxenous	vertebrates (reptiles, mammals)	1:2:8
<i>Isospora</i>	360	monoxenous	vertebrates (mammals, birds, reptiles, fish), invertebrates (molluscs)	1:2:4
<i>Sivatoshella</i>	1	monoxenous	vertebrates (birds)	1:2:16
<i>Eimeria</i>	1,700	monoxenous	vertebrates (mammals, birds, reptiles, fish), invertebrates (arthropods, annelids, hemichordates, protochordates)	1:4:2
<i>Epieimeria</i>	3	monoxenous	vertebrates (fish)	1:4:2
<i>Choleoimeria</i>	16	monoxenous	vertebrates (reptiles)	1:4:2
<i>Wenyonella</i>	18	monoxenous	vertebrates (mammals, birds, reptiles)	1:4:4
<i>Margolisiella</i>	6	monoxenous	invertebrates (molluscs)	1:n:2-4
<i>Octosporella</i>	6	monoxenous	vertebrates (fish, reptiles, echidnas, some possibly pseudoparasites)	1:8:2
<i>Gousseffia</i>	1	monoxenous	vertebrates (hedgehogs, possibly pseudoparasites)	1:8:n
<i>Polysporella</i>	1	monoxenous	vertebrates (birds, possibly pseudoparasites)	1:9-15:2
<i>Skrjabinella</i>	1	monoxenous	vertebrates (rodents, possibly pseudoparasites)	1:16:1
<i>Hoarella</i>	1	monoxenous	vertebrates (lizards)	1:16:2
<i>Pythonella</i>	3	monoxenous	vertebrates (reptiles, birds)	1:16:4

Around 19 *Cyclospora* spp. have been described in millipedes, insectivores, moles, rodents, reptiles (mostly snakes) and primates, including humans. *C. cayentanensis* is the only species found in humans. Its identity was unclear for many years and infections were reported as CLBs: an acronym for coccidia-like bodies (sometimes mistaken for large *Cryptosporidium*) or cyanobacterium-like bodies (once called blue-green algae). The coccidial nature of CLBs was subsequently demonstrated by ultrastructural and molecular characterization studies. *C. cayentanensis* differs from most other *Cyclospora* species in that its oocysts are smaller and spherical rather than oblong. The detection of similar species in non-human primates (*C. cercopitheci* in green monkeys, *C. colobi* in colobus monkeys, and *C. papionis* in baboons) suggested that two species groups may exist: those that infect primates and produce small spherical oocysts; and those that infect insectivores and rodents and form large oblong oocysts. All species described to date are thought to be highly host specific and experimental studies attempting to cross-transmit isolates between a variety of animals and humans have proven unsuccessful. Epidemiological studies have not implicated any animal species as reservoirs of human infection, despite the occasional detection of *Cyclospora* oocysts in the faeces of asymptomatic domestic animals (ducks, chickens and dogs) in endemic areas (their occurrence is thought to be due to high environmental contamination). While *C. cayentanensis* has been found worldwide in developed and developing countries and in urban and rural areas, it is most common in tropical and subtropical areas, particularly Latin America, the Indian subcontinent, and Southeast Asia.

<i>Cyclospora</i> species*	Oocyst size (µm)	Hosts	Location	Clinical signs	Distribution
<i>C. angimurinensis</i>	22 x 19	Rodentia: heteromyid (hispid pocket mouse)	jejunum		North America
<i>C. ashtabulensis</i>	18 x 14	Eulipotyphla: talpid (hairy-tailed mole)	jejunum		North America
<i>C. caryolytica</i>	18 x 12	Eulipotyphla: talpid (European mole, eastern mole, hairy-tailed mole)	small and large intestines (intranuclear)		Europe
<i>C. cayentanensis</i>	10 x 8	Primates: hominid (human, chimpanzee, baboon)	small intestines	watery diarrhoea	cosmopolitan
<i>C. cercopitheci</i>	8-10	Primates: cercopithecid (African green monkey)	duodenum/jejunum		Africa

<i>C. colobi</i>	8-9	Primates: cercopithecid (colobus monkey)	duodenum/jejunum		Africa
<i>C. duszynskii</i>	11 x 10	Eulipotyphla: talpid (eastern mole)	intestines		North America
<i>C. glomericola</i> (type species)	30 x 9	Diplopoda: glomerid (pill millipede)	intestines		Europe
<i>C. macacae</i>	8-9	Primates: cercopithecid (rhesus macaque, crab-eating macaque)	intestines		China
<i>C. megacephali</i>	19 x 16	Eulipotyphla: talpid (eastern mole)	jejunum		North America
<i>C. niniae</i>	15 x 13	Serpentes: colubrid (redback coffee snake)	small intestines	gut destruction	Central America
<i>C. papionis</i>	8-10	Primates: cercopithecid (olive baboon)	duodenum/jejunum		Africa
<i>C. parascalopi</i>	17 x 14	Eulipotyphla: talpid (hairy-tailed mole)	jejunum		North America
<i>C. schneideri</i>	20 x 17	Serpentes: aniliid (coral cylinder snake)	small intestines	nonpathogenic	South America
<i>C. scinci</i>	10 x 7	Sauria: scincid (sandfish skink)	small intestine		Egypt
<i>C. talpae</i>	14 x 10	Eulipotyphla: talpid (European mole)	liver, bile ducts		Europe
<i>C. viperae</i> (syn. <i>C. babaulti</i>)	17 x 10	Serpentes: viperid (European asp viper, northern viper, smooth snake)	small intestines		Europe
<i>C. yatesi</i>	17 x 15	Eulipotyphla: talpid (eastern mole)	intestines		North America
<i>C. zamenis</i> (syn. <i>C. tropidonoti</i>)	17 x 10	Serpentes: colubrid (green whip snake, common grass snake, Indian grass snake)	small intestines		Eurasia

*Un-named species of *Cyclospora* have also been reported from various hosts: including non-human primates (macaques, drills, vervets, howlers, baboons), carnivores (dogs), artiodactyls (bovids), rodents (rats, mice), birds (chickens, crows), insects (cockroaches) and molluscs (shellfish).

Parasite morphology: *Cyclospora* spp. form 3 different developmental stages: meronts (forming merozoites), gamonts (forming male and female gametes); and oocysts (forming sporocysts containing sporozoites). Meronts (sometimes called schizonts) appear as pleomorphic basophilic stages measuring ~15-20 µm in diameter. As they mature, they divide internally to form multiple slender merozoites. Two types of meronts are formed: type I meronts (first generation) producing 8-12 small merozoites ranging in size from 3-4 x 0.5 µm; and type II meronts (second generation) producing 4 larger merozoites ranging in size from 12-15 x 0.7-0.8 µm. Gamonts appear as round-ovoid cells (10-33 µm in diameter) which exhibit sexual dimorphism as they develop into pale uninucleate macrogametocytes (female) and darker multinucleate microgametocytes (male). Macrogametocytes mature to produce single macrogametes which are highly vacuolated due to the presence of numerous small and large wall-forming bodies often located peripherally. Microgametocytes appear multinucleated as they mature to produce numerous slender flagellated microgametes (5 x 1 µm). Fertilization produces non-motile zygotes which form ovoid oocysts ranging in size from 7-10 µm in diameter. Oocysts are surrounded by bilayered membranous walls and are initially unsporulated containing an undifferentiated sporoblast. As they sporulate, each oocyst produces 2 sporocysts bound by membranous sporocyst walls and containing a small polar body and an oocyst residuum. The sporocysts are ovoid measuring 6 x 4 µm and have Stieda and sub-Stieda bodies located at one pole. Each sporocyst contains a granular residuum and 2 elongate folded sporozoites (9 x 1 µm) lacking crystalloid and refractile bodies. The resultant oocyst:sporocyst:sporozoite configuration of 1:2:2 is characteristic for the genus *Cyclospora*.

Site of infection: Some 19 parasite species have been described and named from 22 host species, including 12 mammalian species (cercopithecid and hominid primates, talpid moles, heteromyid rodents), 8 snake species (colubrids, viperids, aniliids), one lizard species (scincid) and one invertebrate (glomerid millipede). For those species where the sites of endogenous development have been determined, the parasites were located within parasitophorous vacuoles in small intestinal epithelial cells, particularly at tips of villi in the jejunum and duodenum. A few species have also been found to infect the large intestines, one species in moles infects the liver, and another in moles develops in the nuclei of epithelial cells. Mature oocysts are exogenous stages that are voided into the external environment with host faeces.

Pathogenesis: These coccidial parasites undergo obligatory endogenous development within intestinal epithelia leading to host cell destruction in order to liberate parasite progeny. The gut lining therefore suffers structural losses which lead to functional

abnormalities. The extent of damage depends on the intensity of infection, parasite pathogenicity (virulence) and host susceptibility. Many infections in animals were detected incidentally in asymptomatic individuals, but infections have been associated with clinical disease (cyclosporiasis) in humans. Endogenous developmental stages may cause surface epithelial injury, moderate to marked erythema and inflammation in the intestines. Mucosal architecture becomes disorganised with villous atrophy, crypt hyperplasia and alterations in enterocyte shapes from columnar to cuboidal to pleomorphic with loss of the microvillous brush border. Infections are characterized initially by mild-severe small bowel diarrhoea, often explosive with soft to watery stools, and acute with abrupt onset but varying in duration from transient to protracted. Most infections are self-limiting but prolonged or relapsing infections may occur leading to a chronic illness with prominent fatigue and anorexia, along with intermittent nausea and diarrhoea. Other associated clinical signs have included flu-like symptoms, nausea, vomiting, dyspepsia, malabsorption, impaired D-xylose absorption, dehydration, abdominal cramping, bloating, flatulence, myalgia, weight loss, and sometimes low-grade fever and tachycardia. The severity of disease depends on the age, nutritional and immune state of the host. Infections occur in people of all age groups, but young children have more severe clinical symptoms and increased duration of infection. The incubation period ranges from 7-14 days, but onset may be delayed by several weeks in some instances. The course of disease usually ranges from 1-7 weeks, but symptoms can persist for several months especially in immunocompromised patients.

Developmental cycle and mode of transmission: *Cyclospora* spp. are enteric coccidia with monoxenous (one-host) life-cycles involving the faecal-oral transmission of resistant oocysts excreted into the external environment to infect new hosts via contaminated food or water. Ingested oocysts excyst in the gut following exposure to gastric acids, bile salts and pancreatic enzymes. The released sporozoites invade epithelial cells and form meronts (schizonts) which undergo asexual proliferation by internal (endogenous) division to form numerous merozoites which invade neighbouring cells. It is thought that at least 2 cycles of merogony occur, with first generation (type I) meronts producing 8-12 merozoites, and second generation (type II) meronts producing 4 merozoites. However, it has occasionally been observed that several cycles of each meront type may be completed before type II merozoites begin to form gamonts. Sexual development (gamogony) involves the formation of male and female gametocytes which produce gametes, robust female macrogametes and small 'sperm-like' male microgametes. Fertilization occurs by gamete fusion resulting in the production of a non-motile zygote which develops into an oocyst with a thick wall. Oocysts are excreted with host faeces into the external environment as unsporulated non-infectious stages. They become infectious by exogenous sporulation over 7-15 days to produce infective sporozoites contained within sporocysts (1:2:2 oocyst:sporocyst:sporozoite configuration). The prepatent period (time from infection to first oocyst excretion) ranged from 2-11 days, and the patent period (duration of oocyst excretion) ranged varied considerably from weeks to months in chronic infections. The environmentally-resistant oocysts contaminate food, water and soil, where they can be inadvertently ingested by new susceptible hosts. Infections have been associated with the consumption of a range of foods, mostly fresh salad greens and vegetables (lettuce, snow peas, spinach, mustard), herbs (basil, coriander, mint, marjoram) and fruits (raspberries) contaminated by human waste during production (indiscriminate defaecation by workers or organic fertilizers containing untreated faeces) or processing (washing produce with contaminated water). Oocysts have also been found in association with numerous water sources, mostly raw untreated waters but also potable and treated waters. The oocysts are small enough to be discharged with final effluents from waste stabilization ponds and sewage treatment works, and they are highly resistant to many disinfectants, including chlorination procedures used for water treatment. Recreational water venues (water parks, sprinkler fountains, lakes, rivers and oceans) have also been implicated in episodic transmission events, and oocysts have also been found in filter-feeding shellfish in several markets. Contaminated soil also poses a risk, particularly in children playing in muddy soils or indulging in geophagia (pica). Many outbreaks of disease appear to be seasonal, particularly in summer rainy seasons in tropical countries, and they have also been linked to unexplained traveler's diarrhoeal disease following international travel to tropical areas.

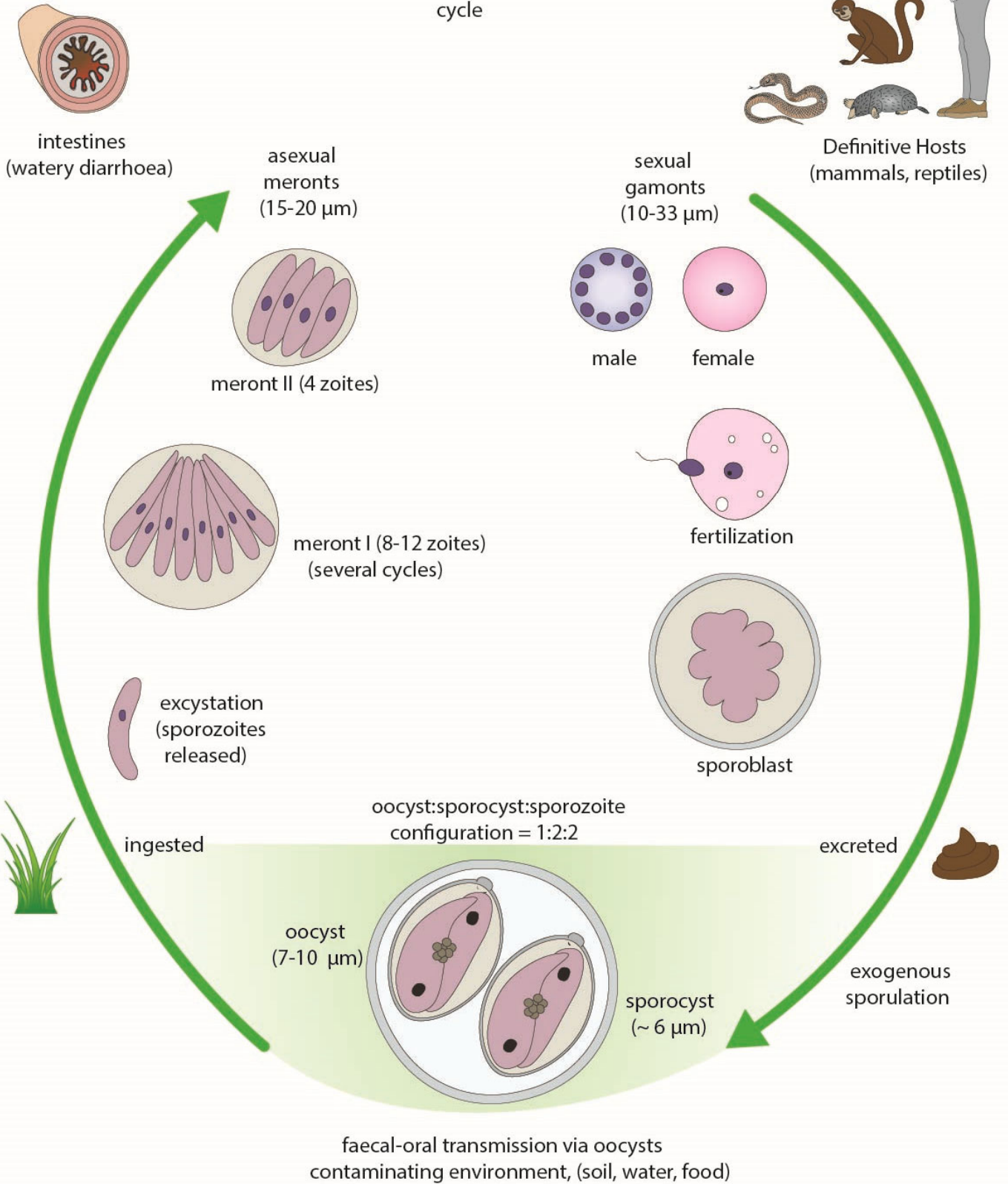
Differential diagnosis: Infections are usually diagnosed by the microscopic detection of oocysts in faecal samples, and sometimes in duodenal or jejunal biopsy samples. It is also recommended that multiple stool samples be collected on alternate days as oocyst excretion can be intermittent. Oocysts may be concentrated from samples by various sedimentation-floatation techniques, including ethyl acetate-formalin sedimentation, and floatation in saturated heavy metal salt solutions or discontinuous sucrose, caesium chloride or Percoll gradients. Wet mounts are best observed by high contrast microscopy (bright-field, phase-contrast or differential interference-contrast) or epifluorescence microscopy (oocysts autofluoresce white-blue using 330-380 nm excitation filters or fluorescent-green with 450-490 nm filters). Alternatively, fixed faecal smears may be examined following acid-fast or safranin staining. Definitive oocyst identification is made difficult by the extended period required for sporulation (1-2 weeks in dilute potassium dichromate). Several immunological techniques (fluorescent-antibody tests, enzyme immunoassays, Western blotting) have been used experimentally to examine host antibody responses to specific parasite antigens, but no commercial tests are available. Molecular biological techniques have been used to detect and characterize parasite isolates by the polymerase chain reaction (PCR) amplification of nuclear gene sequences (18S and 5.8S ribosomal DNA, and internal transcribed spacer region 1), by restriction fragment length polymorphism (RFLP) analyses, and multilocus sequence typing (MLST) based on 5 microsatellite markers.

Treatment and control: Clinical infections in both immuno-competent and immuno-compromised patients have responded well to daily treatment for 4-7 days with the combination antibiotic medication trimethoprim-sulfamethoxazole (co-trimoxazole), usually resulting in the resolution of symptoms and the cessation of oocyst excretion. For patients allergic to sulfa components, treatment

with ciprofloxacin or nitazoxanide helped but were not as effective. All patients benefited from supportive rehydration therapy (oral or intravenous) to replenish fluid losses from profuse and/or prolonged diarrhoea. Various preventive control measures have been instituted to reduce the risks of oocyst transmission through improvements in sanitation, food hygiene, water treatment and personal hygiene. The source of infections are oocysts in human excreta, so proper sanitation processes should be used to collect, treat and dispose of human waste. Nightsoil (fresh faeces) and partially-treated sewage must not be used as organic fertilizers for food crops, and farm workers should be provided with facilities to prevent indiscriminate defaecation around plant crops. Food industries should endeavour to properly process and package foods. Studies have shown that washing produce in clean water does not remove all contaminating oocysts, but that oocysts may be killed by cooking (temperatures $> 70^{\circ}\text{C}$ or microwave heating), freeze-drying (desiccation), freezing (temperatures $< -40^{\circ}\text{C}$) or some disinfectants (sodium dichloroisocyanurate (NaDCC), or magnesium oxide nanoparticles). Water treatment facilities should be checked, and upgraded as required, to provide safe drinking water. Oocysts have proven to be more resistant to chlorination treatments than to ozonation, and membrane filtration appeared to be more effective in removing oocysts than conventional sand filtration. Small volumes of water may be disinfected by boiling, and surrogate studies (using other coccidian oocysts) have suggested that gamma irradiation may be effective. Recreational water providers should periodically check for oocyst contamination and provide toilet facilities to prevent contamination. Public health education programs may be used to promote personal hygiene practices and raise awareness of the disease in populations at risk, including international travellers to tropical holiday destinations.

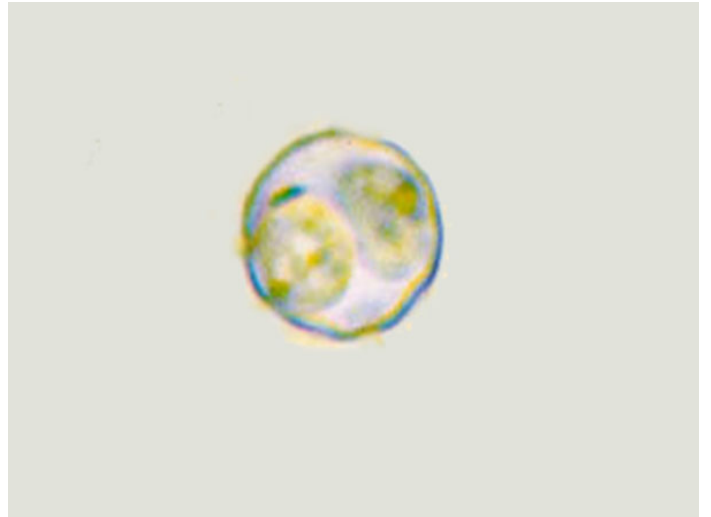
Cyclospora

monoxenous
(1-host)
cycle





Cyclospora oocysts in human faecal smear



Cyclospora oocyst from faeces