***Trypanosoma cruzi***
(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. Trypanosomes have a single flagellum and they form four main developmental stages: trypomastigotes (with a posterior kinetoplast and an emergent flagellum forming a long undulating membrane); epimastigotes (with an anterior kinetoplast and an emergent flagellum forming a short undulating membrane); promastigotes (with an anterior kinetoplast and a short emergent flagellum, but no undulating membrane); and amastigotes (with a kinetoplast but no emergent flagellum or undulating membrane). Many trypanosome species are parasitic only in insects whereas others are transmitted by insect vectors to a wide range of vertebrate hosts. Three main groups infect the blood and/or tissues of humans and animals causing severe clinical diseases: including the cyclic stercorarian trypanosomes which undergo posterior station (hindgut) development in vectors and are transmitted via faecal contamination of bite site to infect blood and tissues of vertebrate hosts (e.g. reduviid bugs transmit *T. cruzi* which causes Chagas' disease in humans).

**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: | Trypanosomatida (parasitic, single anterior flagellum, often forming undulating membrane) |
| Family: | Trypanosomatidae (monogenetic forms in insects/plants, digenetic forms in vertebrates & arthropods) |
| Genus: | *Trypanosoma* (vector-borne haemoparasites) |
| Species: | *T. cruzi* (causes Chagas' disease 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. 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*).

Trypanosomatids are dixenous (2-host) parasites with indirect transmission cycles between vertebrates and invertebrate vectors. *Trypanosoma* spp. form trypo- and/or a-mastigote stages in the blood/tissues of vertebrate hosts, and epi- or pro-mastigote stages in invertebrate haematophagous vectors. Infections have been found in a range of vertebrate species (mammals, birds, reptiles, amphibians and fish) with many different types of haematophagous invertebrates (leeches, bugs, flies, fleas) implicated as vectors or paratenic hosts. The species found in mammals have been grouped into two Sections (convenient groups without formal taxonomic rank) primarily on the basis of their developmental cycles in their vectors and their modes of transmission. Each Section contains several subgenera, as follows:

Section: Stercoraria (posterior station development in vector, contaminative transmission)

- *T.* (*Megatrypanum*), large trypanosomes with kinetoplast close to nucleus;
- *T.* (*Herpetosoma*), medium trypanosomes with subterminal kinetoplast;
- *T.* (*Schizotrypanum*), small C-shaped trypanosomes with voluminous terminal kinetoplast;

Section: Salivaria (anterior station development in vector, inoculative (some mechanical) transmission);

- *T.* (*Duttonella*), former *vivax*-group, monomorphic forms with large terminal kinetoplast;
- *T.* (*Nannomonas*), former *congolense*-group, small forms with medium marginal kinetoplast;
- *T.* (*Trypanozoon*), former *brucei*-group, pleomorphic forms with small subterminal kinetoplast;
- *T.* (*Pycnomonas*), former *suis*-subgroup, stout monomorphic forms with small subterminal kinetoplast.

Recent molecular phylogenetic studies have validated the separation of mammalian salivarian and stercorarian trypanosomes, but indicated complex placements for trypanosomes from non-mammalian hosts, despite earlier suggestions that they be assigned to separate subgenera (*Trypanomorpha* for those in birds, *Trypanosoma* for those in amphibians, and *Haematomonas* for those in fish). Many clades have been identified, most associated with particular vertebrate or invertebrate hosts, or both, suggesting that 'host-fitting' rather than 'co-speciation' has been the principal mechanism for trypanosome evolution. Comparative studies have found many differences between trypanosomes of aquatic and terrestrial hosts, with several clades found for species in freshwater fishes, marine fishes, amphibians, tortoises and platypuses (all thought to be transmitted by leech vectors). *T. cruzi* belongs to the stercorarian trypanosomes which exhibit discontinuous multiplication in the mammalian host and develop in the posterior station in vectors with contaminative transmission (except for *T. rangeli* which also undergoes anterior station development and inoculative transmission). Three stercorarian subgenera are recognized: *Megatrypanum* comprising large trypanosomes with the kinetoplast close to the nucleus (e.g. *T. theileri*); *Herpetosoma* comprising medium-sized trypanosomes with a subterminal kinetoplast (e.g. *T. lewisi*); and *Schizotrypanum* comprising small trypanosomes with a large kinetoplast near the posterior pole (e.g. *T. cruzi*). The parasites utilize a range of invertebrate vectors, including reduviid bugs, biting flies, sheep ked and rat fleas. *T. cruzi* and *T. rangeli* are found throughout the Americas where reduviid bugs are prevalent, while other stercorarian species with other vectors have a broader global distribution. Over 40 *T.* (*Megatrypanum*) species have been described from ruminants, carnivores, marsupials, bats, monkeys, edentates and rodents; some 64 *T.* (*Herpetosoma*) species from rodents, lagomorphs, primates, bats, carnivores,

marsupials and xenarthrans; and 18 *T.* (*Schizotrypanum*) species from primates (including humans), carnivores, marsupials, edentates, lagomorphs and rodents throughout the New World and numerous bats around the world. *T.* (*S.*) *cruzi* causes serious disease in humans throughout South and Central America and many mammal species, including companion and wild animals, act as reservoirs of infection. Recent estimates on the prevalence of Chagas' disease range as high as 8-14 million people, despite considerable efforts made around the turn of the century to prevent infections.

| ***Trypanosoma* species** | **Mastigote length (µm)** | **Hosts** | **Disease** | **Vectors** | **Distribution** |
|---|---|---|---|---|---|
| **CYCLIC TRANSMISSION** (development within vector) | | | | | |
| **STERCORARIA** (free flagellum present, kinetoplast large and not terminal, posterior end pointed, reproduction in mammalian host discontinuous, typically taking place in amastigote or epimastigote stages, development in vector (with formation of metatrypanosomes) in posterior station, transmission contaminative (except for *T. rangeli* where it is anterior station and inoculative transmission)) | | | | | |
| Subgenus: ***Megatrypanum*** (large trypanosomes, kinetoplast typically close to nucleus and far from posterior end of body, mammalian species show similarities with amphibian and reptilian species) | | | | | |
| *T.* (*M.*) *amilcari* (*lapsus T. amileari*) | | Rodentia: cricetid (Brazilian colilargo) | | | Brazil |
| *T.* (*M.*) *binneyi* | 54-79 | Monotremata: ornithorhynchid (platypus) | non-pathogenic | | Australia |
| *T.* (*M.*) *cervi* | 40-61 | Artiodactyla: cervid (elk/wapiti, white-tailed deer, mule deer, reindeer, moose) | non-pathogenic | | North America |
| *T.* (*M.*) *conorhini* (syn. *T. boylei*) | 36-62 | Rodentia: murids (black rat, house mouse); Primates: cercopithecid (macaque) | non-pathogenic | Hemiptera: reduviid (*Triatoma rubrofasciata*) | tropical Asia, Africa, Polynesia |
| *T.* (*M.*) *cyclops* | 33-49 | Primates: cercopithecid (southern pig-tailed macaque, crab-eating macaque), rarely hominid (human) | low | | Southeast Asia |
| *T.* (*M.*) *devei* | 39-46 | Primates: callitrichid (golden-handed tamarin, brown-mantled tamarin, saddleback tamarin) | non-pathogenic | | South America |
| *T.* (*M.*) *freitasi* | 49-52 | Didelphimorphia: didelphid (white-eared opossum) | non-pathogenic | | South America |
| *T.* (*M.*) *helogalei* [incl. subspp. *ichneumoni, helogalei*] | 38-54 | Carnivora: herpestid (common dwarf mongoose, Egyptian mongoose) | non-pathogenic | Hemiptera: reduviid (*Rhodinus prolixus*), cimicid (*Cimex lectularius*) | Africa |
| *T.* (*M.*) *heybergi* (syn. *T. thomasi*) | 25-30 | Chiroptera: nycterid (hairy slit-faced bat) | non-pathogenic | Diptera: culicid (*Aedes?*), Parasitiformes: macronyssid (*Ornithonyssus*) | West and East Africa |
| *T.* (*M.*) *hoarei* | 25-44 | Eulipotyphla: soricid (ornate shrew, American water shrew, Trowbridge's shrew, vagrant shrew) | non-pathogenic | | North America |
| *T.* (*M.*) *incertum* | 20-29 | Chiroptera: vespertilionid (common pipistrelle) | non-pathogenic | | England |
| *T.* (*M.*) *ingens* (syn. *T. schoenebeckei, tragelaphi p.p.*) | 72-130 | Artiodactyla: bovid (cattle, zebu, waterbuck, puku, suni, oribi, southern reedbuck, | non-pathogenic | | tropical Africa, Asia |

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|---|---|---|---|---|---|
| | | common duiker, harnessed bushbuck, sitatunga), tragulids (Java mouse deer) | | | |
| *T.* (*M.*) *irangiense* | 54-61 | Primates: lorisid (potto, Prince Demidoff's bushbaby) | non-pathogenic | | Central Africa |
| *T.* (*M.*) *irwini* | 32-39 | Diprotodontia: phascolarctid (koala) | low | | Australia |
| *T.* (*M.*) *lambrechti* | 42-57 | Primates: atelid (Columbian red howler), cebid (capuchins), pithecid (black-bearded saki, white-faced saki, collared titi monkey) | non-pathogenic | | South America |
| *T.* (*M.*) *legeri* | 26-51 | Pilosa: myrmecophagid (southern tamandua, giant anteater), bradypodid (brown-throated sloth), choleopodid (Hoffmann's two-toed sloth) | non-pathogenic | | Central America |
| *T.* (*M.*) *leleupi* | 35-45 | Chiroptera: hipposiderid (Sundevall's roundleaf bat) | non-pathogenic | Hemiptera: cimicid (*Stricticimex brevispinosus, Afrocimex leleupi*) | West Africa |
| *T.* (*M.*) *leonidasdeanei* | 34-74 | Chiroptera: emballonurid (greater sac-winged bat) | non-pathogenic | Diptera: psychodid (*Lutzomyia vespertilionis*) | Central America |
| *T.* (*M.*) *lizae* | 20-45 | Chiroptera: hipposiderid (cyclops roundleaf bat) | non-pathogenic | | Africa |
| *T.* (*M.*) *lucknovi* | | Primates: cercopithecid (rhesus macaque) | | | Africa |
| *T.* (*M.*) *magnusi* | 27 | Chiroptera: vespertilionid (common pipistrelle), emballonurid (naked-rumped tomb bat) | non-pathogenic | | Africa, Europe, Asia |
| *T.* (*M.*) *mazamarum* | 36-85 | Artiodactyla: cervids (brocket deer) | non-pathogenic | | South America |
| *T.* (*M.*) *megachiropterorum* | 32 | Chiroptera: pteropodid (Pacific flying fox) | non-pathogenic | | Oceania |
| *T.* (*M.*) *megadermae* | 40 | Chiroptera: megadermatid (yellow-winged bat), rhinopomatid (lesser mouse-tailed bat) | non-pathogenic | | Sudan |
| *T.* (*M.*) *melophagium* (syn. *T. woodcocki*) | 25-70 | Artiodactyla: bovid (sheep) | non-pathogenic | Diptera: hippoboscid (*Melophagus ovinus*) | worldwide |
| *T.* (*M.*) *minasense* | 28-48 | Primates: callitrichid (black-tufted marmoset, white-headed marmoset), pitheciid (titi), cebid (squirrel monkey, capuchin), atelid (woolly monkey) | non-pathogenic | | South America |
| *T.* (*M.*) *mojiguaci* | | Didelphimorphia: didelphid (mouse opossum) | | | South America |
| *T.* (*M.*) *morinorum* | 37-45 | Chiroptera: hipposiderid (trident bat) | non-pathogenic | | West Africa |
| *T.* (*M.*) *mpapuense* | 29-35 | Chiroptera: nycterid (slit-faced bat) | non-pathogenic | | Africa |

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|---|---|---|---|---|---|
| *T.* (*M.*) *pessoai* | 24-37 | Chiroptera: phyllostomid (common vampire bat, Seba's short-tailed bat) | non-pathogenic | | South and Central America |
| *T.* (*M.*) *pestanai* | 30-42 | Carnivora: mustelid (European badger) | non-pathogenic | Siphonaptera: ceratophyllid (*Paraceras melis*) | Eurasian |
| *T.* (*M.*) *phyllotis* | 47 | Rodentia: cricetid (Darwin's leaf-eared mouse) | non-pathogenic | Diptera: psychodid (*Phlebotomus noguchii*) | South America |
| *T.* (*M.*) *pifanoi* | 31-54 | Chiroptera: phyllostomid (great fruit-eating bat, greater spear-nosed bat) | non-pathogenic | Hemiptera: reduviid (*Triatoma*) | South America |
| *T.* (*M.*) *rhinopoma* | 31 | Chiroptera: rhinopomatid (lesser mouse-tailed bat) | non-pathogenic | | Sudan |
| *T.* (*M.*) *rochasilvai* | | Rodentia: cricetid (large-headed rice rat) | | | South America |
| *T.* (*M.*) *samueli* | | Didelphimorphia: didelphid (gray short-tailed opossum) | | | South America |
| *T.* (*M.*) *scotophila* | 31 | Chiroptera: vespertilionid (greater Asiatic yellow bat) | non-pathogenic | | IndoChina |
| *T.* (*M.*) *talpae* | 21-38 | Eulipotyphla: talpid (European mole) | non-pathogenic | Siphonaptera: hystrichopsyllid (*Palaeopsylla minor, Histrichopsylla talpae*)? | Europe |
| *T.* (*M.*) *theileri* [type species] (syn. *T. americanum*, *cephalophi, falchawi, franki, himalayanum, lingardi, muktesari, rutherfordi, scheini, tragelaphi p.p., transvaaliense, wrublewskii*) | 12-120 | Artiodactyla: bovids (cattle, zebu, water buffalo, European bison, suni, greater kudu, steenbok, reedbuck, common duiker, Eurasian moose), camelid (camels), cervid (red deer), tragulid (water chevrotain) | non-pathogenic | Diptera: tabanid (*Tabanus glaucopis, striatus, bromius, Haematopota pluvialis, Hybomitra ciureai, Pangonia, Chrysops*), hippoboscid (*Lipoptenia fortisetosa, cervi, Hippobosca maculata, rufipes*), psychodid (*Phlebotomus perniciosus*), culicid (*Aedes excricians, cataphylla, cantans, cinereus, annulipes, punctor, stictus, vexans, aegypti, Anopheles claviger, plumbeus, maculipennis, Culex annulatus, pipiens, Culiseta annulata, Mansonia richardii*); Ixodida: ixodid (*Hyalomma aegyptum*) | worldwide |
| *T.* (*M.*) *theodori* | 30-42 | Artiodactyla: bovids (goat) | non-pathogenic | Diptera: hippoboscid (*Lipoptena capreoli*) | Middle-East |
| *T.* (*M.*) *thylacis* | 30-44 | Diprotodontia: peramelid (southern brown bandicoot) | non-pathogenic | | Australia |
| *T.* (*M.*) *trinaperronei* | | Artiodactyla: cervid (white-tailed deer) | non-pathogenic | Diptera: hippoboscid (*Lipoptenia mazamae*) | Americas |
| *T.* (*M.*) *zeledoni* | 36-56 | Rodentia: heteromyid (Salvin's spiny pocket mouse) | non-pathogenic | | Central America |

| Subgenus: ***Herpetosoma*** (medium trypanosomes, subterminal kinetoplast far from posterior end of body, mammalian host reproduction in amastigote and/or epimastigote stages) | | | | | |
|---|---|---|---|---|---|
| *T.* (*H.*) *acomys* | 50 | Rodentia: murid (Cairo spiny mouse, golden spiny mouse) | non-pathogenic | Siphonaptera: pulicid (*Parapulex chephrensis*) | Sudan, Middle-East |
| *T.* (*H.*) *acouchii* (syn. *T. itriagoi*) | 29-44 | Rodentia: dasyproctid (Azara's agouti, brown agouti, red acouchi) | non-pathogenic | | West Africa, South and Central America |
| *T.* (*H.*) *advieri* | 22-30 | Primates: atelid (red-faced spider monkey) | non-pathogenic | | West Africa |
| *T.* (*H.*) *aenomysi* | 41 | Rodentia: murid (common rufous-nosed rat) | non-pathogenic | | West Africa |
| *T.* (*H.*) *akodoni* | 19-22 | Rodentia: cricetid (blackish grass mouse) | non-pathogenic | | South America |
| *T.* (*H.*) *arvicoli* | nr | Rodentia: cricetid (European water vole) | non-pathogenic | | Russia |
| *T.* (*H.*) *assintis* | | Rodentia: murid (house mouse) | | | Middle-East |
| *T.* (*H.*) *avicularis* (syn. *T. arvicanthi, guisthaui*) | 24 | Rodentia: murid (Barbary striped grass mouse) | non-pathogenic | Siphonaptera: leptopsyllid (*Leptopsylla*), ceratophyllid (*Nosopsyllus*), hystrichopsyllid (*Stenoponia*?) | Africa |
| *T.* (*H.*) *bandicotti* | 24-36 | Rodentia: murid (greater bandicoot rat, short-tailed bandicoot rat) | non-pathogenic | Siphonaptera: pulicid (*Xenopsylla astia*) | India |
| *T.* (*H.*) *blanchardi* (syn. *T. eliomys*) | 25-35 | Rodentia: glirid (garden dormouse, European edible dormouse) | non-pathogenic | Siphonaptera: ceratophyllid (*Myoxopsylla laverani*) | Europe |
| *T.* (*H.*) *brodeni* | 25-34 | Eulipotyphla: soricid (four-toed elephant shrew) | non-pathogenic | | Africa |
| *T.* (*H.*) *countinhoi* | 32-42 | Rodentia: cuniculid (lowland paca) | non-pathogenic | | South America |
| *T.* (*H.*) *crocidurae* | 25-34 | Eulipotyphla: soricid (common shrew, greater white-toothed shrew) | non-pathogenic | Siphonaptera: ctenophthalmid (*Ctenophthalmus agyrtes*) | Europe |
| *T.* (*H.*) *dendromysi* | 30-33 | Rodentia: dendromyid (tree mouse) | non-pathogenic | | Congo |
| *T.* (*H.*) *denysi* (syn. *T. anomaluri*) | 37-48 | Rodentia: anomalurid (Lord Derby's scaly-tailed squirrel) | non-pathogenic | | West Africa |
| *T.* (*H.*) *diasi* | 40-45 | Chiroptera: phyllostomid (great fruit-eating bat, Pallas's long-tongued bat) | non-pathogenic | | South America |
| *T.* (*H.*) *dressei* | 31-35 | Rodentia: murid (African tree rat) | non-pathogenic | | Congo |
| *T.* (*H.*) *ellobii* | nr | Rodentia: cricetid (northern mole vole) | non-pathogenic | | Russia |
| *T.* (*H.*) *evotomys* [incl. subspp. *evotomys, kudickei, clethrionomi*] | 21-32 | Rodentia: cricetid (southern red-backed vole, northern red-backed vole, bank vole) | non-pathogenic | Siphonaptera: ceratophyllid (*Ceratophyllus penicilliger, Nosopsyllus fasciatus*), ctenophthalmid (*Ctenophthalmus agyrtes*) | Eurasia, North America |
| *T.* (*H.*) *ferriolli* | | Rodentia: cricetid | | | South America |

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| | | (terraced rice rat) | | | |
| *T.* (*H.*) *forettinii* | 30-32 | Rodentia: cricetid (Brazilian pygmy rice rat) | non-pathogenic | | South America |
| *T.* (*H.*) *graphiuri* | 24-27 | Rodentia: glirid (woodland dormouse) | non-pathogenic | | West Africa |
| *T.* (*H.*) *grosi* (syn. *T. apodemi, korssaki*) | 21-28 | Rodentia: murid (yellow-necked mouse, wood mice, striped field mouse) | non-pathogenic | Siphonaptera: ctenophthalmid (*Ctenophthalmus agyrtes, congener*) | Eurasia |
| *T.* (*H.*) *indicum* | 18-34 | Rodentia: sciurid (Indian palm squirrel); Artiodactyla: bovid (cattle) | non-pathogenic | | India |
| *T.* (*H.*) *leeuwenhoeki* | 43-46 | Pilosa: choloepodid (Hoffmann's two-toed sloth), bradypodid (brown-throated sloth) | non-pathogenic | | Central America |
| *T.* (*H.*) *lemmi* | | Rodentia: cricteid (Norway lemming) | | | Europe |
| *T.* (*H.*) *lewisi* [type species] (syn. *T. duttoni p.p., eburneense, longocaudense, murinum*, *rattorum*) | 21-37 | Rodentia: murid (black rat, brown rat, Annandale's rat, Maclear's rat, Turkestan rat, Anderson's white-bellied rat, rice field rat, Malayan field rat, Polynesian rat, bush rat, Moluccan prehensile-tailed rat, house mouse, Jackson's soft-furred mouse, Natal multimammate mouse, southern multimammate mouse), nesomyid (Gambian pouched rat); Lagomorpha: leporid (cottontail rabbit) | non-pathogenic | Siphonaptera: ceratophyllid (*Nosopsyllus fasciatus, Ceratophyllus hirudinis*), pulicid (*Ctenocephalides canis, Pulex irritans Xenopsylla cheopis*), leptopsyllid (*Leptopsylla senis*); Phthiraptera: haematopinid (*Haemotopinus spinulosus*) | worldwide |
| *T.* (*H.*) *lineatum* | 16-21 | Chiroptera: phyllostomid (white-lined broad-nosed bat) | non-pathogenic | | South America |
| *T.* (*H.*) *longiflagellum* | | Chiroptera: emballonurid (naked-rumped tomb bat) | | | Iraq |
| *T.* (*H.*) *magnusi* | | Chiroptera: emballonurid (naked-rumped tomb bat), vespertilionid (Kuhl's pipistrelle) | | | Iraq |
| *T.* (*H.*) *mesnilibrimonti* | 30-41 | Pilosa: choloepodid (Linnaeus's two-toed sloth) | non-pathogenic | | South America |
| *T.* (*H.*) *mariae* | 21 | Rodentia: cricetid (large vesper mouse, Brazilian colilargo) | non-pathogenic | Siphonaptera: pulicid (*Xenopsylla cheopis*), rhopalopsyllid (*Polygenis*) | South America |
| *T.* (*H.*) *microti* [incl. subspp. *microti, arvali, nearcticum*] | 20-32 | Rodentia: cricetid (common vole, eastern meadow vole, prairie vole, California vole, short-tailed field vole, tundra vole) | non-pathogenic | Siphonaptera: ceratophyllid (*Nosopsyllus fasciatus*), ctenophthalmid (*Ctenophthalmus agyrtes*) | Eurasia, North America |
| *T.* (*H.*) *musculi* [syn. *T. duttoni p.p.*] | 28-32 | Rodentia: murid (house mouse, brown rat) | non-pathogenic | Siphonaptera: ceratophyllid | Europe, Africa, Americas |

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| | | | | (*Ceratophyllus hirundinis, Nosopsyllus*), ctenophthalmid (*Ctenophthalmus*), leptopsyllid (*Leptopsylla*) | |
| *T.* (*H.*) *mycetae* (syn. T. *forestali*) | 29-37 | Primates: atelid (Columbian red howler, red-handed howler, black howler) | non-pathogenic | | South America |
| *T.* (*H.*) *myocastori* | 31-80 | Rodentia: echimyid (nutria) | non-pathogenic | | South America |
| *T.* (*H.*) *myoxi* | nr | Rodentia: glirid (hazel dormouse) | non-pathogenic | | Europe |
| *T.* (*H.*) *myrmecophagae* | 49 | Pilosa: myrmecophagid (giant anteater) | non-pathogenic | Hemiptera: reduviid (*Rhodnius prolixus*) | South America |
| *T.* (*H.*) *nabiasi* (syn. *T. cuniculi, leporissylvaticus*) | 21-34 | Lagomorpha: leporid (European rabbit, mountain cottontail, desert cottontail, eastern cottontail) | non-pathogenic | Siphonaptera: pulicid (*Spilopsyllus cuniculi*) | worldwide |
| *T.* (*H.*) *neotomae* (syn. *T. woodi*) | 22-34 | Rodentia: cricetid (white-throated woodrat, dusky-footed woodrat, desert woodrat) | non-pathogenic | Siphonaptera: ceratophyllid (*Orchopeas howardi*) | North America |
| *T.* (*H.*) *ochotoni* | nr | Lagomorpha: ochotonid (Pallas's pika) | non-pathogenic | | Russia |
| *T.* (*H.*) *otospermophili* [incl. subspp. *otospermophili, spermophili*] (syn. *T. citelli, iowense, hixsoni, schalaschnikovi*) | 25-40 | Rodentia: sciurid (California ground squirrel, Franklin's ground squirrel, Richardson's ground squirrel, thirteen-lined ground squirrel, speckled ground squirrel, little ground squirrel, yellow ground squirrel, russet ground squirrel, long-tailed ground squirrel) | non-pathogenic | Siphonaptera: ceratophyllid (*Opisocrostis bruneri*) | Eurasia, North America |
| *T.* (*H.*) *palawanense* | | Rodentia: murid (Palawan spiny rat) | | | Philippines |
| *T.* (*H.*) *parkeri* [incl. subspp. *parkeri, marmoti*] | 27-33 | Rodentia: sciurid (yellow-bellied marmot, alpine marmot) | non-pathogenic | | North America, Asia |
| *T.* (*H.*) *pattolii* (syn. *T. agouchyi*) | | Rodentia: dasyproctid (Azara's agouti) | | | South America |
| *T.* (*H.*) *perodictici* | 25-45 | Primates: galagid (brown greater galago, Prince Demidoff's bushbaby), lorisid (potto) | non-pathogenic | | Africa |
| *T.* (*H.*) *peromysci* | 23-37 | Rodentia: cricetid (brush mouse, deermouse, California deermouse, Mexican deermouse, Pinyon mouse) | non-pathogenic | | North and Central America |
| *T.* (*H.*) *petrodromi* [incl. subspp. *petrodromi, chitali*] | 32-41 | Macroscelidea: macroscelidid (short-snouted elephant shrew, four-toed elephant shrew) | non-pathogenic | | East and Central Africa |
| *T.* (*H.*) *pitymydis* | 20-30 | Rodentia: cricetid (alpine pine vole) | non-pathogenic | | Europe |

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| *T.* (*H.*) *preguici* | 45 | Pilosa: choloepodid (Hoffmann's two-toed sloth) | non-pathogenic | | Central America |
| *T.* (*H.*) *primatum* | 28-36 | Primates: hominids (chimpanzee, gorilla), cercopithecid (mustached guenon) | non-pathogenic | | West Africa |
| *T.* (*H.*) *rabinowitschi* (syn. *T. criceti, cricetuli, zabolotnyi*) | 17-42 | Rodentia: cricetid (European hamster, grey dwarf hamster, Chinese striped hamster, Eversmann's hamster, giant rat-headed hamster) | non-pathogenic | Siphonaptera: pulicid (*Ctenocephalides canis*), ctenophthalmid (*Ctenophthalmus*), ceratophyllid (*Nosopsyllus fasciatus*) | Eurasia |
| *T.* (*H.*) *rangeli* (syn. *T. aroarii, cebus, escomeli, guatemalense*) | 25-37 | Primates: hominids (human), cebid (blond capuchin, tufted capuchin, Columbian white-faced capuchin, black-capped squirrel monkey), atelid (spider monkey), aotid (night monkey), callitrichid (marmoset); Pilosa: bradypodid (brown-throated sloth), choloepodid (Hoffmann's two-toed sloth), myrmecophagid (southern tamandua); Carnivora: canid (dog), felid (cat), procyonid (raccoon, coati, kinkajou), mustelid (tayra); Didelphimorphia: didelphid (common opossum, white-eared opossum, grey four-eyed opossum); Rodentia: murid (rat, mouse), caviid (guinea pig), sciurid (squirrel) | non-pathogenic | Hemiptera: reduviid (*Rhodnius prolixus, brethesi, colombiensis, dalessandroi, domesticus, ecuadorensis, milesei, nasutus, neglectus, neivai, pallescens, paraensis, pictipes, robustus, stali, Triatoma dimidiata, infestans, nitida, patagonica, phyllosomae, protracta, vitticeps, Panstrongylus geniculatus, herreri, megistus, Cavernicola hemipterus, pilosa, Triatoma dimidiata, infestans, nitidia, phyllostomae, Mepraia spinolai*); cimicid (*Cimex lectularius, hemipterus*) | South and Central America |
| *T.* (*H.*) *renjifoi* | 21-33 | Rodentia: echimyid (Guyenne spiny rat) | non-pathogenic | | South America |
| *T.* (*H.*) *saimiri* | 25-36 | Primates: cebid (common squirrel monkey, black-capped squirrel monkey) | non-pathogenic | Hemiptera: reduviid (*Rhodnius prolixus, Panstrongylus megistus*) | South America |
| *T.* (*H.*) *sciuri* | 41 | Rodentia: sciurid (Congo rope squirrel, Gambian sun squirrel) | non-pathogenic | Siphonaptera: ceratophyllid (*Nosophyllus alladinis*) | West Africa |
| *T.* (*H.*) *sigmodoni* | 16-25 | Rodentia: cricetid (hispid cotton rat) | non-pathogenic | | North and Central America |
| *T.* (*H.*) *siqueirai* | | Rodentia: echimyid (black-spined Atlantic tree-rat) | | | South America |
| *T.* (*H.*) *soricis* | 17 | Eulipotyphla: soricid (vagrant shrew) | non-pathogenic | | North America |
| *T.* (*H.*) *tamiasi* | 37-39 | Rodentia: sciurid (eastern chipmunk) | non-pathogenic | Siphonaptera: ceratophyllid (*Megabothris acerbus, quirini*), hystrichopsyllid | North America |

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| | | | | (*Tamiophila grandis*)) | |
| *T.* (*H.*) *ulanovi* (syn. *T. berestnev*i, *pygere*thmi) | | Rodentia: dipodid (great jerboa, small five-toed jerboa, William's jerboa, greater fat-tailed jerboa) | non-pathogenic | | Iran |
| *T.* (*H.*) *xeri* | 33 | Rodentia: sciurid (striped ground squirrel) | non-pathogenic | | West Africa |
| *T.* (*H.*) *zapi* | 26-37 | Rodentia: dipodid (meadow jumping mouse, western jumping mouse, Pacific jumping mouse) | non-pathogenic | Siphonaptera: ceratophyllid (*Megabothris abantis*) | North America |
| Subgenus: ***Schizotrypanum*** (small C-shaped trypanosomes, voluminous kinetoplast near short pointed posterior end of body, mammalian host reproduction in amastigote and/or epimastigote stages, intracellular development in vertebrate cells, transmitted by haematophagous hemipterans (triatomine and cimicid bugs), homogenous assemblage of morphologically indistinguishable species) | | | | | |
| *T.* (*S.*) *cruzi* [type species] (syn. *T. deanei*, *minanense, rhesii*, *triatomae*, *vickersae*) | 12-30 | Primates: hominid (human), atelid (brown woolly monkey, red-handed howler, black howler, Columbian red howler, spider monkey), callitrichid (brown-mantled tamarin, black-mantled tamarin, red-crested tamarin, cottonhead tamarin, common marmoset, black-tufted marmoset, silvery marmoset, pygmy marmoset), cebid (tufted capuchin, white-fronted capuchin, Columbian white-faced capuchin, black-capped squirrel monkey, Guianan squirrel monkey), cercopithecid (rhesus macaque), pithecid (black-fronted titi monkey, bald uakari); Didelphimorphia: didelphid (common opossum, grey opossum, grey short-tailed opossum, grey four-eyed opossum, big-eared opossum, woolly opossum, brown four-eyed opossum, big lutrine opossum, agile gracile opossum, white-bellied fat-tailed mouse opossum, Alston's mouse opossum, Robinson's mouse opossum); Pilosa: bradypodid (three-toed sloth), myrmecophagid (southern tamandua); Cingulata: chlamyphorid (pichi, six-banded armadillo, southern | Chagas' disease | Hemiptera: reduviid (*Triatoma brasiliensis, barberi, carrioni, dimidiata, gerstaeckeri, guasayana, hegneri, infestans, lecticularia, longipennis, maculata, neotomae, pallidipennis, patagonica, phyllosoma, protracta, rubida, rubrofasciata, rubrovaria, sanguisuga, sordida, tibiamaculata, vitticeps, Panstrongylus chinai, lignarius, megistus, geniculatus, herreri, rufotuberculatus, Rhodnius ecuadoriensis, neglectus, prolixus, pallescens, pictipes, Eratyrus cuspidatus;* plus reports in *Cavernicola, Dipetalogaster, Neotriatoma, Parabelminus* and *Psammolestes* spp.) | southern North America, Central and South America |

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| | | three-banded armadillo, northern naked-tailed armadillo, southern naked-tailed armadillo, big hairy armadillo, screaming hairy armadillo), dasypodid (nine-banded armadillo, greater long-nosed armadillo, southern long-nosed armadillo, Yepe's mulita); Lagomorpha: leporid (European rabbit, eastern cottontail); Rodentia: caviid (guinea pig, Brazilian guinea pig, Spix's yellow-toothed cavy, southern mountain cavy), cricetid (brush mouse, Pinyon mouse, montane grass mouse, scaly-footed water rat, dusky-footed woodrat, southern plains woodrat, white-throated woodrat, pack rat, large-headed rice rat, terraced rice rat, hairy-tailed akodont), ctenomyid (Tucuman tuco-tuco), cuniculid (lowland paca), dasyproctid (red-rumped agouti, Azara's agouti, Brazilian agouti), echimyid (drab Atlantic tree-rat, Guyenne spiny rat), erethizontid (Bahia porcupine, brown hairy dwarf porcupine, Mexican hairy dwarf porcupine, Brazilian porcupine, Andean porcupine), murid (Mongolian gerbil, black rat, brown rat, Natal multimammate mouse, house mouse), octodontid (common degu), sciurid (antelope squirrel, red-tailed squirrel, Brazilian squirrel, Bolivian squirrel, white-tailed prairie dog), Artiodactyla: suid (pig); Chiroptera: emballonurid (lesser dog-like bat, proboscis bat, greater sac-winged bat), molossid (black mastiff bat, Mexican free-tailed bat, white-striped free-tailed bat), noctilionid | | | |

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| | | (lesser bulldog bat), phyllostomid (common vampire bat, spectral bat, tent-making bat, golden bat, little big-eared bat, greater spear-nosed bat, lesser spear-nosed bat, pale spear-nosed bat, Goldman's nectar bat, great fruit-eating bat, Gervais's fruit-eating bat, Jamaican fruit bat, Seba's short-tailed bat, Pallas's long-tongued bat), vespertilionid (big-eared brown bat, free-tailed bat, black bonneted bat, dwarf bonneted bat, Brazilian brown bat, Argentine brown bat, black myotis, red myotis, Chilean myotis); Carnivora: canid (dog, culpeo, grey fox, hoary fox, South American gray fox, crab-eating fox), felid (cat), mephitid (striped skunk, hooded skunk), mustelid (tayra, lesser grison, greater grison), procyonid (white-nosed coati, South American coati, raccoon, ringtail) | | | |
| *T.* (*S.*) *aunawa* | | Chiroptera: miniopterid (great bent-winged bat) | | | Indonesia |
| *T.* (*S.*) *assiutis* | | Rodentia: murid (house mouse) | | | Egypt |
| *T.* (*S.*) *erneyi* | | Chiroptera: molossid (free-tailed bat) | non-pathogenic | | East Africa |
| *T.* (*S.*) *hendricki* | | Chiroptera: vespertilionid (big brown bat) | non-pathogenic | Hemiptera: cimicid (*Cimex brevis*) | Americas |
| *T.* (*S.*) *hipposideri* | 14-21 | Chiroptera: hipposiderid (bicolored roundleaf bat) | non-pathogenic | | Australia |
| *T.* (*S.*) *janseni* | | Didelphimorphia: didelphid (big-eared opossum) | | | Brazil |
| *T.* (*S.*) *lesourdi* | 19 | Primates: atelid (red-faced spider monkey) | non-pathogenic | | South America |
| *T.* (*S.*) *livingstonei* | 32 | Chiroptera: rhinolophid (Lander's horseshoe bat), hipposiderid (Sundevall's roundleaf bat) | non-pathogenic | | Africa |
| *T.* (*S.*) *myoti* | ? | Chiroptera: vespertilionid (little brown bat) | non-pathogenic | Hemiptera: cimicid (*Cimex brevis*) | North America |
| *T.* (*S.*) *noyesi* | two forms 8, 25 | Diprotodontia: potoroid (bettong), macropodid (grey kangaroo, hare-wallaby), phalangerid (brush-tailed possum) | non-pathogenic | | Australia |

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| *T.* (*S.*) *pecarii* | | Artiodactyla: tayassuid (collared peccary) | | | Americas |
| *T.* (*S.*) *phyllostomae* (possible synonym of *T. cruzi*) | 15-24 | Chiroptera: phyllostomid (greater spear-nosed bat, Seba's short-tailed bat) | non-pathogenic | Hemiptera: reduviid (*Triatoma infestans*, *Cavernicola pilosa, Panstrongylus geniculatus*), cimicid (*Cimex hemipterus*); Ixodida: argasid (*Ornithodorus moubata*?) | South and Central America |
| *T.* (*S.*) *prowazeki* | 21 | Primates: pitheciid (uakari) | non-pathogenic | | originally from Brazil |
| *T.* (*S.*) *pteropi* | 26-32 | Chiroptera: pteropodid (black flying fox) | non-pathogenic | | Australia |
| *T.* (*S.*) *sanmartini* (possible synonym of *T. cruzi*) | 17-24 | Primates: cebid (common squirrel monkey) | non-pathogenic | Hemiptera: reduviid (*Rhodnius prolixus*) | South America |
| *T.* (*S.*) *vespertilionis* (syn. *T. dionisii, nicolleorum, pipistrelli*) | 10-24 | Chiroptera: emballonurid (gland-tailed free-tailed bat), hipposiderid (Sundevall's roundleaf bat), miniopterid (common bent-wing bat), molossid (black bonneted bat, western mastiff bat, velvety free-tailed bat, black mastiff bat, Mexican free-tailed bat, northern free-tailed bat, broad-eared bat), mormoopid (Davy's naked-backed bat, Allen's common mustached bat), noctilionid (greater bulldog bat), phyllostomid (common vampire bat, Ipanema bat, Pallas's long-tongued bat, greater spear-nosed bat, tailed tailless bat, Seba's short-tailed bat, California leaf-nosed bat), vespertilionid (small big-eared brown bat, tropical big-eared brown bat, lesser mouse-eared bat, pallid bat, common noctule, common pipistrelle, slender-winged pipistrelle, Kuhl's pipistrelle, serotine bat, Ognev's serotine, Rafinesque's big-eared bat, southern yellow bat, diminutive serotine, big brown bat, eastern red bat, hoary bat, Natterer's bat, black myotis, canyon bat, cave myotis, Arizona myotis, | non-pathogenic | Hemiptera: cimicid (*Cimex pipistrelli*, *lectularus*), reduviid (*Rhodinus prolixus, Panstrongylus megistus*, *Triatoma megista*?); Ixodida: argasid (*Ornithodorus moubata*?) | Africa, Eurasia, Iran, South America |

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| | | Yuma myotis); Rodentia: murid (house mouse) | | | |
| *T.* (*S.*) *wauwau* | | Chiroptera: mormoopid (naked-backed bat) | non-pathogenic | | South and Central America |

**Parasite morphology:** Three developmental stages are usually formed: trypomastigotes, amastigotes and epimastigotes. Trypomastigotes are elongate thin stages with a posterior kinetoplast and an undulating membrane along the length of the body. They are often curved in shape ranging from 15-55 µm in length by 1-4 µm in width. Trypomastigotes undergo a maturation process known as metacyclogenesis whereby they become smaller and broader as they become infective metacyclic forms (sometimes known as metatrypanosomes). Amastigotes are small rounded non-flagellated cells with an eccentric nucleus and kinetoplast. These cells are among the smallest known eukaryotic cells ranging from 1.5-4.0 µm in diameter. Epimastigotes are long thin cells with an anterior kinetoplast, a short undulating membrane and a long free flagellum. They are pleomorphic in shape and range in size from 10-30 µm in length by 1-4 µm in width. Occasionally, rounded sphaeromastigotes have been described for some species as transient divisional stages with rounded bodies, anterior kinetoplasts and a short flagellum emerging from a flagellar pocket.

**Site of infection:** Parasites undergo posterior station (hindgut) development in their invertebrate vectors and stercorarian transmission by faecal contamination to vertebrates. Amastigotes are found within vertebrate hosts in many different tissues. Host cells most frequently invaded are reticuloendothelial cells of the spleen, liver and lymphatics and cells in cardiac, smooth and skeletal musculature. The amastigotes divide repeatedly ultimately lysing the host cell and infecting neighbouring cells, sometimes resulting in cyst-like colonies (called pseudocysts) in muscle cells. Some amastigotes give rise to haematozoic trypomastigotes which circulate in the blood. A total of 125 stercorarian *Trypanosoma* spp. have been described in over 240 mammalian host species belonging to 48 families in 12 orders (mainly bats, rodents and primates, but also some artiodactylans, carnivores, opossums, shrews, marsupials, pilosans, and a few lagomorphs, cingulates and monotremes). Trypomastigotes ingested by vectors transform into epimastigotes which multiply in the gut. Around 130 arthropod species have been found to act as vectors for stercorarian trypanosomes: including 66 hemipteran species (mostly reduviids, and some cimicids), 33 dipteran species (culicids, hippoboscids, psychodids, and some tabanids), 26 fleas (ceratophyllids, ctenophthalmids, hystrichopsyllids, leptopsyllids, pulicids, and rhopalopsyllids), 2 ticks (argasid and ixodid), one mite (macronyssid), and one louse (haematopinid).

**Pathogenesis**: *T. cruzi* causes New World (or American) trypanosomiasis (AT), a chronic condition commonly known as Chagas' disease. Most infections may cause few or no symptoms, but acute symptoms may develop particularly in children. The first sign is often acute inflammation and swelling of the skin at the site of infection (lesion called a chagoma). If this involves the conjunctiva of the eye, unilateral orbital oedema (known as Romana's sign) may develop. Amastigotes infect many cells, either actively or by phagocytosis, and undergo proliferation causing cell lysis and tissue lesions. Acute clinical signs include inflammation, fever, hepatosplenomegaly, lymphadenopathy, cardiac arrhythmia and general malaise. If the acute stage of infection is not treated, then patients enter a chronic stage which is initially asymptomatic. Amastigotes continue to multiply in host cells and spread throughout the body via the lymphatics and circulation to most tissues and organs, especially histiocytes, adipocytes, myocardial fibres and autonomic ganglia in the gastro-intestinal tract. Most infected patients continue in this state for the remainder of their lives. However, around a third develop serious clinical manifestations 10-30 years after infection, particularly involving significant organ enlargement and pathology in the heart and intestines. The myocardium may contain large pseudocysts of amastigotes without any surrounding inflammation as well as destroyed myocardial cells with lymphocyte, macrophage and plasma cell infiltrates forming 'microabscesses' that later become fibrotic. The heart undergoes marked hypertrophy and dilatation, with the left ventricular wall becoming so thin as to be transilluminable. Chronic infections are characterized by palpitations (colloquially known in Brazil as baticum), arrhythmias, myositis, thromboses, chest pain, cardiac failure and 'megaviscera syndrome' (dilation of tubular organs, especially the oesophagus and colon). Different *T. cruzi* strains often produce different clinical presentations: e.g. group I strains (rare north of the Amazon basin) usually produce cardiac but not digestive tract lesions; while group II strains may produce both (including meningoencephalopathy in HIV-AIDS patients). Clinical and experimental studies have revealed many complex immune interactions between hosts and parasites. *T. cruzi* amastigotes may infect any nucleated mammalian cell and multiply intracellularly within parasitophorous vacuoles or free in the cytoplasm. Infections have been shown to stimulate many innate and acquired (adaptive) host immune responses, but the parasites are masters at immune evasion and persist for years. While around 90% of infected persons recover from acute infections, they are not immune but continue to have low parasitaemia for indefinite periods. Nonetheless, the prospect of inducing strong host protection has fuelled the search for a vaccine, although differences in parasite virulence and host susceptibility have confounded many studies in laboratory animal models. Most infections by other stercorarian species in animals (domesticated and wild species) are cryptic and do not cause clinical disease, including the *T. theileri* group (*T. theileri, T. melophagium, T. cervi, T. trinaperronei*) in livestock.

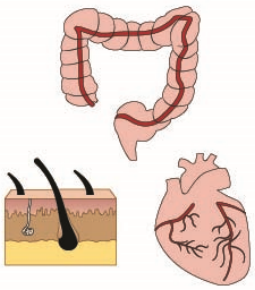
**Developmental cycle and mode of transmission:** Infections by *T. cruzi* are transmitted by blood-sucking reduviid bugs belonging to the subfamily Triatominae, commonly known as assassin- or kissing-bugs because they often feed around the lips of sleeping persons. The disease is often associated with poverty, because the bugs live in cracks in the mud walls of houses in poor areas. The parasites undergo posterior station (stercorarian) development where epimastigotes develop in the hindgut and metacyclic

trypomastigotes are passed in the bug faeces during or after feeding (contaminative transmission). The parasites enter the vertebrate host through the bite site, scratched skin or through mucous membranes rubbed with contaminated fingers. Various regional cultural practices facilitate transmission, including children playing with triatomine bugs, native populations eating bugs with hot sauce, using bug faeces in folklore remedies for warts, or consuming bug-infested sugarcane juice or palm fruit juice. In vertebrate hosts, invading trypomastigotes transform into amastigotes which multiply within host cells giving rise to haematozoic trypomastigotes which are taken up by feeding vectors. Infections by *T. cruzi* and *T. rangeli* are transmitted by reduviid bugs whereas *T. theileri*, *T. melophagium* and *T. lewisi* are transmitted by tabanid flies, sheep ked and rat fleas, respectively. Infections in humans have occasionally been shown to be transmitted horizontally through organ or blood transfusion or sharing intravenous needles for recreational drug use, and sometimes vertically by crossing the placenta and invading developing foetuses. The incubation period in vectors ranges from 10-30 days, while that in vertebrate hosts ranges from 5-42 days. Infections in animals by members of the *T. theileri* group have been shown to be transmitted by ingesting infected vectors, by the contamination of skin abrasions, mucous membranes or bite sites by vector faeces (aided by the process of prediuresis where the vector voids water to concentrate their bloodmeals), and possibly by transplacental transfer in some bovids and cervids.

**Differential diagnosis:** Trypanosomes may be detected in blood, lymph, cerebrospinal fluid or biopsy tissues before or after laboratory culture. The parasites grow well *in vitro* in a range of media (especially nutrient agar-blood mixtures) and they readily infect laboratory mice. In the past, xenodiagnosis has also been used where clean laboratory-reared reduviid bugs are allowed to feed on patients and then examined several weeks later for parasites. A range of immunoserological tests (complement fixation, haemagglutination, immunofluorescence, enzyme immuno-assays and rapid diagnostic tests) have been developed to detect host antibodies and more recently, polymerase chain reaction (PCR) techniques have been used to amplify parasite DNA from clinical samples. Molecular characterization studies have identified various biodemes, zymodemes, schizodemes and genetic lineages which have been grouped into *T. cruzi* I (mainly in wild mammals and sylvan triatomines), *T. cruzi* II (usually in humans) and other non-grouped strains. Sequences examined have included ribosomal DNA, internal transcribed spacers, mitochondrial (kinetoplast) cytochrome B, mini-exon genes and microsatellites (tandem array repetitive DNA).

**Treatment and control:** Infections do not respond well to chemotherapy due to the ‘hidden’ intracellular location of the amastigotes. Nifurtimox, benznidazole, allopurinol, pentamidine, melarsoprol, eflornithine and suramin have been reported to reduce the severity of some early-stage infections but some have serious adverse and toxic side-effects and are not effective against chronic infections. Cure rates are low and successful treatment requires hospitalization or careful monitoring of the patient. It is regrettable that only around 1% of patients are ever treated for Chagas’ disease, due to the lack of early intervention, effective treatment and affordable healthcare. Control measures based on vector eradication using residual insecticidal sprays, paints or fumigant canisters have proven partially effective but expensive. Houses may be sprayed with pyrethroids such as deltamethrin, cyhalothrin or cyfluthrin and then monitored long-term for bug re-infestations. Prevention includes eliminating potential bug habitats by repairing cracked walls and using better building products and techniques, as well as avoiding bug bites through the use of insecticide-impregnated bed nets.

# *Trypanosoma*
## (mammalian 'stercorarian' species)
## (e.g. *T. cruzi*)



dermis, internal organs
(inflammation, oedema,
cardiomyopathy, mega-
dilation of tubular organs)

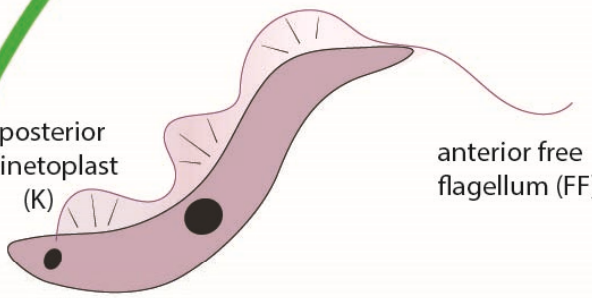
division by
longitudinal
binary fission

Vertebrate Hosts
(mammals, esp.
humans, cattle)

long undulating
membrane (UM)

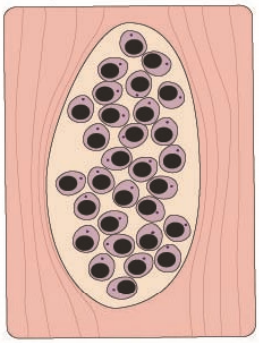
posterior
kinetoplast
(K)

anterior free
flagellum (FF)



trypomastigotes (15-55 µm)

cyst-like colonies

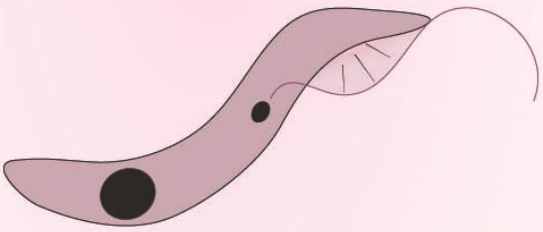


[no FF,
no UM]

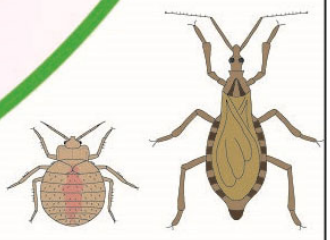
amastigotes (1.5-4 µm)

contaminative (stercorarian) transmission
(infective stages contaminate bite site)

ingested with
bloodmeal

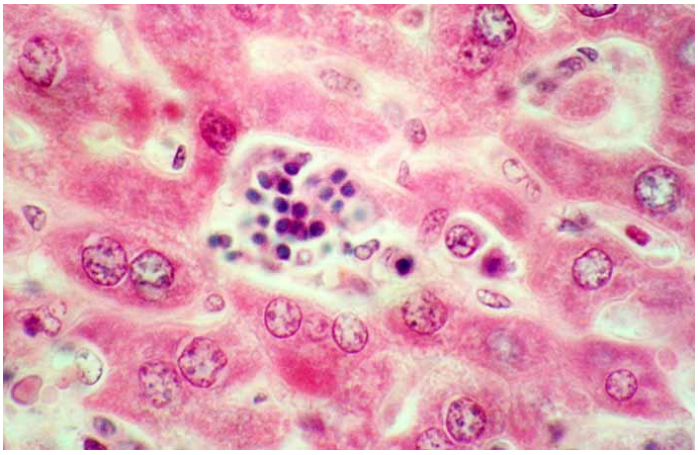


epimastigotes (10-35 µm)
[anterior K, short UM, FF]

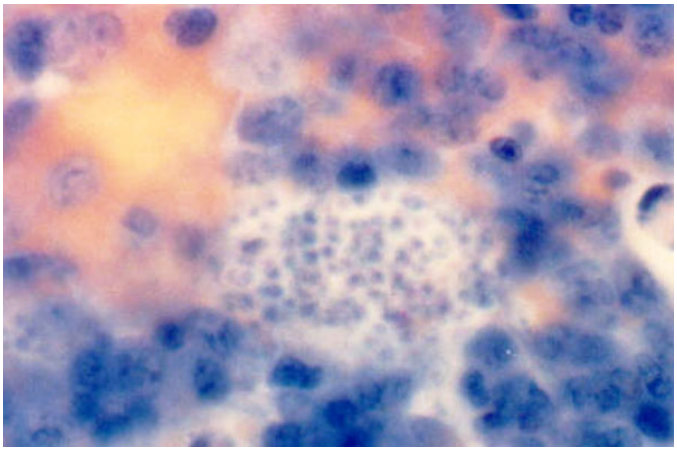


vector-borne transmission

Invertebrate Hosts
(reduviid/cimiciid bug vectors)
(posterior alimentary tract)



*Trypanosoma cruzi* amastigotes in human liver



*Trypanosoma cruzi* amastigotes in human spleen

Reduviid bug vector for *Trypanosoma cruzi*