

Redescription of Genera of Family Eimeriidae Minchin, 1903

Tirth R. Ghimire

Strathclyde Institute of Pharmacy and Biomedical Sciences, University of Strathclyde, Glasgow, Scotland.

Correspondence: ghimiretr7@yahoo.co.in

ABSTRACT

Taxonomy includes collection, identification, naming and ordering of specimens into a system of words consistent with any kind of relationships among them, the study of literatures and analysis of variations shown by the specimens and finally the publication of data. Practical reasons for the degree of stability-even for a relatively short period of time are: for teaching purposes at advanced levels and for the benefit of many non-protozoologists. The eimeriid coccidia are one of the more controversial groups of protozoa. The problems of describing different species within family Eimeriidae Minchin, 1903 are due to their abnormal phenotypic and phylogenetic characters, occurrence in abnormal hosts with different lifecycle patterns. The basis of classification of the genera under this family includes the Phenotypic and Phylogenetic characters and the lifecycle of parasites and data of their hosts. I have updated the information of classification system given by the Society of Protozoologists (Lee JJ, Hutner SH, Bovee EC and Upton J, 2001. The Illustrated Guide to the Protozoa, 2nd Edition. Allen Press, Lawrence, KS) and online materials by Duszynski DW, Couch L and Upton SJ, Supported by NSF-PEET DEB 9521687. In this review, I have focused on seventeen true species and seven pseudospecies with the information of their synonyms, oocyst formula, generic characters, and total number of named species, type species and type host.

Keywords: *Eimeriidae, Genera, Phenotypic, phylogenetic, pseudoparasitism, Redescription.*

INTRODUCTION

Taxonomy, a synthetic science, is the mother of biological sciences that guides the generalists and specialists in academic and applied field. It includes collection, identification, naming and ordering of specimens into a system of words consistent with any kind of relationships among them, the study of literatures and analysis of variations shown by the specimens and finally the publication of data. It is the natural philosophical science that requires as much wisdom and intelligence as any other fields of biology. It advances through the three phases: alpha or analytical phase, beta or synthetic phase and gamma or biological phase trained by trial and error and is slow and steady, but without any intelligent discoveries.

Any classification, published or unpublished, should be a suggestion rather than a dogma. It is liable to be modified by any specialist or competent teacher, but he must give his

reasons for the changes he introduces. Taxonomy has two purposes: to summarize ideas concerning the natural relationships of organism and to provide a tool for use in academic and applied field. For the latter purpose, the non-taxonomist, such as me, requires clarity, universality and stability. Practical reasons for the degree of stability-even for a relatively short period of time are: for teaching purposes at advanced levels and for the benefit of many non-protozoologists (biochemists, physiologists, computational biologists, bioinformatists, and bioengineers).

In this paper, I have highlighted the species description procedures, problems of taxonomy, basis of classification, examples and discussion of genera included in the eimeriidae family till now. A stable classification of the eimeriidae, which comprise many important parasites of humans and animals, at the basic level is urgently needed. So, I have updated the current taxonomic knowledge described by the Society of Protozoologists (Lee JJ, Hutner SH, Bovee EC and Upton J, 2001. The Illustrated Guide to the Protozoa, 2nd Edition. Allen Press, Lawrence, KS) and online materials by Duszynski DW, Couch L and Upton SJ, Supported by NSF-PEET DEB 9521687.

Problems of Taxonomy of Eimeriidae Minchin, 1903

The first major reclassification was undertaken by an 'International Taxonomy and Taxonomic Problems' which was set up by the Society of Protozoologists in 1954 and published a revised classification of the phylum Protozoa based on phenotypic characters 10 years later (Honigberg et al. 1964). But this classification system included only few ultrastructural data, which became available after the advent of electron microscopy in the 1950s and 1960s, and was thus confounded by incomplete knowledge on heteroxenous lifecycle such as those of the tissue cyst-forming coccidia that were elucidated only in the 1970s (Tenter and Johnson 1997). Since the conventional classification proposed by the Society of Protozoologists (Levine et al. 1980), there have been many changes to our understanding of relatedness among phylogenetic lineages of coccidia. Many traditional genera are no longer valid and have been abandoned. The eimeriid coccidia are one of the more controversial groups of protozoa, and their taxonomy and classification have been debated for more than 50 years (Cox 1991, 1994; Tenter and Johnson 1997).

A) Problems due to phenotypic characters

Levine (1962), in his article, showed the calculation of about 2654736 structurally different sporulated oocysts (and hence structurally different species) in the *Eimeria* alone, in reality it doesn't work that way. He hypothesized this calculation on the basis of oocyst and sporocyst size and shape, the number of layers in the oocyst wall, its color, degree of roughness, the absence or presence and type of micropyle, micropylar cap, oocyst residuum, sporocyst residuum, persistent polar granule, Stieda body, sporozoite refractile globules, and other factors (Levine 1962). In some cases, oocysts from unrelated host species look very nearly identical in size and structure and can't be reliably differentiated by morphology and size alone (Joyner 1982). A single coccidian species may produce oocysts that vary greatly in size (40%) and appearance (Parker and Duszynski 1986; Gardener and Duszynski 1990). Within the protozoan phylum Apicomplexa Levine, 1970, about one-third of the approximately 5,000 described species

reside in a single family, Eimeriidae, an about 98% of these species are known only from 1 life-cycle stage, the sporulated oocyst, which has a limited number of structural characters. When a group of parasites have few numbers of morphological characteristics, it is always very hard to taxonomize the species. So, it is not easy to define a particular species within Eimeriidae. For example, the thick-walled oocysts of *Cryptosporidium parvum* bear similarities with oocysts of the cyst-forming coccidia (*Cystoisospora*, *Toxoplasma*, and *Sarcocystis*) and with oocysts of the genus *Goussia* (Beier et al. 2001). The joining of *Alveocystis intestinalis* and *Pfeifferinella gugleri* into one genus based on a similarity of their oocyst structure is incorrect (Kostygov 2000). This conclusion is also supported by the long evolutionary and ecological distances between hosts of these species. Similarly, Tadros and Laarman (1976) proposed 'giant schizonts' of *Eimeria* species for the parasitophorous vacuole and tissue cyst wall of *Globidium*. Thus, Lom and Arthur's view of myxosporean classification (1989), "ridicules taxonomic research in this group in the eyes of other parasitologists" can be applied for the taxonomy of species within Eimeriidae.

B) Problems due to pseudoparasitism

Most species of coccidia possess a resistant oocyst or sporocyst wall so that they are able to migrate in the intestinal tract of non-host species. In literatures, we can find many descriptions of the occurrence of coccidia in non-specific animals transmitted mostly by feeding behavior of the animals. So, before giving a description of a coccidian species, the significance of pseudoparasitism is always within 'Taxonomic Common Sense'. Taxonomists should consider the common sense of pseudoparasitism within coccidia because it has been reported that most of the genera fall into either pseudoparasitism or into wrongly classified genera. The literature reviews studies show that seven of the genera within the family Eimeriidae appear to represent adelid coccidia ingested either by insectivores, herbivores, or scavengers. The genera *Gousseffia*, *Hoarella*, *Octosporella*, *Polysporella*, *Skryabinella*, *Sivatoshella*, and *Pythonella* (**figure 1**) may be the true pseudoparasites with uncertain validity and may show different sporulation states in their morphologic forms.

Pseudoparasitism is important during parasite transmission. For example, a few species of *Isospora* have been shown to use paratenic (transport) hosts (Frenkel and Dubey 1972), and extraintestinal stages have been shown experimentally to be able to transfer/transmit a successful infection in some mammalian *Eimeria* species (Mayberry et al. 1989; Mottalei et al. 1992). Sporozoites excyst from oocysts ingested by these paratenic hosts, infect cells in various places within the body, and become dormant. If the infected host is eaten by the appropriate predator, these dormant sporozoites become active, infect enterocytes of the predator, and initiate a typical coccidian lifecycle. Besides, some species of coccidia can develop aberrantly under conditions of abnormal temperature or oxygen concentration. Under these changed conditions, a non-heritable change occurs in the numbers of sporocysts and sporozoites without any effect on their morphology and function (Cerna 1974; Lindsay et al. 1982; Matsui et al. 1989).

Eimeria spp of rodents or rabbits are frequently seen in the feces and intestinal contents of predators such as snakes, raptors, felids, or canids. Canine such as hunting dogs have

been reported to shed oocysts of *Eimeria* in their feces, but their oocysts are not reported to infect these animals. The dogs may acquire the infection by feeding on lagomorphs which may be the sources of the oocysts. Similarly, the sporulated oocysts of the squirrel coccidian, *Eimeria mira*, are reported as pseudoparasites in the intestinal contents of an English bog person; Grauballe Man (Hill et al. 1990). Cyclosporan oocysts of similar morphologic forms have been isolated from humans, monkeys, dogs, and ducks from different regions (Ghimire and Sherchand 2006). Isosporan oocysts of passeriform birds are commonly found in herbivores, scavengers, and waterfowl that accidentally or naturally ingest the oocysts of these parasites. Fish coccidia are found in fish eating birds and snakes, invertebrate adelids are found in insectivorous hosts and *Pfeifferinella* spp. of terrestrial or freshwater gastropods are occasionally found in turtles and waterfowl. The problem how a species give cumbersome classification can be described on the basis of *Isospora* genus too. *Isospora rara* is the only one species of *Isospora* described in an invertebrate (Levine 1988b). Schneider (1881) has not clearly described the sources and infection of *Isospora* genus in gastropod. So, it may be possible that this species may be categorized under a pseudoparasite. And we are using the invalid and conventional species of *Isospora* as type species of the genus for more than 129 years.

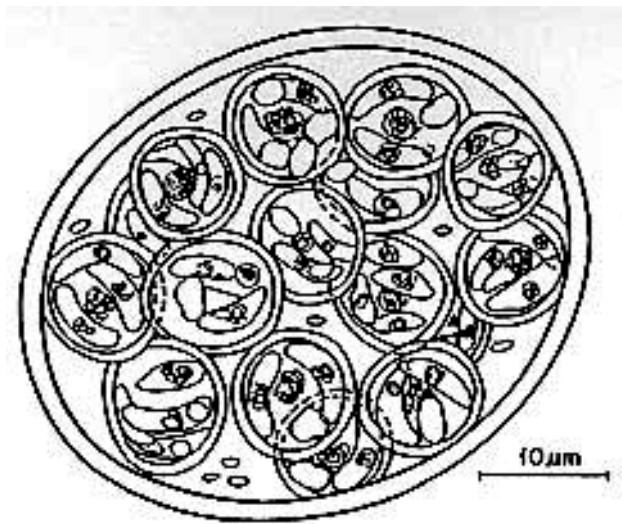


Figure 1: A line drawing of a mature oocyst of *Pythonella scleruri* with 16 sporocysts each with 4 sporozoites. It is a pseudoparasite with various sporulation states. (After Kawazoe and Gouvêa 1999.)

C) Problems due to hosts

Besides the presence of oocysts in unusual hosts, coccidiologists face the problem of strict host specificity. For example, ground squirrels are infected with coccidia that are not always strictly host-specific (Duszynski 1986; Wilber et al. 1998). Many species occur naturally over large geographic

ranges (*Eimeria nieschulzi*, *Eimeria arizonensis*), especially when hosts (*Rattus*) are introduced from continent to continent through human activities or when individuals in a spacious host genus (*Peromyscus*) have contiguous ranges across a continent.

The study of the degree of host specificity seems to vary among host species. For examples, *Eimeria* species from goats cannot be transmitted to sheep and *vice versa* (Lindsay and Todd 1993), but *Eimeria* from cattle (*Bos*) are found to infect American bison (*Bison*). *Eimeria* species from certain rodents (Sciuridae) seem to cross host generic boundaries easily (Wilber et al. 1998), while other rodent species (Muridae) may cross species, but not genus, boundaries (Hnida and Duszynski 1999a). Similarly, some species from gallinaceous birds can be transmitted only to congenetics, while others can be cross-transmitted between genera. One species (*Eimeria chinchilla*) even has been

reported to cross familial lines rarely (DeVos 1970). The comparative literature reviews published in pubmed till date suggests the variability of parameters such as host and site specificity, immunological specificity, epidemiological specificity (pathogenicity, prepatent period, sporulation time) and molecular characters (enzyme variation and DNA buoyant density) among different *Eimeria* species used in the *Eimeria* identification.

D) Problems due to lifecycle patterns

Eimeriids are organ-specific in different hosts. They are found in a variety of locations in the invertebrate hosts, whereas most species infecting vertebrates develop in the intestine. *Eimeria steidai* develops in epithelial cells of the bile duct and parenchymal cells of the liver of rabbits. Other species have been found to develop in cells of the gall bladder (goat), placenta (hippopotamus), epididymis (elk, a deer species), uterus (impala, an African antelope, *Aepyceros*), genitalia of both sexes (hamsters, rodents), bile duct (chamois, high altitude goat), liver parenchyma (wallaby, macropod, a marsupial), and pyloric antrum (kangaroo) (Duszynski and Upton 2001).

The analysis of the genera found in different hosts show that the lifecycle stage and lifecycle patterns create a cumbersome system in coccidian taxonomy. For example, the genus *Atoxoplasma* Garnham 1950 seems to be a combined species of an avian isosporan Box (1970, 1975, 1977, 1981) and avian lankesterellids, the former of which has at least one extraintestinal merogonous stage in mononuclear cells, lung, and or other visceral tissues and gametocytes are of the *Eimeria* type: the zygote nucleus divides to produce an asporous and polyzoic oocyst containing a large number of sporozoites (Lainson 1959). Some experiments show that the species of *Atoxoplasma* from birds have been transferred to *Isospora* (Barta et al. 2005; Schrenzel et al. 2005). So, some members belong in the family Eimeriidae, whereas others belong in the family Lankesterellidae. Cranes infected with *Eimeria reichenowi* Yakimoff and Marschoulsky 1935, some of the ruminants eimerians (Ball et al. 1989) and *Lankesterella garnhami* Latinson, 1959 (*Atoxoplasma*) have extraintestinal merogony and gamogony (Carpenter et al. 1980; Novilla et al. 1981, 1989) which prove that *Atoxoplasma* spp fall under Eimeriidae. However, *Atoxoplasma* infections in passeriforms birds have been shown to differ from those of isosporan oocysts with the transmission of *Atoxoplasma* by an infected mite vector (*Dermanyssus gallinae*) (Lainson 1959, 1960).

E) Problems due to phylogenetic characters

There are many limitations of the basis of phylogenetic characters to confirm species within Eimeriidae. The phenotypic characters currently used for the classification of eimeriidae are limited in their phylogenetic information content. It also suggests the incomplete taxonomic status of most species within Eimeriidae. On the basis of rRNA gene of *Cyclospora cayetanensis*, *Cyclospora* should be placed in the genus *Eimeria* because the rRNA genes of the two genera have similar sequences (Pieniazek and Herwaldt 1997). Similarly, classification based on 18S rDNA suggests that *Isospora* spp are more related with family Sarcocystidae (with *Toxoplasma*, *Sarcocystis* and *Neospora*) than to the family Eimeriidae (*Eimeria*, *Cyclospora*) (Carreno et al. 1998). The phylogenetic studies are suffering from the lack of fossil records and bridge or

connecting links of coccidia. Thus, the only way of studying phylogenetic assay is by comparing the homologous characters of the existing species.

Basis of Classification

A. Phenotypic Characters of Parasites

Phenotypic characters are the common and conventional basis of classification. Here, I have described the rules of 'Head-to-Tail' system. In this system, we can apply all the available information of morphology of all the stages of the species [Figure 2, 3, 4]. I have described some phenotypic characters used for the classification of family eimeriidae [Table 1].

Table 1: Phenotypic characters to be studied for the definition of eimeriidae species.

- | |
|--|
| <ol style="list-style-type: none"> 1. Presence or absence of Oocyst and if present; its thin or thick wall 2. Relative numbers of layers and approximate thickness of oocyst wall 3. Spines or conical projections in oocysts 4. Shape, size and length: width (L:W) of sporulated and unsporulated oocysts 5. Number of sporocysts 6. Morphology of sporocyst wall 7. Shape, size and length: width (L:W) of sporocysts 8. Presence of Micropyle and its width in sporulated oocyst 9. Presence of Micropyle cap and its width and depth in sporulated oocyst 10. Presence of Polar granule(s) in sporulated oocyst, its/their diameter, shape or if they are attached in a unique manner to the inner surface of the oocyst wall 11. Presence of Residual body in sporulated oocyst, its diameter and description 12. Presence of surface features such as sporopodia, adhering membranes or sutures, residuum and its diameter and description, Stieda body and associated filaments; Substieda body; and or Parastieda body in or on the sporocyst. 13. Number of sporozoites 14. Shape and size of sporozoites 15. Presence of refractile body, its number, position, diameter, shape, nucleus and other defining features such as anterior striations if visible in/on the sporozoites 16. Location of rhoptries with regard to nucleus 17. Location of micronemes with regard to nucleus and their number 18. Duration of sporulation 19. Favorable condition of sporulation (such as temperature, sunlight, humidity, pH etc. |
|--|

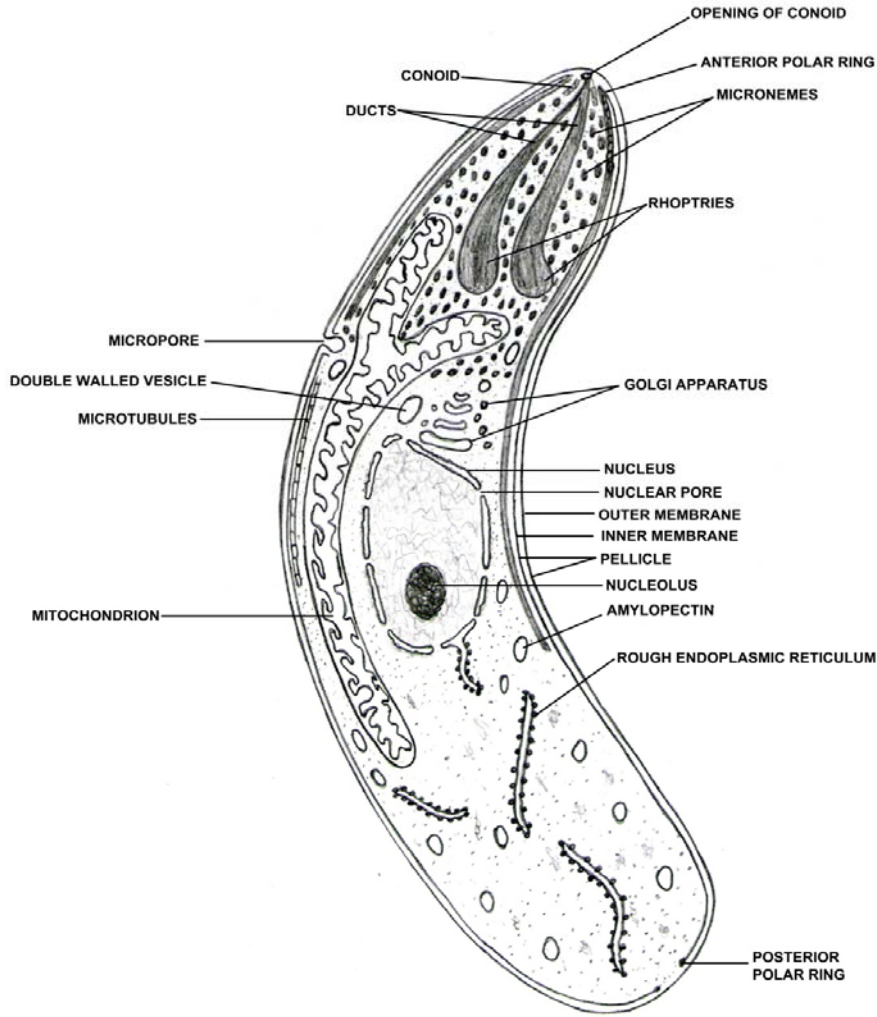


Figure 2: Coccidian merozoite: diagrammatic representation of the ultrastructure as seen in longitudinal section. [After Scholtyssek 1979].

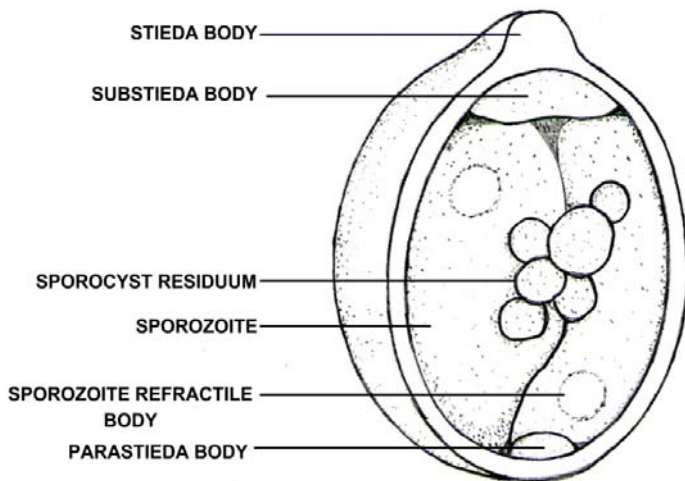


Figure 3: Composite sporulated sporocyst of an oocyst of *Eimeria* species (Hypothetical). [After Duszynski and Wilber 1997].

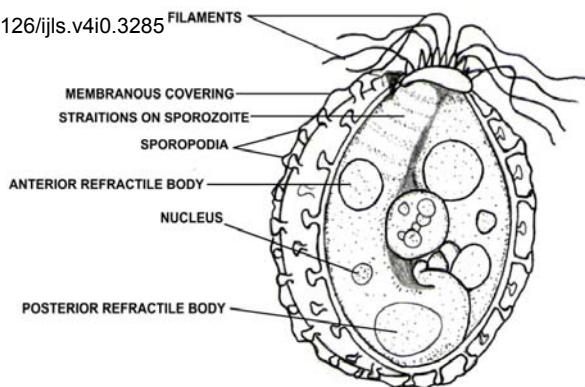


Figure 4: Composite sporulated sporocyst of some eimeriidae (hypothetical). [After Duszynski and Wilber 1997].

B. The host: Why parasitology is quite different from other sciences? That is because parasitologists who study parasites should collect and have a well-known to parasites, and the hosts directly or indirectly related to them. So, a true coccidiologist who wants to be a perfect taxonomist should have enough knowledge related to the particular species and the complete taxonomic status of their hosts. The coccidiologists have to study about some of information about the hosts for the classification of eimeriidae species as shown in the table [Table 2].

Table 2: The information of hosts and the informant to be studied for Eimeriidae classification.

- | |
|---|
| <ol style="list-style-type: none"> 1. Host Specificity 2. Intermediate, paratenic (transport) and definitive host 3. New and complete taxonomic position of host (s) 4. Host lifecycle stage infected (larva, juvenile, adult) 5. Locality, date and other relevant data of infected host 6. Prevalence of infection by locality and by season 7. Ecological, habitat and host genetic data 8. Name of the coccidiologist 9. Geologic age and stratiographic position for fossil species of both parasites and hosts. 10. Infected cells, tissues, organs 11. Pathogenicity and histopathological observations 12. Prepatent, Patent and Incubation period 13. Routes of transmission 14. Oocyst infective for definitive and or intermediate host 15. Epidemiologic information |
|---|

On the basis of presence of host, *Grasseella* and *Pseudoklossia* should be in different genera. Oocysts with no sporocysts but 8 naked sporozoites have either been placed in the genera *Alveocystis* Bel'tenev 1980 or *Pfeifferinella* von Wasielewski 1904. The former genus is found in priapulids whereas the latter is in terrestrial and freshwater gastropods. The latter species were placed in its own family, Pfeifferinellidae Grasse 1953, as it was thought that fertilization was through a vaginal tube associated with the macrogamete. The vaginal tube most likely represents an elongate modification of the micropyle that occurs in some species after fertilization and during early sporulation. They are morphologically and developmentally similar though Levine (1985a) separated the genus *Pfeifferinella* from *Alveocystis* based on the presence or absence of the vaginal tube. Thus, each genus may denote either synonyms or morphotypes proving the need of the host specificity for classification of different genera within family Eimeriidae.

Besides the study of morphologic characters, Levine (1980b) created a new genus *Dorisa* Levine 1980, for those *Dorisiella* species that occurred inside vertebrates.

C. Lifecycle

The points given in the table 3 should be considered for the classification of different species within family Eimeriidae, Minchin 1903.

Table 3: Information about the lifecycle of Eimeriidae to be studied for classification.

<ol style="list-style-type: none"> 1. Homoxenous or heteroxenous type of lifecycle 2. Intestinal or extraintestinal merogony or agametogony (structure of merozoites) 3. Intestinal or extraintestinal gamogony (structure of microgametes, macrogametes) 4. Location of zygote, its structure 5. Endogenous or exogenous sporogony 6. Extraintestinal hypnozoites
--

A typical Eimeriidae comprise members with a typical coccidian lifecycle consisting of three phases: one or more generations of asexual multiplication by merogony or agametogony, sexual reproduction by gamogony, and asexual reproduction by sporogony. The lifecycle begins with the ingestion of a sporulated oocyst. Sporozoites excyst and penetrate intestinal epithelial cells where they form meronts containing merozoites. The final generation of merozoites infects new cells to become gamonts. Most gamonts become macrogametes, whereas some undergo multiple karyokinesis followed by multiple cytokinesis to form numerous flagellated microgametes. Gamogony in these coccidia are characterized by the independent development of macrogametes (female) and microgametes (male), with the latter being motile and often produced in large numbers. After fertilization, a resistant oocyst wall is laid down around the zygote. The genetically determined sporozoites are normally enclosed in sporocysts within oocysts. The development of sporozoites within each sporocyst and each oocyst (sporulation) may occur endogenously or exogenously and the resulting oocysts of most species are passed into the outer environment (Long 1982, 1990, 1993; Lindsay and Todd 1993). The exogenous sporulation is determined by the appropriate environmental conditions such as oxygen, moisture, temperature (Levine 1980a,b; Levine 1985b, 1988a, b; Kreier and Baker 1987; Cox 1994; Hausmann and Hulsman 1996; Lee et al. 2001). It should be noted that unsporulated oocysts are undeveloped and non-infective.

Several genera (*Grasseella*, *Ovivora*, and *Pseudoklossia*) that were included previously in the family Aggregatidae Labbe 1899 have been now transferred to the family eimeriidae Minchin 1903 on the basis of their homoxenous lifecycle pattern because species of both families are morphologically similar and the only parameter of their difference is homoxenous or heteroxenous lifecycle characteristics.

The basis for family Caryotrophidae originally was the lack of definite oocyst walls; however, all species within the Lankesterellidae, many species within the family Aggregatidae, and subfamily Sarcosytinae Poche 1913 and even a few species within the Eimeriidae have so thin membranous oocyst walls that free sporocysts or sporozoites are released and walls disappear during sporulation. Besides, merogony, gamogony and formation of oocysts of *Caryospora* occurs in the intestinal tract of the predator; however

a facultatively homoxenous cycle in rodents is known for two of the serpentine species and involves dissemination of merogony, gamogony and formation of thin-walled oocyst in extraintestinal tissues. Sporozoites exit from the oocysts *in situ*, infect new cells, and become dormant in mononuclear cells as monozoic cysts (hypnozoites) (Ball et al 1989; Lainson et al. 1991; Upton and Sundermann 1990). So, the two monotypic genera within the homoxenous family Caryotrophidae Luhe 1908, *Caryotropha* Siedlecki 1902 and *Dorisiella* Ray 1930 are placed within the Eimeriidae. I have illustrated the lifecycle of typical coccidia in the **figure 5** on the basis of Hoare 1949.

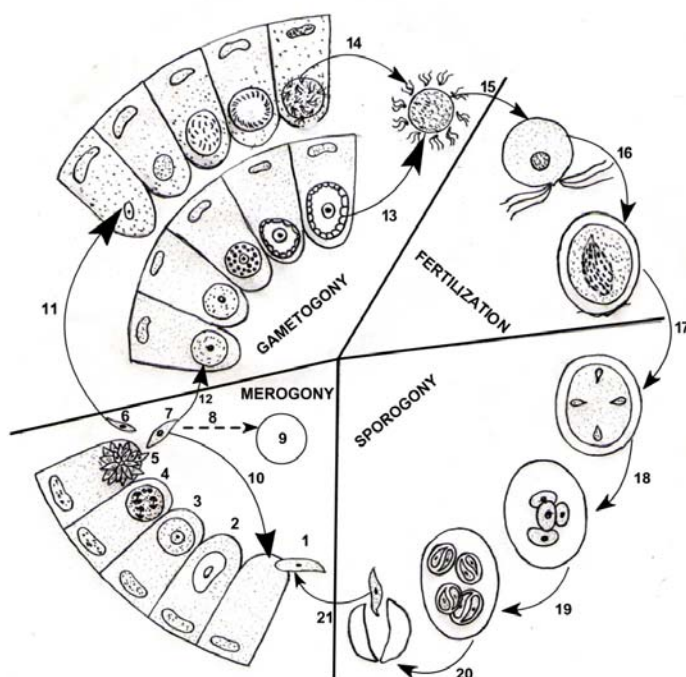


Figure 5: Lifecycle of a coccidian, based on *Eimeria* sp. (After Hoare 1949). 1: a sporozoite invading mucosa. 2, 3, 4, 5: multiplication of sporozoite and development of merozoite inside intestinal epithelium from meront in 4. 6: released male gametocyte 7: released female gametocyte. 8: extraintestinal merogony. 9: Extraintestinal organ or tissue. 10: repetition of intestinal merogony. Infection of intestinal epithelium by male and female gametocytes in 11 and 12 to form male gametes and female gamete respectively. 13: female gamete and 14: male gametes releasing from epithelium for fertilization. 15, 16: multiple fertilization. 17: oocyst released into gut lumen. 18, 19: formation of sporozoites and sporocysts inside oocyst. 20, 21: sporozoite releasing out sporocyst and oocyst in duodenum.

D. Phylogenetic Characters

Conventional taxonomy was based on light microscopic structures and lifecycle patterns to separate different genera within protozoa. Apicomplexan displays enormous variations in lifecycle patterns, physiology, cytology, biochemistry. Prototaxonomists have different views regarding the basis of phylogenetic relationships among eimeriidae genera with the same numbers of sporozoites and sporocysts. One can not get genetic relationship with using qualitative phenotypic characters because the latter lacks the quantitative characters. To get quantitative phylogenetic characters, taxonomists should compare the sequence similarities of proteins, enzymes or genes. These genetic studies are mostly based on the small subunit 18S rRNA gene sequences and their coding regions (Barta 1997, Barta et al. 2001; Jeffries et al. 1997; Morrison and Ellis 1997; Pieniasek and Herwaldt 1997; Tenter and Johnson 1997; Carreno et al. 1998, 1999; Votypka et al. 1998; Carreno and Barta 1999; Eberhard et al. 1999; Holmdahl et al. 1999; Jenkins et al. 1999;

Lopez et al. 1999; Ellis et al. 2000). More recently, a few studies have used sequences of the nuclear 28S rRNA gene, the internal transcribed spacer (ITS) 1 region, or nuclear sequences of mitochondria or plastid to infer relationships among closely related species of eimeriidae, i.e. within the genus *Eimeria* and the group of the tissue cyst-forming coccidia (Ellis et al. 1999, 2000; Hnida and Duszynski 1999b; Mugridge et al. 1999a,b; Zhao and Duszynski 2001a,b; Zhao et al. 2001; Carreno et al. 1999; Barta et al. 2001; Criado-Fornelio et al. 2003, 2004). Molecular characters clearly present the range of evolutionarily preserved characters that may be used to infer phylogenetic relationships among different organisms (Sogin and Silberman 1998). These characters can be both homologous as well as variable sufficiently that help to differentiate unique character states for analysis (Barta 1997).

One can 'google' the web data to search literatures that show how phylogenetic study overcomes the limitations of phenotypic characters. For example, *Eimeria leukarti* Reichenow 1940 from horses and *E. cameli* Reichenow 1952 from dromedaries have been proved to be the most prominent example of morphotypes. Recent molecular genetic studies on rodent and bat *Eimeria* species revealed that some morphologic features (such as oocysts residuum) show a clear correlation to the phylogenetic relationships (Zhao and Duszynski 2001a, b).

Genera of family Eimeriidae Minchin, 1903

Eimeriidae are the homoxenous, occasionally facultatively heteroxenous. But if they are facultatively heteroxenous, alternate mode of transmission by way of dormant free merozoites or monozyotic cysts (hypnozoites) is found in a prey species either to infect a new definitive host (Frenkel and Dubey 1972; Dubey 1975; Dubey and Mehlhom 1978) or to establish infections in the same host, presumably following arrested development or a wane in immunity (Dubey and Frenkel 1972; Marquardt et al. 1984; Mayberry et al. 1989). The following genera can be described under this family:

1. Genus *Atoxoplasma* sensu lato Garnham 1950

Synonyms: *Drepanidium* Lankester, 1871, *pro parte*; *Haemogregarina* Danilewsky 1885, *pro parte*; *Lankesterella* Labbe, 1899, *pro parte*; *Hepatozoon* Miller, 1908, *pro parte*; *Leukocytozoon* Porter, 1909, *pro parte*; *Toxoplasma* Nicolle and Manceaux, 1909, *pro parte*.

Oocyst formula: O.2.4

Characters: Oocyst with 2 sporocysts, each sporocyst with 4 sporozoites; merogony, gamogony and formation of oocysts intestinal, additional merogonous stages extraintestinal and disseminated in mononuclear leukocytes and or viscera; in passeriform birds and related hosts.

Total number of named species: Nineteen

Type species: *Atoxoplasma paddae* (Aragao 1911) Laird 1959.

Type host: *Padda oryzivora* Linnaeus 1758 (Aves: Passeriformes: Estrildidae).

2. Genus *Barroussia* Schneider 1885

Synonyms: *Eimeria* Schneider, 1875 *pro parte*; *Echinospora* Leger 1897; *Urobarroussia* Mesnil 1903; *Barroussia* Schellack & Reichenow 1921.

Oocyst formula: O.n.1.

Characters: Oocyst with many sporocysts, each sporocyst with one sporozoite, sporocysts bivalved; in invertebrates.

Total number of named species: 10.

Type species: *Barroussia ornata* Schneider 1885.

Type Host: *Nepa rubra* (= *Nepa cinerea*) (Arthropoda: Hemiptera: Nepidae).

3. Genus: *Caryospora* Leger 1904

Synonyms: *Karyospora* Leger 1904, *lapsus*; *Eumonospora* Allen 1933.

Oocyst formula: O.1.8

Characters: Oocyst with 1 sporocyst, each sporocyst with 8 sporozoites; in vertebrates, predominantly in snakes and raptors.

Total number of named species: 60.

Type species: *Caryospora simplex* Leger 1904.

Type host: *Vipera aspis* (Reptilia: Squamata: Viperidae).

4. Genus: *Caryotropha* Siedlecki 1902

Oocyst formula: O.20.12

Characters: Oocyst with 20 sporocysts each sporocyst with 12 sporozoites; Oocyst wall thin, membrane-like; in polychaetes.

Total number of named species: 1.

Type species: *Caryotropha mesnili* Siedlecki 1902.

Type host: *Polymnia nebulosa* (Annelida: Polychaeta: Canalipalata: Spionidae).

5. Genus: *Cyclospora* Schneider 1881

Oocyst formula: O.2.2

Characters: Oocyst with 2 sporocysts, each sporocyst with 2 sporozoites; human predominant parasites.

Total number of named species: 15, predominantly in mammals including humans; most of the species reported from the non-mammalian (reptilian) hosts probably misidentifications of *Isospora* or *Sarcocystis* or pseudoparasites. Several in primates may be synonyms.

Type species: *Cyclospora glomericola* Schneider 1881.

Type host: *Glomeris* (Arthropoda: Diplopoda: Glomerida: Glomeridae).

6. Genus: *Diaspora* Leger 1898

Oocyst formula: O(?)2.1

Characters: Oocysts unknown, two sporocysts each with one sporozoite, sporocysts lacking suture; in invertebrates.

Total number of named species: 1.

Type species: *Diaspora hydatidea* Leger 1898.

Type host: *Polydesmus* (Arthropoda: Diplopoda: Polydesmida: Polydesmidae).

7. Genus: *Dorisa* Levine 1980

Synonym: *Dorisiella* Ray, 1930, *pro parte*.

Oocyst formula: O.2.8

Characters: Oocyst with 2 sporocysts, each sporocyst with 8 sporozoites; Oocyst wall definite; in vertebrates.

Total number of named species: 13, although most appear to represent abnormal sporulation of isosporan oocysts.

Type Species: *Dorisa hoarei* (Yakimoff and Gousseff 1935) Levine 1980.

Type Host: *Elaphe quatuorlineata sauromates* (Reptilia: Squamata: Colubridae).

8. Genus : *Dorisiella* Ray 1930

Oocyst formula: O.2.8

Characters: Oocyst with 2 sporocysts, each sporocyst with 8 sporozoites; Oocysts wall thin, membrane-like; in polychaetes.

Total number of named species: 1.

Type Species: *Dorisiella scolelepidis* Ray 1930.

Type Host: *Scolelepis fuliginosa* (Annelida: Polychaeta: Canalipalata: Spionidae).

9. Genus: *Eimeria* Schneider 1875

Synonym: *Acroeimeria* Paperna & Landsberg, 1989; *Acystis* Labbe, 1894, *pro parte*; *Ampulleimeria* Pellerdy, 1964; *Archeococcidia* Schmidt, Duszynski, & Martin 1992; *Bananella* Labbe, 1895;

Caryophagus Druner, 1894, *lapsus*; *Choleoeimeria* Paperna & Landsberg 1989; *Coccidium* Leuckart, 1879, *pro parte*; *Crystallospora* Labbe 1899; *Cytophagus* Steinhaus 1891, *pro parte*; *Cytospermium* Rivolta 1878, *pro parte*; *Eimeriella* Stiles 1901; *Ellipseimeria* Pellerdy 1964; *Epieimeria* Dykova & Lom 1981; *Globideimeria* Pellerdy 1964; *Globidium* Flesch 1894, *pro parte*; *Gousseimeria* Pellerdy 1964; *Goussia* Labbe 1896; *Gregarina* Eimer 1870, *pro parte*; *Ileocystis* Gilruth & Bull 1912; *Jarrina* Leger & Hesse 1922; *Karyophagus* Steinhaus 1889; *Lymphocystis* Gilruth & Bull 1912; *Marotelia* Ratz 1905; *Nucleoeimeria* Daoudi 1987; *Nucleogoussia* Daoudi 1987; *Orcheocystis* Trinci 1916; *Orthospora* Schneider 1881, *pro parte*; *Oveimeria* Pellerdy 1964; *Paracoccidium* Laveran & Mesnil 1902; *Pfeifferella* Labbe 1899; *Pfeifferia* Labbe 1894; *Poleimeria* Pellerdy 1964; *Psorospermium* Rivolta 1878, *pro parte*; *Rotundeimeria* Pellerdy 1964; *Stomateimeria* Pellerdy 1964.

Oocyst formula: O.4.2

Characters: Oocyst with 4 sporocysts, each sporocyst with 2 sporozoites; in vertebrates and invertebrates.

Total number of named species: over 1700.

Type species: *Eimeria falciformis* (Eimer 1870) Schneider 1875.

Type host: *Mus musculus* (Mammalia: Rodentia: Muridae).

10. Genus: *Grasseella* Tuzet and Ormie'res 1960

Oocyst formula: O.n.2

Characters: Oocyst with many sporocysts, each sporocyst with 2 sporozoites; in ascidians.

Total number of named species: 1

Type Species: *Grasseella microcosmi* Tuzet and Ormie'res 1960.

Type Host: *Microcosmus sulcatus* (Chordata: Urochordata: Ascidiacea).

11. Genus: *Isospora* Schneider 1881

Synonym: *Coccidium* Leuckart 1879, *pro parte*; *Cystoisospora* Frenkel 1977; *Diplospora* Labbe, 1893; *Hyaloklossia* Labbe 1896, *pro parte*; *Klossia* Labbe 1894, *pro parte*; *Levineia* Dubey 1977; *Lucetina* Henry & Leblois 1925, *pro parte*; *Psorospermium* Rivolta 1878, *pro parte*.

Oocyst formula: O.2.4

Characters: Oocyst with 2 sporocysts, each sporocyst with 4 sporozoites; merogonous stages not disseminated extraintestinally in mononuclear cells; in invertebrates and vertebrates including humans.

Total number of named species: about 250.

Type species: *Isospora rara* Schneider 1881.

Type host: *Limax* sp. (Mollusca: Gastropoda: Pulmonata: Limacidae).

12. Genus: *Mantonella* Vincent 1936.

Oocyst formula: O.1.4

Characters: Oocysts with 1 sporocyst, the sporocyst with 4 sporozoites; in invertebrates and vertebrates. *M. hammondi* Wacha and Christiansen 1976 from a turtle is described a pseudoparasite.

Total number of named species: 4 (?)

Type species: *Mantonella peripati* Vincent 1936.

Type host: *Peripatopsis sedgwicki* (Onychophora: Onychophorida: Euonychophora: Peripatopsidae).

13. Genus *Ovivora* Mackinnon & Ray 1937

Oocyst formula: O.n.12

Characters: Oocyst with many sporocysts, each sporocyst with upto 12 sporozoites; in eggs of echuroids.

Total number of named species: 1.

Type species: *Ovivora thalassemae* (Lankester 1885) Mackinnon & Ray 1937.

Type host: *Thalassema neptuni* (Echiura: Echiuroidea: Echiurida: Echiuridae).

14. Genus *Pfeifferinella* von Wasielewski 1904

Synonym: *Alveocystis* Bel'tenev 1980.

Oocyst formula: O.0.8-14

Characters: Oocyst lacking sporocyst, usually with large micropyle and a large oocyst residuum. A distinct convex micropyle is generally present at one end of the oocyst and 8-14 free sporozoites; in invertebrates (Priapulids and Gastropods).

Total number of named species: 6.

Type species: *Pfeifferinella ellipsoides* von Wasielewski 1904.

Type Host: *Planorbarius corneus* (Mollusca: Gastropoda: Basommatophora: Planorbidae).

15. Genus *Pseudoklossia* Leger & Duboscq 1915

Synonyms: *Hyaloklossia* Leger, 1897, *pro parte*; *Margolisiella* Desser & Bower 1997

Oocyst formula: O.n.2

Characters: Oocysts with many sporocysts, each sporocyst with 2 sporozoites; in marine mollusks.

Pseudoklossia pectinis Leger and Duboscq 1917 has syzygy and may be misclassified.

Total number of named species: 7 (?).

Type species: *Pseudoklossia glomerata* Leger & Duboscq 1915.

Type Host: *Tapes floridus* (Mollusca: Pelecypoda: Veneridae).

16. Genus *Tyzzeria* Allen 1936

Synonym: *Koidzumiella* Matubayasi 1936.

Oocyst formula: O.0.8

Characters: Oocysts without sporocysts, each with 8 free sporozoites; sporozoites are surrounded by a thin membrane in vertebrates.

Total number of named species: 10, but parasites found in non-avian hosts represent misidentifications.

Type species: *Tyzzeria perniciososa* Allen 1936.

Type host: *Anas platyrhynchos domestica* (Aves: Anseriformes: Anatidae).

17. Genus *Wenyonella* Hoare 1933

Oocyst formula: O.4.4

Characters: Oocyst with 4 sporocysts, each sporocyst with 4 sporozoites; in vertebrates.

Total number of named species: 18, although some most likely represent misidentifications of eimerian oocysts.

Type Species: *Wenyonella africana* Hoare 1933.

Type Host: *Boeodon lineatus* (Reptilia: Squamata: Colubridae).

18. Genus *Gousseffia* Levine 1980

Synonym: *Yakimovella* Gousseff 1937, *nomen preocc.*

Oocyst formula: O.8.n

Characters: Oocyst with 8 sporocysts, each sporocyst with many sporozoites.

Type species: *Gousseffia erinacei* (Gousseff 1937) Levine 1980.

Type Host: *Erinaceus europaeus* Linnaeus 1758 (Mammalia: Erinaceomorpha: Erinaceidae).

Probable description: Oocysts probably represent an adelid pseudoparasite.

19. Genus *Hoarella* de Peraza LA 1963

Oocyst formula: O.16.2

Characters: Oocyst with 16 sporocysts, each sporocyst with 2 sporozoites.

Type species: *Hoarella garnhami* de Peraza LA1963.

Type Host: *Cnemidophorus lemniscatus* (Reptilia: Squamata: Teiidae).

Probable description: Meronts and gametes were found in the gut and thought to belong to the parasite. The coccidian most likely represents a parasite of arthropods and the developmental stages those of another coccidian.

20. Genus *Octosporella* Ray and Ragavachari 1942

Synonyms: *Octosporella hystrix* Barker, Beveridge, and Munday 1985 from *Tachyglossus aculeatus* (Monotremata), *Octosporella notropis* Li and Desser 1985 from *Notropis cornutus* (Cypriniformes), *Octosporella opeongoensis* Li and Desser 1985 from *Notemigonus crysoleucas* (Cypriniformes), *Octosporella sanguinolenta* Ovezmukhammedov 1975 from *Agama sanguinolenta* (Sauria), *Octosporella sasajewunensis* Li and Desser 1985 from *Notemigonus crysoleucas* (Cypriniformes)

Oocyst formula: O.8.2

Characters: Oocysts with 8 sporocysts, each sporocyst with 2 sporozoites.

Type species: *Octosporella mabuiae* Ray and Ragavachari 1942.

Type Host: *Mabuia* sp. (Reptilia: Sauria).

Probable description: The species from lizards and the echidna probably represent parasites of arthropods. Any developmental stages noted are probably those of other coccidia. The species from the fish were described from smears and the sporocyst plates misidentified as intact sporocysts.

21. Genus *Polysporella* McQuiston 1990

Oocyst formula: O.9-15.2

Characters: Oocysts with 9-15 sporocysts, each sporocyst with 2 sporozoites

Type species: *Polysporella genovesae* McQuiston, 1990.

Type Host: *Nesomimus parvulus* (Aves: Passeriformes: Mimidae).

Probable description: This coccidian most likely represents an adelid pseudoparasite.

22. *Pythonella* Ray and Das Gupta 1937

Oocyst formula: O.16.4

Characters: Oocyst with 16 sporocysts, each sporocyst with 4 sporozoites.

Type species: *Pythonella bengalensis* Ray and Das Gupta 1937.

Type Host: *Python* sp. (Reptilia: Squamata).

Probable description: All species [*Pythonella karakalensis* Glebezdin 1971 from *Calomyscus bailwardi* (Rodentia), *Pythonella scelopori* Duszynski 1969 from *Sceloporus squamosus* (Sauria), *Pythonella* sp. Kawazoe, Gouvea, Jorge, Caputo, and Perdigo 1989 from *Sclerurus scansor* (Passeriformes) *Pythonella scleruri* Kawazoe and Gouvêa 1999 from a Brazilian Bird Rufous-Breasted-Leaftosser, *Sclerurus scansor*] appear to represent adelid pseudoparasites.

23. Genus *Sivatoshella* Ray and Sarkar 1968

Oocyst formula: O.2.16

Characters: Oocysts with 2 sporocysts, each sporocyst with 16 sporozoites.

Type species: *Sivatoshella lonchurae* Ray and Sarkar 1968, *type species*.

Type Hosts: *Lonchura malabarica*, *L. punctulata* (Aves: Passeriformes: Estrildidae).

Probable description: The oocysts appear to be the result of abnormal sporulation of an isosporan.

24. Genus *Skrjabinella* Matschoulsky 1949

Oocyst formula: O.16.1

Characters: Oocyst with 16 sporocysts, each sporocyst with 1 sporozoite.

Type species: *Skrjabinella mongolica* Matschoulsky 1949.

Type Host: *Allactaga saltator* (Mammalia: Rodentia: Dipodidae).

Probable description: This coccidian appears to be an adelid pseudoparasite.

ACKNOWLEDGEMENTS

I am very much glad to get a great opportunity of discussion about the taxonomic status of protozoa with some biologists like John H. Cross Professor, Department of Preventive Medicine and Biometrics, Uniformed Services University of the Health Sciences School of Medicine, US, Dr. Purna Nath Mishra, Professor, Central Department of Zoology, TU, Kirtipur, Kathmandu, Tek Bahadur Gurung, Lecturer, Department of Biology, Bagmati Modern College, Sukhedhara, Dr. Jeevan Bahadur Sherchand, Professor, Department of Microbiology and Parasitology, Institute of Medicine, Maharajgunj, and Madan Jamarkattel, Central Department of Zoology, TU, Kathmandu. I am grateful to Raj Kumar Shahu, Central Department of Zoology, TU, Kirtipur, Kathmandu and Hunny Manandhar, Advanced College of Engineering and Management (TU), Kupondole, Lalitpur, Nepal for their efforts of drawing the figures of these coccidia. I acknowledge to Kris Stacy-Bates, Librarian Staff, Iowa State University, USA, Kern Lorglon, Document Supply, Radcliffe Science Library, Parks Road, Oxford, United Kingdom, Valerie

Mayman, Librarian, Interlibrary Loan Service, McGill University Library, Canada, Rita Bisley, Document Supply Service, The Library, James Cook University, Australia for sending me invaluable and the published articles and books.

REFERENCES

1. **Allen EA (1933)** *Eumonospora tremula* gen. et sp. nov., a coccidium from the intestine of the turkey buzzard, *Cathartes aura septentrionalis* Weid. *Transactions of the American Microscopical Society*. **52**: 192-194.
2. **Allen EA (1936)** *Tyzzeria perniosa* gen. et sp. nov., a coccidium from the small intestine of the Pekin duck, *Anas domesticus* L. *Archiv fur Protistenkunde*. **87**: 262-267.
3. **Ball SJ, Pittilo RM and Long PL (1989)** Intestinal and extraintestinal life cycles of eimeriid coccidia. *Advances in Parasitology*. **28**: 1-54.
4. **Barker IK, I Beveridge and Munday BL (1985)** Coccidia (*Eimeria tachyglossi* n. sp., *E. echidnae* n. sp., and *Octosporella hystrix* n. sp.) in the echidna, *Tachyglossus aculeatus* (Monotremata: Tachyglossidae). *Journal of Protozoology*. **32**: 523-525.
5. **Barta JR (1997)** Investigating phylogenetic relationships within the Apicomplexa using sequence data: the search for homology. *Methods*. **13**: 81-88.
6. **Barta JR, Martin DS, Carreno RA, Siddall ME, Profous- Juchelka H, Hozza M, Powles MA and Sundermann C (2001)**. Molecular phylogeny of the other tissue coccidia: *Lankesterella* and *Caryospora*. *The Journal of Parasitology*. **87**: 121-127.
7. **Barta JR, Schrenzel MD, Carreno R and Rideout BA (2005)** The genus *Atoxoplasma* (Garnham 1950) as a junior objective synonym of the genus *Isospora* (Schneider 1881) species infecting birds and resurrection of *Cystoisospora* (Frenkel 1977) as the correct genus for *Isospora* species infecting mammals. *Journal of Parasitology*. **91**: 726-727.
8. **Beier TB, Svezhova NV and Sidorenko NV (2001)** Oocyst structure and problem of coccidian taxonomy. *Tsitologiya*. **43(11)**: 1005-1012.
9. **Bel'tenov AE (1980)** *Alveocystis intestinalis* n. sp., n. gen. - a new species of coccidian from the intestine of Priapulida. *Voprosy Parazitl Vodnykh Bespozvov. Zhivotnykh (Temat. Sbornik)*, Vilnyus, USSR 1980:10-11.
10. **Box ED (1970)** *Atoxoplasma* associated with an isosporan oocyst in canaries. *Journal of Protozoology*. **17**: 391-396.
11. **Box ED (1975)** Exogenous stages of *Isospora serine* (Aragao) and *Isopora canaria* sp. n. in the canary (*Serinus canarius* Linnaeus). *Journal of Parasitology*. **22**: 165-169.
12. **Box ED (1977)** Life cycles of two *Isospora* species in the canary, *Serinus canaries* Linnaeus. *Journal of Protozoology*. **24**: 57-67.
13. **Box ED (1981)** *Isospora* as an extraintestinal parasite of passeriform birds. *Journal of Protozoology*. **28**: 244-246.
14. **Butschli O (1880-1889)** Protozoa. Abt. I (1880-1882) Sarkodina und Sporozoa. Abt. II (1883-1887) Mastigophora. Abt. III (1887-1889) Infusoria und system der radiolarian. In: Bronn, H. G. (ed.), *Klassen und Ordnung des Their-Reichs*. Vol. 1, C.F. Winter, Leipzig. pp: 1-616, 617-1097, 1098-2035.
15. **Carpenter JW, Spraker TR and Novilla MN (1980)** Disseminated visceral coccidiosis in whooping cranes. *Journal of American Veterinary Medical Association*. **177**: 845-848.
16. **Carreno RA and Barta JR (1999)** An eimeriid origin of isosporoid coccidia with Stieda bodies as shown by phylogenetic analysis of small subunit ribosomal RNA gene sequences. *The Journal of Parasitology*. **85**: 77-83.
17. **Carreno RA, Martin DS and Barta JR (1999)** *Cryptosporidium* is more closely related to the gregarines than to coccidia as shown by phylogenetic analysis of apicomplexan parasites inferred using small-subunit ribosomal RNA gene sequences. *Parasitology Research*. **85**: 899-904.
18. **Carreno RA, Schnitzler BE, Jeffries AC, Tenter AM, Johnson AM and Barta JR (1998)** Phylogenetic analysis of coccidia based on 18S rDNA sequence comparison indicates that *Isospora* is

most closely related to *Toxoplasma* and *Neospora*. *The Journal of Eukaryotic Microbiology*. **45**: 184–188.

19. **Cerna Z (1974)** Une anomalie de la sporulation de la coccidie des Oiseaux: *Isospora lacazei* (Eimeriidae). *Journal of Protozoology*. **21**: 481-482.
20. **Cox FEG (1991)** Systematics of parasitic protozoa. In: Kreier JP, In: Baker JR (Eds.). Parasitic Protozoa, 2nd Edition, Vol. 1. Academic Press, San Diego, CA. pp: 55–80.
21. **Cox FEG (1994)** The evolutionary expansion of the Sporozoa. *The International Journal of Parasitology*. **24**: 1301–1316.
22. **de Peraza LA (1963)** Studies on two new coccidia, from the Venezuelan lizard *Cnemidophorus lemniscatus lemniscatus*: *Hoarella garnhami* gen. nov., sp. nov. and *Eimeria flaviviridis americana* subsp. nov. *Parasitology*. **53**: 95-107.
23. **Desser SS, and Bower SM (1997)** *Margolisiella kabatai* gen. et sp. n. (Apicomplexa: Eimeriidae), a parasite of native littleneck clams, *Protothaca staminea*, from British Columbia, Canada, with a taxonomic revision of the coccidian parasites of bivalves (Mollusca: Bivalvia). *Folia Parasitologica (Praha)*. **44**: 241-247.
24. **DeVos AJ (1970)** Studies on the host range of *Eimeria chinchillae* DeVos and Van der Westhuizen, 1968. *Onderstepoort Journal of Veterinary Research*. **37**: 29-36.
25. **Dolezel D, Koudela B, Jirku M, Hyspa V, Obornik M, Votypka J, Modry D, Slapeta JR and Lukes J (1999)** Phylogenetic analysis of *Sarcocystis* spp. of mammals and reptiles supports the coevolution of *Sarcocystis* spp. with their final hosts. *The International Journal of Parasitology*. **29**: 795–798.
26. **Dubey JP (1975)** Experimental *Isospora canis* and *Isospora felis* infection in mice, cats, and dogs. *The Journal of Protozoology*. **22**: 416-417.
27. **Dubey JP and Mehlhorn H (1978)** Extraintestinal stages of *Isospora ohioensis* from dogs in mice *The Journal of Parasitology*. **64**: 689-695.
28. **Duszynski DW (1969)** *Pythonella scelopori* sp. n. (Protozoa: Eimeriidae) from a Costa Rican lizard. *Journal of Parasitology*. **55**: 684-685.
29. **Duszynski DW (1986)** Host specificity in the coccidia of small mammals: Fact or fiction? In Advances in protozoological research, Bereczky M (ed.). Symposia Biologica Hungarica, Vol. 33. Akademiai Kiado, Budapest, Hungary. pp: 325-337.
30. **Duszynski DW and Upton SJ (2001)** Enteric protozoans: *Cyclospora*, *Eimeria*, *Isospora* and *Cryptosporidium* (Cryptosporidiidae) spp. Chapter 16, In, Parasitic Diseases of Wild Mammals, 2nd ed. (W.M. Samuel, M.J. Pybus, A.A. Kocan, eds.) Iowa State University Press, Ames, IA. pp: 416-459.
31. **Duszynski DW and Wilber PG (1997)** A guideline for the preparation of species descriptions in the Eimeriidae. *Journal of Parasitology*. **83**: 333-336.
32. **Dykova I and Lom J (1981)** Fish coccidia: critical notes on life cycles, classification and pathogenicity. *Journal of Fish Diseases*. **4**: 487-505.
33. **Eberhard ML, da Silva AJ, Lilley BG and Pieniazek NJ (1999)** Morphologic and molecular characterization of new *Cyclospora* species from Ethiopian monkeys: *C. cercopithecii* sp. n. *C. colobi* sp. n. and *C. papionis* sp. n. *Emerging Infectious Diseases*. **5**: 651–658.
34. **Eimer T (1870)** Ueber die ei-oder Kugelformigen sogenannten Psorospermien der Wirbelthiere. Ein Beitrag zur Entwicklungsgeschichte der Gregarinen und zur Kenntniss dieser Parasiten als Krankheitsursache. A. Stuber's Verlagshandlung, Wurzburg. pp: 1-58.
35. **Ellis JT, Holmdahl OJ, Ryce C, Njenga JM, Harper PA and Morrison DA (2000)** Molecular phylogeny of *Besnoitia* and the genetic relationships among *Besnoitia* of cattle, wildebeest and goats. *Protist*. **151**: 329–336.
36. **Ellis JT, Morrison DA, Liddell S, Jenkins MC, Mohammed OB, Ryce C and Dubey JP (1999)** The genus *Hammondia* is paraphyletic. *The Journal of Parasitology*. **118**: 357–362.
37. **Frenkel JK and Dubey JP (1972)** Rodents as vectors for feline coccidia, *Isospora felis* and *Isospora rivolta*. *Journal of Infectious Diseases*. **125**: 69-72.
38. **Gardener SL and Duszynski DW (1990)** Polymorphism of eimerian oocysts can be a problem in naturally infected hosts: an example from subterranean rodents in Bolivia. *The Journal of Parasitology*. **76**: 805-811.
39. **Ghimire TR and Sherchand JB (2006)** Human infection of *Cyclospora cayetanensis*: A review on its Medico-biological and Epidemiological pattern in global scenario. *Journal of Nepal Health Research Council*. **4(2)**: 25-40.

40. **Glebezdin VS (1971a)** Coccidia in wild mammals in Turkmenia. *Materialy Pervogo Skada Vsesoiuznogo Obshchestva Protozoologov*, Baku. pp: 30-32.
41. **Glebezdin VS (1971b)** Concerning the fauna of *Calomyscus bailwardi* Thom. In South Turkmenia. *Izvestiya Akademii Nauk Turkmenskoi SSR Seriya Biologicheskikh Nauk*. **0(4)**: 74-76.
42. **Gousseff WF (1936)** A new coccidium from crayfish. *Journal of the Royal Microscopical Society*. **56**: 326-327.
43. **Gousseff WF (1937)** *Yakimovella erinacei* n. gen., n. sp., a coccidium from the hedgehog. *Journal of the Royal Microscopical Society*. **57**: 200-202.
44. **Grasse PP (1953)** *Traite de Zoologie Anatomie, Systematique, Biologie. I. Protozoaires: Rhizopodes, Actinopodes, Sporozoaires, Cnidosporidies*. Masson, Paris. pp: 1160.
45. **Hausmann K and Hulsmann N (1996)** *Protozoology*, 2nd Edition. Georg Thieme, Stuttgart.
46. **Hausmann K, Hulsmann N and Radek R (2003)** *Protistology*. 3rd ed. Schweizerbart'sche, Stuttgart. pp: 379.
47. **Hill BD, Blewett DA, Dawson AM and Wright S (1990)** Analysis of the kinetics, isotype and specificity of serum and coproantibody in lambs infected with *Cryptosporidium parvum*. *Research in Veterinary Science*. **48**: 76-81.
48. **Hnida JA and Duszynski DW (1999a)** Cross-transmission studies with *Eimeria arizonensis*, *E. arizonensis*-like oocysts and *E. lankebarteli*: host specificity within the Muridae and other rodents. *Journal of Parasitology*. **85**: 873-877.
49. **Hnida JA and Duszynski DW (1999b)** Taxonomy and systematics of some *Eimeria* species of murid rodents as determined by the ITS1 region of the ribosomal gene complex. *The Journal of Parasitology*. **119**: 349-357.
50. **Hoare CA (1933)** Studies on some new ophidian and avian coccidia from Uganda, with a revision of the classification of the Eimeriidea. *The Journal of Parasitology*. **25**: 359-388.
51. **Hoare CA (1949)** *Handbook of Medical Protozoology*. Balliere, Tindall and Cox, London.
52. **Holmdahl OJ, Morrison DA, Ellis JT and Huang LT (1999)** Evolution of ruminant *Sarcocystis* (Sporozoa) parasites based on small subunit rDNA sequences. *Molecular Phylogenetics and Evolution*. **11**: 27-37.
53. **Honigberg BM, Balamuth W, Bovee EC, Corliss JO, Gojdics M, Hall RP, Kudo RR, Levine ND, Loeblich AR, Weiser J and Wenrich DH (1964)** A revised classification of the phylum Protozoa. *Journal of Protozoology*. **11**: 7-20.
54. **Jeffries AC, Schnitzler B, Heydorn AO, Johnson AM and Tenter AM (1997)** Identification of synapomorphic characters in the genus *Sarcocystis* based on 18S rDNA sequence comparison. *The Journal of Eukaryotic Microbiology*. **44**: 388-392.
55. **Jenkins MC, Ellis JT, Liddell S, Ryce C, Munday BL, Morrison DA and Dubey JP (1999)** The relationship of *Hammondia hammondi* and *Sarcocystis mucosa* to other heteroxenous cyst-forming coccidia as inferred by phylogenetic analysis of the 18S SSU ribosomal DNA sequence. *Parasitology*. **119**: 135-142.
56. **Joyner LP (1982)** Host and site specificity. In *The biology of the coccidia*. Ed. L. Long. Baltimore, MD:University Park Press. pp: 35-62.
57. **Kawazoe U and Gouvêa H (1999)** Description of *Pythonella scleruri* n. sp. (Apicomplexa: Eimeriidae) from a Brazilian Bird Rufous-Breasted-Leaftosser *Sclerurus scansor*, 1835 (Passeriformes: Furnariidae). *Memorias do Instituto Oswaldo Cruz*. **94(2)**: 157-159.
58. **Kawazoe U, Gouvea H, Jorge P, Caputo CME, and Perdigao JC (1989)** New coccidian species from the wild Brazilian bird Rufous-Breasted Leafscraper *Sclerurus scansor* Menetries, 1835 (Passeriformes: Furnariidae). *Journal of Protozoology*. **36 (Abstract 85)**: 15A
59. **Kostygov Alu (2000)** The morphology of the macrogametes and oocysts of *Alveocystis intestinalis* (Sporozoa: Coccidia). *Parazitologiya*. **34(4)**: 335-339.
60. **Kreier JP and Baker JR (1987)** *Parasitic Protozoa*. Allen and Unwin, Boston, Lee MA, J.J., Hutner, S.H., Bovee, E.C., 1985. An Illustrated Guide to the Protozoa. Allen Press, Lawrence, KS.
61. **Labbe A (1893)** Sur deux coccidies nouvelles, parasites des poissons. *Bulletin, Societe Zoologique de France*. **18**: 202-204.
62. **Labbe A (1895)** *Bananella lacazei* genre nouveau de coccidie oligosporee. *Archives de Zoologie Experimentale et Generale, Series 3. Notes et Revue*. **3**: 15-16.
63. **Labbe A (1896)** Recherches zoologiques, cytologiques et biologiques sur les coccidies. *Archives de Zoologie Experimentale et Generale, Series 3*. **4**: 517-654.

64. **Labbe A (1899)** Sporozoa. In, *Das Tierreich. Eine Zusammenstellung und Kennzeichnung der Rezenten Tierformen*, Volume 5, Schulze, F.E. and Butschli, O., editors. Verlag von R. Friedlander und Sohn, Berlin. pp: 58-73.
65. **Lainson R (1959)** *Atoxoplasma* Garnham, 1950, as a synonym for *Lankesterella* Labbé, 1899. Its life cycle in the English sparrow (*Passer domesticus domesticus*, Linn.). *The Journal of Eukaryotic Microbiology*. **6 (4)**: 360–371.
66. **Lainson R (1960)** The transmission of *Lankesterella* (= *Atoxoplasma*) in birds by the mite *Dermanyssus gallinae*. *Journal of Protozoology*. **7**: 321-322.
67. **Lainson R, Paiva do Nascimento F and Shaw JJ (1991)** Some new species of *Caryospora* (Apicomplexa: Eimeriidae) from Brazilian snakes, and a re-description of *C. jararacae* Carini, 1939. *Memorias do Instituto Oswaldo Cruz*. **86**: 349-364.
68. **Lankester ER (1881)** On *Thalassema neptuni* Gaertner. *Zoologischer Anzeiger*. **54**: 350-356.
69. **Lee JJ, Hutner SH, Bovee EC and Upton J (2001)** *The Illustrated Guide to the Protozoa*, 2nd Edition. Allen Press, Lawrence, KS.
70. **Leger L (1897)** *Echinospira labbei*, nouvelle coccidie polysporee du tube digestif des myriapodes. *Comptes Rendus des Sciences de la Societe de Biologie*. **49**: 1082-1084.
71. **Leger L (1897)** Sur la presence des coccidies chez les mollusques lamelibranches. *Comptes Rendus Societe de Biologie*. **49**: 987-988.
72. **Leger L (1898)** Essai sur la classification des coccidies et description de quelques especes nouvelles ou peu connues. *Annales du Musee d'Histoire Naturelle de Marseille, Serie II, Bulletin Notes Zoologiques, Geologiques, Paleontologiques Varietes*. **1**: 71-123.
73. **Leger L (1904)** Protozoaires parasites des Viperes (*Vipera aspis*). *Bulletin Mensuel, Association Francaise pour l'avancement des Sciences (Abstract)*. **9**: 268.
74. **Leger L and Duboscq O (1915)** *Pseudoklossia glomerata* n. g. n. sp., coccidie de lamelibranche. *Archives de Zoologie Experimentale et Generale*. **55**: 7-16.
75. **Leger L, and Duboscq O (1917)** *Pseudoklossia pectinis* n. sp. et l'origine des Adeleidees. *Archives de Zoologie Experimentale et Generale*. **56**: 88-94.
76. **Leuckart R (1879-1886)** *Die Parasiten des Menschen und die von ihnen herrührenden Krankheiten*. C.F. Winter Leipzig, pp. 221–334, 959–968.
77. **Levine ND (1962)** Protozoology Today. *Journal of Protozoology*. **9**: 1-6.
78. **Levine ND (1980a)** Some corrections of coccidian (Apicomplexa: Protozoa) nomenclature. *The Journal of Parasitology*. **66(5)**:830-834.
79. **Levine ND (1980b)** *Dorisa* n. gen. (Protozoa, Apicomplexa, Eimeriidae). *The Journal of Parasitology*. **66**: 11.
80. **Levine ND (1985b)** *Erhardorina* n. g., *Ascogregarina polynesiensis* n. sp., *Eimeria golemanskii* n. sp., *Isospora tamariscini* n. sp., *Gregarina kazumii* n. nom., new combinations and emendations in the names of apicomplexan protozoa. *Journal of Protozoology*. **32**: 359-363.
81. **Levine ND (1985b)** Phylum II. Apicomplexa Levine 1970. In: Lee JJ, Hutner SH, Bovee EC (Eds.), *An Illustrated Guide to the Protozoa*, Allen Press, Lawrence. KS, pp. 322–374.
82. **Levine ND (1988a)** *The Protozoan Phylum Apicomplexa*. CRC Press, Boca Raton. Volume 1. pp: 203.
83. **Levine ND (1988b)** *The Protozoan Phylum Apicomplexa*. CRC Press, Boca Raton. Volume 2. pp: 154.
84. **Levine ND 1985**. Species of the coccidian genus *Alveocystis*. *Journal of Protozoology*. **32**: 368-369.
85. **Levine ND and Ivens V (1979)** The coccidia (Protozoa, Apicomplexa) of Insectivores. *Revista Iberica de Parasitologia*. **39**: 261-297.
86. **Levine ND and Ivens V (1990)** The coccidian parasites of rodents. CRC Press, Boca Raton. pp: 228.
87. **Levine ND and Ivens VR (1987)** Corrections in the names of rodent coccidia (Apicomplexa, Coccidiasina). *The Journal of Protozoology*. **34(4)**: 371.
88. **Li L and Desser SS (1985a)** The protozoan parasites of fish from two lakes in Algonquin Park, Ontario. *Canadian Journal of Zoology*. **63**: 1846-1858.
89. **Li L and Desser SS (1985b)** Three new species of *Octosporella* (Protozoa: Coccidia) from cyprinid fish in Algonquin Park, Ontario. *Canadian Journal of Zoology*. **63**: 1859-1862.
90. **Lindsay DS and Todd KS Jr. (1993)** Coccidia of mammals. In, *Parasitic protozoa*. Academic Press, Inc., New York. Vol. 4. pp: 89-131.

91. **Lindsay DS, Current WL, and Ernst JV (1982)** Sporogony of *Isoospora suis* Biester, 1934 of swine. *The Journal of Parasitology*. **68**: 861-865.
92. **Lom J and Arthur JR (1989)** A guideline for the preparation of species descriptions in Myxosporidia. *Journal of Fish Diseases*. **12**: 151-156.
93. **Long PL (1982)** The biology of the coccidia. Baltimore, MD: University Park Press. pp: 502.
94. **Long PL (1990)** Coccidiosis of Man and Domestic Animals. CRC Press, Boca Raton, Florida.
95. **Long PL (1993)** Avian Coccidiosis. In: Kreier, J. P. (ed.), Parasitic Protozoa, 2nd ed. Academic Press., New York, New York. **4**: 1-88.
96. **Long PL and Joyner LP (1984)** Problems in the Identification of Species of *Eimeria*. *The Journal of Eukaryotic Microbiology*. **31 (4)**: 535-541.
97. **Lopez FA, Manglicmot J, Schmidt TM, Yeh C, Smith HV and Relman DA (1999)** Molecular characterization of *Cyclospora*-like organisms from baboons. *Journal of Infectious Diseases*. **179**: 670-676.
98. **Lowenstein M (1991)** Parasitosen des Igels und deren Bekämpfung. *Wiener Tierärztlichen Mschr*. **78(4)**: 127-135.
99. **Marquardt WC, Osman AY and Miller TA (1984)** Arrested development in *Eimeria nieschulzi* (apicomplexa: eimeriina): results of single infection. *The Journal of Parasitology*. **70**: 40-42.
100. **Matschoulsky SN (1949)** On the study of coccidia of rodents of the Southern district of Buryat-Mongolia USSR. *Trudy Buryat-Mongolia Zoovetinstututa Veposk*. **5**: 40-56.
101. **Matsui T, Morii T, Ti Lijima, Kobayashi F, and Fujino T (1989)** Transformation of oocysts from several coccidian species by heat treatment. *Parasitology Research*. **75**: 264-267.
102. **Matubayasi H (1936)** On a new coccidia, *Koidzumiella natix* n.g., n.sp., parasitic in Japanese snakes; with some remarks on two other ophidian coccidia of the genus *Caryospora* and *Isoospora*. *Keio-Igaku*. **16**: 1719-1729.
103. **Mayberry LF, Gaytan O, and Bristol JR (1989)** Transfer of *Eimeria nieschulzi* using extraintestinal tissue. *The Journal of Parasitology*. **75**: 470-472.
104. **McCully RM, Basson PA, DeVos V and DeVos AJ (1970)** Uterine coccidiosis of the impala caused by *Eimeria neitzi* spec. nov. *Onderstepoort Journal of Veterinary Research*. **37**: 45-58.
105. **McKinnon DL and Ray HN (1937)** A coccidian from the eggs of *Thalassema neptuni* Gaertner. *Parasitology*. **29**: 457-468.
106. **McQuiston TE (1990)** *Polysporella genovesae* n. gen., n. sp. (Apicomplexa: Eimeriidae) from the fecal contents of the Galapagos mockingbird, *Nesomimus parvulus* (Passeriformes: Mimidae). *Transactions of the American Microscopical Society*. **109**: 412-416.
107. **Mesnil F (1903)** Les travaux recents sur less coccidies. Bulletin de l'Institut Pasteur (Paris). **1**: 473-480.
108. **Minchin EA (1903)** The Protozoa (continued). Section K.-The Sporozoa. In, A Treatise on Zoology, Part I. Introduction and Protozoa, Lankester, E.R., editor. Adam & Charles Black, London. pp: 150-360.
109. **Molnar K (1996)** Remarks on the morphology, site of infection and validity of some coccidian species from fish. *Acta Veterinaria Hungarica*. **44**: 295-307.
110. **Morrison DA, Ellis JT (1997)** Effects of nucleotide sequence alignment on phylogeny estimation: a case study of 18S rDNAs of Apicomplexa. *Molecular Biology and Evolution*. **14**: 428-441.
111. **Mottalei F, Mayberry LF and Bristol JR (1992)** Localization of extraintestinal *Eimeria nieschulzi* (apicomplexa: Eimeriidae) stages in the rat utilizing an indirect immunofluorescence technique. *Transactions of the American Microscopical Society*. **111**: 61-64.
112. **Mugridge NB, Morrison DA, Heckerroth AR, Johnson AM and Tenter AM (1999b)** Phylogenetic analysis based on full-length large subunit ribosomal RNA gene sequence comparison reveals that *Neospora caninum* is more closely related to *Hammondia heydorni* than to *Toxoplasma gondii*. *The International Journal of Parasitology*. **29**: 1545-1556.
113. **Mugridge NB, Morrison DA, Johnson AM, Luton K, Dubey JP, Votypka J and Tenter AM (1999a)** Phylogenetic relationships of the genus *Frenkelia*: a review of its history and new knowledge gained from comparison of large subunit ribosomal ribonucleic acid gene sequences. *The International Journal of Parasitology*. **29**: 957-972.
114. **Musaev MA and Veisov AM (1965)** Coccidia of rodents of the USSR. Izdatelbstvo Akademii Nauk Azerbaidzanskoj SSR, Baku. pp: 154.

115. Novilla MN, Caropenter JW, Spraker TR and Jeffers TK (1981) Parental development of eimerian coccidia in sandhill and whooping cranes. *Journal of Protozoology*. **28**: 248-255.
116. Novilla MN, Carpenter JW, Jeffers TK, and White SL (1989) Pulmonary lesions in disseminated visceral coccidiosis of sandhill and whooping cranes. *Journal of Wildlife Diseases*. **25**: 527-533.
117. Ovezmukhammedov A (1975) A new species of coccidia *Octosporella sanguinolenti* sp. n. from lizards Agama in Turkmenistan. *Izvestiya Akademii Nauk Turkmenskoi SSR Seriya Biologicheskikh Nauk*. **0(4)**: 87-88.
118. Parker BB and Duszynski DW (1986) Coccidiosis of sandhill cranes (*Grus canadensis*) wintering in New Mexico. *Journal of Wildlife Diseases*. **22**: 25-35.
119. Pellerdy L (1974) Coccidia and Coccidiosis. 2nd edition. Verlag Paul Parey, Berlin and Hamburg, and Akademiai Kiado, Budapest. pp: 959.
120. Pieniazek NJ and Herwaldt BL (1997) Reevaluating the molecular taxonomy: is human-associated *Cyclospora* a mammalian *Eimeria* species? *Emerging Infectious Diseases*. **3**: 381-383.
121. Ray HN (1930) Studies on some sporozoa in polychaete worms. II. *Dorisiella scolelepidis*, n. gen., n. sp. *The Journal of Parasitology*. **22**: 471-480.
122. Ray HN and das Gupta M (1937) On a new coccidium from the intestine of Python sp. *Proceedings of the Indian Science Congress, Calcutta*. **24**: 292.
123. Ray HN and Raghavachari K (1942) Observations on a new coccidium, *Octosporella mabuiae* n. gen., n. sp., from the intestine of *Mabuia* sp. *Proceedings of the 28th Indian Science Congress*. **28**: 170.
124. Ray HN and Sarkar AC (1967) On some new coccidia from the Indian passerine birds, *Zosterops palpebrosa* (Temm.), *Lonchura malabarica* (Linn.), *L. punctulata* (Linn.) and *Passer domesticus* (Linn.). *Proceedings of the 54th Indian Science Congress*. **54**: 448-449.
125. Ray HN and Sarkar AC (1968) A new coccidium *Sivatoshella lonchurae* n. gen., n. sp., from *Lonchura malabarica* and *L. punctulata*. *Journal of Protozoology*. **15**: 640-643.
126. Sam-Yellowe TY (1996) Rhoptry organelles of the Apicomplexa: Their role in host cell invasion and intracellular survival. *Parasitology Today*. **12**: 308-315.
127. Schellack C and Reichenow E (1913) Coccidien-untersuchungen. I. *Barrouxia schneideri*. *Arbeiten aus dem Kaiserlichen Gesundheitsamte, Berlin*. **44**: 30-77.
128. Schneider A (1881) Sur les psorospermies oviformes ou coccidies especes nouvelles ou peu connues. *Archives de Zoologie Experimentale et Generale*. **9**: 387-404.
129. Schneider A (1886) Coccidies nouvelles ou peu connues. *Tablettes Zoologie, Poitiers*. **1**: 4-9.
130. Scholtz E (1979) Fine structure of parasitic protozoa. Springer-verlag, Heidelberg.
131. Schrenzel MD, Maalouf GA, Gaffney PM, Tokarz D, Keener LL, McClure D, Griffey S, Mcaloose D, and Rideout BA (2005) Molecular characterization of isosporoid coccidia (*Isoospora* and *Atoxoplasma* spp.) in passerine birds. *The Journal of Parasitology*. **91**: 635-647.
132. Siedlecki MM (1902) Historia rozwoju nowego gatunku kokcydi: *Caryotropha mesnili* nob. (Cycle evolutif de la *Caryotropha mesnili*, coccidie nouvelle des polyminies; note preliminaire). *Bulletin International de l'Academie des Sciences de Cracovie. Classef des Sciences Mathematiques et Naturelles*. **1902**: 561-568.
133. Silberman JD (1998) Evolution of the Protists and protistan parasites from the perspective of molecular systematics. *The International Journal of Parasitology*. **28**: 11-20.
134. Tadros W and Laarman JJ (1976) *Sarcocystis* and related coccidian parasites: a brief general review, together with a discussion on some biological aspects of their life cycles and a new proposal for their classification. *Acta Leidensia*. **44**: 1-137.
135. Tenter AM and Johnson AM (1997) Phylogeny of the tissue cyst-forming coccidia. *Advances in Parasitology*. **39**: 69-139.
136. Upton SJ and Sundermann CA (1990) *Caryospora*: Biology. Chapter 10. In, *Coccidiosis of Man and Domestic Animals*, Long, P.L., editor. CRC Press, Boca Raton. pp: 187-204.
137. Vincent M (1936) Un nouveau type de coccidie des peripates. *Comptes Rendus des Sciences de la Societe de Biologie (Paris)*. **122**: 260-262.
138. Votypka J, Hypsa V, Jirku M, Flegr J, Vavra J and Lukes J (1998) Molecular phylogenetic relatedness of *Frenkelia* spp. (Protozoa, Apicomplexa) to *Sarcocystis falcatula* Stiles 1893: is the genus *Sarcocystis* paraphyletic? *The Journal of Eukaryotic Microbiology*. **45**: 137-141.
139. Wacha RS and Christiansen JL (1976) Coccidian parasites from Iowa turtles: Systematics and Prevalence. *Journal of Protozoology*. **23**: 57-63.

- 140. Wasielewski T (1904)** Studien und Mikrophotogramme zur Kenntnis der Pathogenen Protozoen. Johann Ambrosius Barth, Leipzig. pp: 118.
- 141. Wilber PG, Duszynski DW, Upton SJ, Seville RS and Corliss JO (1998)** A revision of the taxonomy and nomenclature of the eimerians (Apicomplexa: Eimeriidae) from rodents in the tribe marmotini (Sciuridae). *Systematic Parasitology*. **39**: 113-135.
- 142. Yakimoff WL and Gousseff FF (1935)** Une coccidie de serpent. *Annales de Parasitologie Humaine et Comparee*. **13**: 28-31.
- 143. Zhao X and Duszynski DW (2001a)** Molecular phylogenies suggest the oocyst residuum can be used to distinguish two independent lineages of *Eimeria* spp in rodents. *Parasitology Research*. **87**: 638-643.
- 144. Zhao X and Duszynski DW (2001b)** Phylogenetic relationships among rodent *Eimeria* species determined by plastid ORF470 and nuclear 18S rDNA sequences. *The International Journal of Parasitology*. **31**: 715-719.
- 145. Zhao X, Duszynski DW and Loker ES (2001)** Phylogenetic position of *Eimeria antrozoi*, a bat coccidium (Apicomplexa: Eimeriidae) and its relationship to morphologically similar *Eimeria* spp. from bats and rodents based on nuclear 18S and plastid 23S rDNA sequences. *The Journal of Parasitology*. **87**: 1120–1123.