Trypanoplasma
(protist: flagellate)

Overview

Protists are single-celled organisms with membrane-bound nuclei (eukaryotes). Flagellates are protists that swim using one or more flagella (undulipodia); each arising from a small centriole (basal body, kinetosome) and having a microtubular axoneme core (2+9 configuration). Rather than forming a monophyletic group, flagellates are divided into several disparate groups: metamonads (amitochondriate flagellates), heteroloboseans (amoeboflagellates), euglenozoans (euglenids and kinetoplastids), stramenopiles (heterokonts), alveolates (dinoflagellates) and cercozoans (biflagellates). Most kinetoplastids are parasitic in vertebrate or invertebrate hosts (some in plants) whereas the remainder are free-living aquatic organisms. All species are characterized by the possession of extranuclear DNA in the form of a kinetoplast, a unique structure formed by massed DNA (circles or lattice) within the single large mitochondrion near the flagellar basal body. The flagellates reproduce by longitudinal binary fission and parasitic species may have simple monoxenous (one-host) or more complicated heteroxenous (two-host) life cycles involving different developmental stages. Parabodonids include members of the genus *Trypanoplasma* which are parasitic in the blood of fishes and are transmitted by leech vectors.

Classification:

Domain:	Eukaryota (membrane-bound nucleus)
Supergroup:	Excavata (with conspicuous ventral feeding groove)
Group:	Discoba (diverse group supported robustly by molecular studies)
Phylum:	Euglenozoa (flagella inserted in anterior pocket, some heterotrophs, some autotrophs (with chloroplasts))
Class:	Kinetoplastea (heterotrophs, with extranuclear DNA (= kinetoplast) associated with mitochondrion)
Subclass:	Metakinetoplastina (large polyphyletic group supported by molecular studies)
Order:	Parabodonida (biflagellated, recurrent flagellum attached or free)
Family:	Parabodonidae (Cryptobiidae, Trypanoplasmatidae) (epizoic or endozoic in invertebrates and/or fish)
Genus:	*Trypanoplasma* (parasitic in blood of fish, indirect cycles involving leeches)
Species:	various species cause anaemia in fish

Parasite biodiversity and host range: Protists are unicellular eukaryotes that move using undulipodia (flagella or cilia), pseudopodia (false-feet) or a unique gliding motion. Flagellated species have one or more flagella with an internal microtubular core (in a characteristic 2+9 configuration comprising 2 single central microtubules and 9 peripheral doublets) anchored to a submembranous protein structure (known variously as a centriole, basal body, kinetosome or blepharoplast). Many types of flagellated cells have been described and recent phylogenetic studies have classified them into several disparate groups: including the metamonads (amitochondriate flagellates), heteroloboseans (amoeboflagellates), euglenozoans (euglenids and kinetoplastids), stramenopiles (heterokonts), alveolates (dinoflagellates) and cercozoans (biflagellates). While most flagellated protists are free-living organisms swimming and feeding in aquatic environments, representatives of several groups have developed symbiotic relationships with various hosts; some being endoparasitic in vertebrates (notably anaerobic metamonads in tubular organs, and heterotrophic euglenozoans occurring in blood or tissues), and some being parasitic in invertebrates (alveolates in crustacean tissues) (representatives tabulated below).

Higher taxonomy	Class or order	Family	Genera	Hosts (tissues)	Trans-mission*
Supergroup: Excavata (with conspicuous ventral feeding groove)					
Group: Metamonad (amitochondriate flagellates with karyomastigonts)					
Phylum: Fornicata (diplomonads)	Order: Diplomonadida (1-2 karyomastigonts)	Hexamitidae (2 karyomastigonts with binary axial symmetry)	*Giardia*	vertebrates (gut)	direct (f-o)
			Hexamita *Spironucleus*	vertebrates (tissues)	direct (f-o, w)
Phylum: Parabasalia (with parabasal body)	Order: Trichomonadida (3-5 anterior flagella plus recurrent flagellum)	Monocercomonadidae (costa absent, most without undulating membrane)	*Histomonas*	birds (gut, liver)	direct (f-o)
			Dientamoeba	vertebrates (gut)	direct (f-o)
		Trichomonadidae (stout axostyle, costa, undulating membrane)	*Trichomonas*	vertebrates (urogenital tract, gut)	direct (f-o, v)
		Cochlosomatidae (anterior adhesive disc)	*Cochlosoma*	birds (gut)	direct (f-o)
Group: Discoba (diverse group supported robustly by molecular studies)					
Phylum: Euglenozoa (flagella inserted in anterior pocket, heterotrophs, autotrophs)	Class: Kinetoplastea (heterotrophs, with extranuclear DNA (= kinetoplast) associated with mitochondrion)	Ichthyobodonidae (flagellar pocket continues as groove)	*Ichthyobodo* (= *Costia*)	fish (gills, skin)	direct (w)
		Parabodonidae (epizoic or endozoic)	*Cryptobia*	fish (gills, skin)	direct (w)
			Trypanoplasma	fish (blood)	indirect (v-b)
		Trypanosomatidae (monogenetic forms in insects/plants, digenetic forms in vertebrates & arthropods)	*Trypanosoma*	vertebrates (blood, tissues)	indirect (v-b)
			Leishmania	vertebrates (blood, tissues)	indirect (v-b)
Supergroup: SAR (Stramenopiles + Alveolata + Rhizaria) (3 groups unified by molecular studies)					
Group: Alveolata (with cortical alveoli)					
Phylum: Dinoflagellata (with unique mesokaryotic nuclei)	Order: Blastodiniales (uninucleate trophonts with chloroplasts)	Oodiniaceae (trophont with rhizoid-like invasive organelle)	*Amyloodinium* *Crepidoodinium* *Piscinoodinium*	fish (skin)	direct (w)
	Order: Syndiniales (multinucleate plasmodial trophonts)	Syndiniaceae (without chloroplasts)	*Haematodinium* *Ichthyodinium*	crustaceans, fish (tissues)	direct (w)
Phylum: Perkinsozoa (parasitic)	Order: Perkinsorida (released trophonts form biflagellated zoospores)	Perkinsidae (incomplete conoid)	*Perkinsus*	gastropods, bivalves (tissues)	direct (w)

*f-o = faecal-oral transmission; v-b = vector-borne transmission, w = water-borne transmission; v = venereal transmission

Euglenozoans comprise a large group of excavates (with ventral feeding groove), most with 1-2 flagella inserted into an anterior pocket. Many species are free-living aquatic autotrophs possessing chloroplasts while others are free-living or symbiotic heterotrophs feeding on solutes, particles and even other organisms. Kinetoplastids are characterised by the possession of a kinetoplast (containing mitochondrial DNA separate from nuclear DNA), a flagellar pocket, basal bodies with three microtubular roots and paraxonemal (paraxial or paraflagellar) rods, and asexual multiplication by longitudinal binary fission. The unique kinetoplast is formed by massed DNA (circles or lattice) usually closely associated with the flagellar basal body (eukinetoplastic) although some species may be polykinetoplastic (with several kinetoplasts) or pankinetoplastic (irregular kDNA) and some mutants even dyskinetoplastic (without a kinetoplast). Two major kinetoplastid groups are recognized: bodonids with two flagella (most being free-living bactivores in aquatic/terrestrial habitats); and trypanosomes with a single flagellum (most being parasites of animals or plants with monoxenous or dixenous life-cycles). Different kinetoplastid assemblages exhibit increasing morphological/ultrastructural complexity in their cellular organization thought to reflect evolutionary grades or clines. Amastigotes are simple non-flagellated cells, choano-, pro- and opistho-mastigotes are flagellated cells with elongate flagella, while epi- and trypo-mastigotes are flagellated cells with undulating membranes. Most kinetoplastids have amastigote and promastigote developmental stages but monoxenous parasites of insects (e.g. *Crithidia*, *Herpetomonas*) do not have more elaborate forms whereas dixenous parasites of plants or animals with invertebrate vectors (e.g. *Trypanosoma, Leishmania*) do have more morphologically complex forms such as epimastigotes and trypomastigotes.

Traditional classification	Molecular classification	Genera	No. spp.	Vertebrate hosts	Transmission (vectors)
F: Trypanosomatidae	SC: Metakinetoplastina F: Trypanosomatidae	*Trypanosoma*	537	mammals, reptiles, frogs, birds, fish	indirect (arthropods, leeches)
		Leishmania	53	mammals, lizards	indirect (sand flies)
F: Bodonidae	SC: Metakinetoplastina F: Parabodonidae	*Cryptobia, Trypanoplasma*	79	fish	direct or indirect (leeches)
	SC: Prokinetoplastina F: Ichthyobodonidae	*Ichthyobodo* (*Costia*)	5	fish	direct

Conventional taxonomic classification systems divide the kinetoplastids into 2 groups: the free-living bi-flagellated Bodonina; and the parasitic uni-flagellated Trypanosomatina. Over 600 species have been described on the basis of multiple phenotypic characters (host occurrence, geographic distribution, vectors, transmission cycles, morphology, development, pathogenicity, culture requirements, etc.). Modern molecular characterization studies, however, have shown that many traditional groups are polyphyletic and composed of numerous clades. Contemporary phylogenetic classifications recognize 2 main lineages: the Prokinetoplastina represented by 2 diverse genera (*Ichthyobodo* biflagellates ectoparasitic on freshwater and marine fishes, and *Perkinsela* (= *Perkinsiella*) aflagellates endosymbiotic (as parasomes or parasome-like organisms (PLOs)) in amoeba *Paramoeba* and *Neoparamoeba*); and the Metakinetoplastina containing 4 groups, including free-living aquatic eu-bodonids (with one genus *Bodo*), free-living neo-bodonids (with 10 genera, including *Rhynchomonas*), free-living or commensal/parasitic para-bodonids (with 5 genera, including *Cryptobia, Trypanoplasma*), and the parasitic trypanosomatids (containing some 39 genera, including *Trypanosoma* and *Leishmania*). The genus *Cryptobia* was originally proposed for biflagellated organisms in the reproductive systems of snails, but was later expanded to include similar organisms in other invertebrates as well as some aquatic vertebrates. The genus *Trypanoplasma* was originally proposed for biflagellated organisms in the blood of freshwater fishes and the crops of leeches. Some workers consider *Trypanoplasma* to be a junior synonym of *Cryptobia*, while others regard them as separate subgenera. Recent molecular phylogenetic studies have suggested that they should continue to be considered as separate genera, with epizoic/endozoic species (thought to undergo direct transmission) being retained within the genus *Cryptobia,* and haemozoic species (thought to undergo indirect transmission via leech vectors) forming the genus *Trypanoplasma* (note that many species have been transferred between genera). Some 45 *Trypanoplasma* species have been recorded in fish, most in freshwater fish but 4 species in marine fish and one in abalone. The host specificity of all species is uncertain. Several species (*T. salmositica, T. borreli* and *T. bullocki*) cause disease (anaemia and lesions in haematopoietic tissues) and mortality in many fish species throughout the world.

***Trypanoplasma* species**	**Mastigote length (µm)**	**Hosts**	**Location (disease)**	**Vectors**	**Distribution**
Species in freshwater fish					
T. abramidis		Cypriniformes: cyprinid (common bream)	blood		Eurasia
T. acipenseris		Acipenseriformes: acipenserid (beluga sturgeon, bastard sturgeon, sterlet, starry sturgeon, Persian sturgeon, Darya sturgeon)	blood		Eurasia
T. alii		Cypriniformes: cyprinid (red garra)	blood		Iraq
T. al-jaferi		Siluriformes: bagrid (Tigris mystus)	blood		Iraq
T. barbi		Cypriniformes: cyprinid (common barbel)	blood		Europe
T. bliccae		Cypriniformes: cyprinid (white bream)	blood		Asia
T. borreli (syn. *T. carassii, cyprini, keysselitzi, kharbulaewi, tincae*)	20-25	Cypriniformes: cyprinid (common carp, Eurasian carp, crucian carp, grass carp, goldfish, common rudd, red-eye, tench), catostomid (white sucker), leuciscid (common minnow)	blood (anaemia, peritonitis)	Clitellata (leeches): glossiphonid (*Hemiclepsis marginata*), piscicolid (*Piscicola geometra*)	Eurasia, North America
T. capoetobramae		Cypriniformes: cyprinid (Chu sharpray)	blood		Russia

T. cataractae	17	Cypriniformes: cyprinid (longnose dace, eastern blacknose dace, cutlips minnow, central stoneroller)	blood	Clitellata: piscicolid leech (*Cystobranchus virginicus*)	North America
T. catastomi	30-43	Cypriniformes: catostomid (white sucker, longnose sucker)	blood		Canada
T. cavacius	15-20	Siluriformes: bagrid (Gangetic mystus)	blood		India
T. chongqingensis	53	Cypriniformes: cobitid (pond loach)	blood		Asia
T. clariae		Siluriformes: clariid (broadhead catfish)	blood		Asia
T. cotti		Scorpaeniformes: cottid (Baikal yellowfin, longfin Baikal sculpin, vitim sculpin, flathead sculpin, rough sculpin, eurystome sculpin, Godlewski's sculpin, long-spined bullhead)	blood	Clitellata: piscicolid leech (*Calliobdella punctata*)	Russia
T. erythroculteri		Cypriniformes: cyprinid (lake skygazer)	blood		Asia
T. flesi nomen nudum		Pleuronectiformes: pleuronectid (European flounder)	blood		Europe
T. gandei	53	Cypriniformes: cyprinid (macrostome carp)	blood		Africa
T. guernei		Scorpaeniformes: cottid (European bullhead)	blood		Europe
T. gurneyorum		Esociformes: esocid (northern pike), Salmoniformes: salmonid (lake whitefish, lake charr)	blood		Eurasia, North America
T. krishnamurthyi	15-28	Siluriformes: bagrid (Gangetic mystus)	blood		India
T. litoralis		Perciformes: percid (European perch); Scorpaeniformes: cottid Baikal yellowfin)	blood		Russia
T. lomakini		Scorpaeniformes: cottid Baikal yellowfin)	blood		Caspian
T. lynchi	8-25	Scorpaeniformes: cottid (torrent sculpin, coastrange sculpin)	blood		North America
T. makeevi		Salmoniformes: salmonid (chum salmon, pink salmon)	blood, spleen		Russia
T. markewitschi		Anguilliformes: anguillid (European eel)	blood		Europe
T. megalobrami		Cypriniformes: cyprinid (Wuchang bream)	blood		Asia
T. mirabilis		Cypriniformes: cyprinid (Caucasian scraper)	blood		Asia
T. misgurni		Cypriniformes: cobitid (loach)	blood		China
T. neghmei		Pleuronectiformes: pleuronectid (Chilean flounder, fine flounder)	blood		South America
T. ninaekohlyakimovi		Siluriformes: silurid (wels catfish)	blood		Eurasia
T. pseudobagri		Siluriformes: bagrid (yellowhead catfish)	blood		China
T. pseudocaphirhynchi		Acipenseriformes: acipenserid (sturgeon)	blood		Russia
T. rutili		Cypriniformes: cyprinid (roach)	blood		Russia
T. salihi		Siluriformes: (Tigris cat)	blood		Iraq
T. salmositica (syn. *T. lynchi, Cryptobia*)	6-25	Salmoniformes: salmonid (coho salmon, chum salmon, pink salmon, masu salmon, sockeye salmon, brown trout, rainbow trout, brook trout, mountain whitefish); Cypriniformes:	blood (anaemia, ascites)	Clitellata: piscicolid leech (*Piscicola salmositica*) plus occasional direct transmission	North America

		cyprinid (longnose dace), catostomid (Klamath largescale sucker); Scorpaeniformes: cottid (torrent sculpin, coastrange sculpin, inland riffle sculpin, paiute sculpin, reticulate sculpin, mottled sculpin, prickly sculpin), gasterosteid (three-spined stickleback)			
T. sarcocheilichthysi		Cypriniformes: cyprinid (rainbow gudgeon)	blood		China
T. seenghali	15-33	Siluriformes: bagrid (giant river catfish)	blood		India
T. varium		Cypriniformes: nemacheilid (stone loach), cobitid (spined loach, weatherfish)	blood	Clitellata: glossiphonid leech (*Hemiclepsis marginata*),	Europe
T. vidyai	15-30	Siluriformes: bagrid (giant river catfish)	blood		India
T. willoughbii (syn. *T. truttae, valentini*)	20-40	Salmoniformes: salmonid (brown trout, Windermere charr)	blood		Europe
T. zaiki		Scorpaeniformes: cottid (multiradiate sculpin, vitim sculpin, flathead sculpin, big red sculpin, deepwater sculpin)			Russia
Species in marine fish and shellfish					
T. abalonensis	12	Gastropoda: haliotid (variously-coloured abalone)	blood		Asia
T. beckeri	43-165	Scorpaeniformes: cottid (cabezon)	blood	Clitellata: piscicolid leech (*Malmiana diminuta*)	North America
T. bullocki (syn. *T. newingtoniensis*)	11-30	Pleuronectiformes: pleuronectid (winter flounder, American smooth flounder, American plaice), paralichthyid (summer flounder, southern flounder), achirid (hogchoker); Acanthuriformes: sciaenid (Atlantic croaker); Batrachoidiformes: batrachoidid (oyster toadfish); Cyprinodontiformes: fundulid (mummichog, striped killifish)	blood (anaemia)	Clitellata: piscicolid leech (*Calliobdella vivida*)	North America
T. parmae	12-15	Perciformes: pomacentrid (white-ear)	blood		Australia

Parasite morphology: *Trypanoplasma* spp. only form one type of developmental stage, namely biflagellated trophozoites. These cells are elongate slender stages ranging in size from 10-30 x 2-6 μm, with a broader anterior end and a pointed posterior end. They possess a single central rounded nucleus, an elongate-oval anterior kinetoplast (containing mitochondrial DNA) and 2 subapical flagellar basal bodies (microtubule complexes) giving rise to 2 heterodynamic (unequal) flagella from a small flagellar pocket. One flagellum is short and extends free anteriorly, while the other is very long and recurrent (trailing) being attached along the cell body to form an undulating membrane before extending free posteriorly. The trophozoites often exhibit some pleomorphic variation and several studies have recognized several different morphotypes: type I comprising long forms with long undulating membranes; type II being intermediary forms with small undulating membranes; and type III apparently being small newly-divided forms with very small inconspicuous undulating membranes. Contractile vacuoles have only been observed in blood forms of one species, *T. salmositica*.

Site of infection: Trophozoites are usually found in the circulatory system of fish, where they occur as extracellular parasites swimming in the plasma. A total of 45 parasite species have been described: including 41 species found in 83 species of freshwater fish belonging to 16 families (notably cyprinids and sculpins); 4 species found in 12 species of marine fish belonging to 8 families (particularly flounder) and another species in a marine gastropod (abalone). Trophozoites have also been found in the upper alimentary tract of leech vectors where they occur as extracellular parasites in the crop and proboscis sheath. Infections have been found in 7 leech species, including 2 marine piscicolid species, 4 freshwater piscicolid species and one freshwater glossiphonid species.

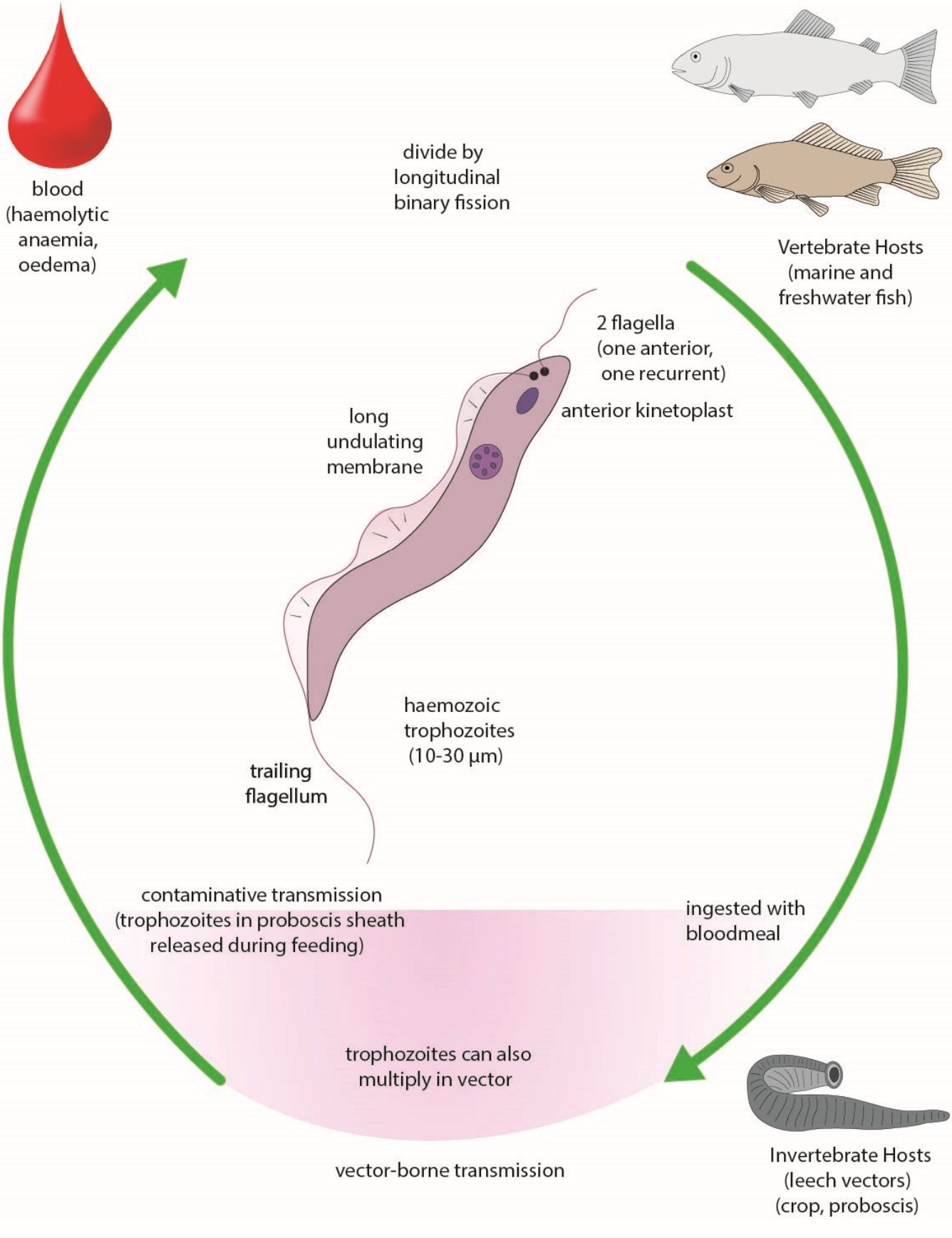
Pathogenesis: Infections by most parasite species are asymptomatic or subclinical, but several species have been associated with clinical disease, particularly in juvenile salmonids in hatcheries, occasionally in fish held in estuarine or marine sea-cages, and also in wild sexually-mature salmon (pre- and post-spawning). Trophozoites in the bloodstream feed on nutrients taken up across their membranes and they are thought to release various secretory/excretory products, including proteases (cysteine protease and metalloprotease) which act as histolytic enzymes causing lesions. Haemolysins are also released when trophozoites are lysed by complement fixation. Heavy haemozoic infection may cause intravascular and extravascular haemolysis either directly or following immune complex formation. This results in progressive haemolytic anaemia (microcytic and hypochromic) exacerbated by haemodilution (through general oedema). Other clinical signs observed in fish include hepatomegaly, splenomegaly, ascites, abdominal distention, exophthalmia (protrusion of eyeballs), anorexia, poor growth, lethargy, emaciation, compromised swimming performance and some mortalities. Death has usually been associated with loss of osmoregulatory control, although infected fish are more sensitive to poor water quality and environmental hypoxia. Histopathological changes in dead fish include haemorrhagic foci, cellular necrosis, ulcerative lesions, inflammation, mononuclear cellular infiltrates, congested blood vessels, and occlusion of capillaries by parasites. Disease may become apparent within several weeks in fish in cold waters, but earlier in fish in warmer waters. The severity of disease has been found to be influenced by parasite factors (species/strain virulence, intensity of infection), host factors (age, nutritional state, physiological stress) and environmental factors (culture conditions, water quality, temperature, crowding). Immunological studies have shown there is some innate resistance to infection (involving complement lysis, neutralization of parasite proteases, and enhanced respiratory burst activities of circulating granulocytes) as well as some acquired immunity (involving humoral (agglutinating, neutralizing and complement-fixing antibodies) and cellular responses (phagocytes and lymphocytes). Fish developed some protection against subsequent challenge and studies found that the passive transfer of lymphocytes and plasma from recovered fish conferred protection on naive fish.

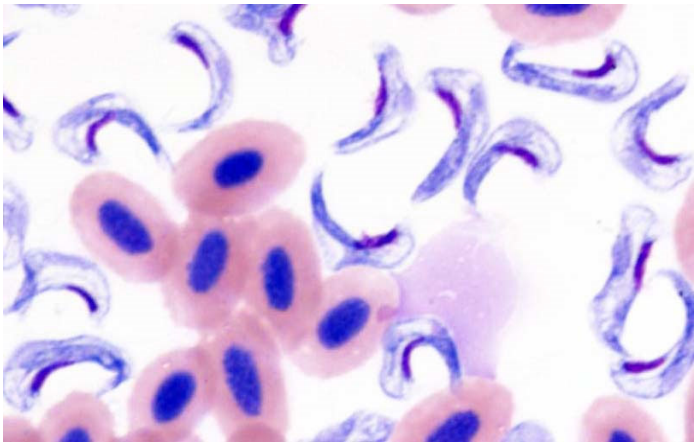
Developmental cycle and mode of transmission: Life-cycles have only been determined for some 7 *Trypanoplasma* spp. which all used haematophagous aquatic leeches as vectors for the transmission of infections between fish. The parasites undergo asexual multiplication in both the vertebrate and invertebrate hosts, but only one life-cycle stage is involved (trophozoites). Leeches act as more than mechanical paratenic (transport) hosts as the parasites undergo multiplication, but they are not true biological vectors as the parasites do not undergo any cyclic developmental processes, such as that exhibited by trypanosomes undergoing metacyclogenesis to form metacyclic infective stages. Even though some early studies tentatively described slender forms in leeches as putative 'metacyclic' forms, similar forms occur in fish and in cultures. Parasites multiply in the blood of fish by binary fission whereby nuclei and organelles (kinetoplast, flagella) are replicated before cytokinesis. Two divisional processes have been observed: one involving symmetric division of rounded maternal cells with the formation of similar daughter cells each inheriting an old and a new flagellum (e.g. *T. catostomi*); and another involving asymmetric division of slender maternal cells with formation of dissimilar daughter cells where the slender sibling retains both maternal flagella (e.g. *T. salmositica*). In leeches, the parasites divide by binary fission within 24 hours in the crop and slender forms accumulate in the proboscis sheath and may be transmitted to fish when the leech next feeds. The prepatent period ranges from 1-5 days and appears to be dependent on temperature (taking longer at lower temperatures). Experimental studies have also shown that some haemozoic infections may be transmitted directly between fish kept in tanks without leeches. Infections were transmitted to uninfected fish co-mingling or separated by wire mesh in the same tank. Live parasites were found in mucus on the body surface and may be transmitted to uninfected fish by mucus strands. Trophozoites may be released to the body surface from blisters or ulcers but how they are taken up by new hosts is unknown.

Differential diagnosis: Infections are diagnosed by the microscopic detection of trophozoites in blood samples preferably collected into anticoagulant. Wet mounts of whole blood, serum samples from clotted blood, buffy coat layers harvested by centrifugation, or ascites fluid are best examined by high-contrast microscopy for motile flagellates, while fixed smears can be examined by bright-field microscopy after staining with Giemsa or Leishman's stains. Parasites are readily cultured *in vitro* using semi-solid or liquid media, including biphasic blood agar (NNN or SNB-9), Ponselle's medium, Hank's solution or minimum essential medium (MEM) with heat-inactivated foetal calf serum. Explosive growth of *T. salmositica* occurs when trace amounts of fresh plasma from sexually-mature trout are added to media, but continuous culture appears to attenuate strains as they lose their virulence and sometimes infectivity for fish. Several immunoserological techniques (neutralization, agglutination, immunofluorescence and enzyme immunoassays) have been developed to detect specific host antibodies against *T. salmositica* antigens. Molecular biological techniques have recently been used to detect and characterize parasite isolates following the polymerase chain reaction (PCR) amplification of nuclear gene sequences (small subunit (18S) ribosomal DNA, and some repetitive DNA fragments), precipitating major revisions of the parabodonid genera and species (major reshuffling of taxa between the genera *Cryptobia* and *Trypanoplasma*).

Treatment and control: There is currently no effective chemotherapeutic treatment for haemozoic infections by *Trypanoplasma* spp. in fish. Conventional trypanocidal drugs (suramin, berenil, antrycide) had little effect, although isometamidium chloride (samorin) injections gave variable results. Treatments with various antibiotics (penicillin, streptomycin, amphotericin) were purported to have some effect, while treatment with crystal violet (triphenylmethane dye) had some *in vitro* effects but exhibited *in vivo* toxicity problems. Preventive control programmes are based around vector control (reducing leech populations by chemical treatment and clearing vegetation used as substrates for cocoons) and maintaining healthy fish in stress-free conditions (proper nutrition, good water quality, avoid over-handling and over-crowding, and treating concomitant infections). Because infections have been found to be influenced by temperature, some control has been credited to acclimating fish to warmer waters (above 20°C). Experimental studies indicated that fish were able to moderate infections by innate and acquired immune responses resulting in parasite lysis, with complement, antibodies and phagocytes playing a pivotal role in protection. This prompted studies on vaccine development and some success was reported in protecting salmonids against *T. salmosticia* infection by vaccination with live attenuated cultured strains (up to 2 years protection in some instances). Monoclonal antibodies raised against surface membrane epitopes of *T. salmositica* were also found to be therapeutic when injected into fish with acute infections.

Trypanoplasma





Trypanoplasma trophozoites