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# AN OVERVIEW OF CLASSIFICATION OF THE PHYLUM APICOMPLEXA

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**Summary:**Species belonging to the phylum *Apicomplexa* are parasitic organisms which share a common feature called the apical complex. The apical complex is found at the anterior end of sporozoites which consists of conoid, polar ring, rhoptries and micronemes and is assumed to function during host cell invasion. The apical complex was used as a major criterion to establish the phylum *Apicomplexa* but some members of the phylum such as *Plasmodium, Theileria* and *Babesia* lack a complete apical complex .
There is a general consensus that protists represent the oldest and most diverse group of the eukaryotic kingdom.
**Key Words:** Classification, *Apicamplexa, Eimeria.*

## Kök Apicomplexa Sınıflamasına Genel Bakış

**Özet:***Apicomplexa* köküne ait türler apikal kompleks denilen ortak bir yapıya sahiptirler. Hücre invazyonu esnasında görev yaptığı sanılan, apikal kompleks; konoid, polar ring, roptiriler ve mikronemlerden oluşmuştur ve sporozoitlerin ön ucuna yerleşmiştir. *Apicomplexa* kökünün oluşturulmasında ana karakter olarak apikal kompleks kullanılmıştır fakat kökün, Plasmodium, *Theileria* ve *Babesia* gibi bazı üyeleri tam bir apikal komplekse sahip değillerdir.
Protist'lerin, Eukaryota aleminin en eski ve en dağınık grubu olduğu yolunda yaygın bir kanı vardır.
**Anahtar Sözcükler:** Sınıflandırma, *Apicomplexa, Eimeria.*

## INTRODUCTION

The first coccidia were seen in 1674, when Leeuwenhoek found the oocysts of *Eimeria stiedai* in rabbit bile. It was more than 150 years later that the oocysts were described by Hake (1839) as pus-globules of liver carcinoma[1].

While it was recognised that the coccidia were protozoa, it was not realised that they had a complicated life cycle involving both sexual and asexual reproduction. As a result oocysts of the same species were placed in one genus, suborder or family and the meronts(schizonts) in another[2].

Intensive studies were carried out on the Eimeria in 1890ís because Eimeria were thought to be the agent of certain cancers. During those works the complex life cycle of Eimerian parasites was identified and this forced a revision of their taxonomy and nomenclature[1].

Minchin (1903) revised the initial classification and classified coccidia upon the number of sporocysts formed in each oocyst. While Grasse (1953) further reviewed the classification when the use of the electron microscope provided more knowledge about coccidian parasites. Levine classified them under subphylum *Apicomplexa* based on the organelle "*apical complex*" which appears in at least one stage of the coccidia life cycle. This complex organelle is presumed to facilitate attachment to or entry into the host cell[1-4].

The organelles include: one or more electron dense polar rings: a conoid formed by several spiral coiled microtubules inside the polar ring; a number of rhoptries i.e. electron dense, tubular or saccular organelles, often enlarged posteriorly and a number of micronemes i.e. elongate, electron dense organelles extending longitudinally in the anterior part of the cell. A number of subpellicular microtubulues also form slender, electron dense, hollow structures extending back just under the pellicle from the polar ring[3-8].

There is a general consensus that protists

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represent the oldest and most diverse group of the eukaryotic kingdom[9]. Comparative studies of phenotypes were found to be untenable for the classification of protists, mainly because of their remarkable diversity[10]. The alternative approach is to use molecular biological techniques to infer phylogeny[10-13]. Both DNA and RNA can be used to determine evolutionary distances as nucleotide sequences tend to diverge over time and to evolve at a more regular rate than do morphological characters[14]. Ribosomal RNA has been widely used for taxonomic and phylogenetic investigations. This approach has been used in a number of studies to examine relationships among coccidian parasites[10,15-19]. The monophyly of the *Sarcocystidae* and *Eimeriidae* was supported by molecular biological studies [10,16,20]. *Neospora caninum* and *Toxoplasma gondii* were found to be close relatives sharing a common ancestor with *Sarcocystis* species [18,21,22]. *E. tenella* and *E. necatrix* were shown to form a basal clade suggesting a probable host switch from turkey to chicken[10].

The true *coccidia* (*Eimeriorina*), the malarial parasites (*Haemosporina*) of man and other animals, the piroplasm of domestic and wild animals, the heteroxenous *hemogregarines* and *gregarines* of invertebrates are placed under the phylum *Apicomplexa* as we know today[3-8]. In the light of the above, it is highly probable that there will be revisions to the classification of phylum *Apicamplexa* in the near future.

**Classification of Phylum APICOMPLEXA**

**Subkingdom: PROTOZOA (van Leeuwenhoek 1674)**

The protozoa are single-celled, eukaryotic organisms. Modern classifications divide living specimens into a number of kingdoms. The most widely used is the 5-kingdom classification system (MONERA, PROTISTA, FUNGI, PLANTAE, ANIMALIA). In this, the Protozoa would be considered a subkingdom of Protista. If the classical classification is preferred, the Protozoa would be considered a subkingdom of Animalia. Protozoa range in size, most being between 5 $\mu$m and 250 $\mu$m.

**Phylum: APICOMPLEXA** (Levine, 1970)

Apical complex presents at some stage (visible with electron microscope), generally consisting of a polar ring, rhoptries, micronemes, conoid and subpellicular microtubules; micropores generally present at some stage; cilia absent; sexuality by syngamy: all species parasitic.

**Class 1: Perkinsea** (Levine, 1978)

Conoid forming incomplete cone; "zoo-spores" (sporozoites) flagellated, with anterior vacuole: no sexual reproduction ; homoxenous.

**Order 1: Perkinsida** (Levine, 1978)

With characters of the class Perkinsus. One named species.

**Class 2: Sporozoea** (Leukart, 1879)

Conoid, if present, forming complete cone; reproduction generally both sexual and asexual; oocysts generally containing infective sporozoites which result from sporogony; locomotion of mature organisms by body flexion, gliding or undulation of longitudinal ridges; flagella present only in microgametes of some groups; pseudopods ordinarily absent, if present used for feeding, not locomotion; homoxenous or heteroxenous.

**Subclass 1: Gregarina** (Dufour, 1828)

Mature gamonts large, extracellular : mucron or epimerite in mature organism; mucron formed from conoid; generally syzygy of gamonts; gametes usually similar (isogamous) or nearly so; with similar numbers of male and female gametes, produced by gamonts; zygotes forming oocysts within gametocytes; life cycle characteristically consisting of gametogony and sporogony; in digestive tract or body cavity of invertabrates or lower chordates; generally homoxenous.

**Order 1: Archigregarinida** (Grasse, 1953)

Life cycle apparently primitive, characteristically with merogony, gametogony, sporogony; gamonts (trophozoites) aseptate; in annelids, spinculids hemichordates or ascidians. Exoshizon, Selenidioides.

**Order 2: Eugregarinida** (Leger, 1900).

Merogony absent; gamegony and sporogony present; Locomotion progressive, by gliding or undulation of longitudinal ridges, or nonprogressive; typically parasites of annelids and arthropods, but some species found in other invertebrates.

**Suborder 1: Blastogregarinina** (Chatton and Villeneuve, 1936)

**Suborder 2: Aseptatina** (Chakravarty, 1960)

**Suborder 3: Septatina** (Lankester, 1885

**Subclass 2: Coccidia** (Leucart, 1879)
Gamonts usually present, normally small and intracellular; conoid not modified into mucron or epimerite; syzygy usually absent, if present involves gametes; gametes usually anisogametes; life cycle normally consists of merogony, gamegony and sporogony; most species are parasites of vertebrates.

**Order 1: Agamococcidiida** (Levine, 1979)
Merogony and gametogony absent. Rhytidocystitis

**Order 2: Protococcidiida** (Kheisin, 1956)
Merogony absent in invertebrates. Elutheroschizon, Grellia

**Order 3: Eucoccidiorida** (Leger and Doboscq 1910)
Merogony present; in vertebrates and/or invertebrates.

**Suborder 1: Adeleina** (Leger, 1911)
Macrogamete and microgamont usually associated in syzygy during development; microgamont producing 1-4 microgametes; sporozoites enclosed in envelope; no endodyogeny; homoxenous or heteroxenous. Adelea, Haemogregarina, Klossiella.

**Suborder 2: Eimeriorina** (Leger, 1911)
Macrogamete and microgamont developing independently; no syzygy; microgamont typically producing many microgametes; zygote not motile;. sporozoites typically enclosed in sporocysts within oocysts; homoxenous or hetroxenous. Aggregata. Eimeria, Isospora, Sarcocystis, Toxoplasma

**Family: Eimeriidae** (Minchin, 1903)
Development in host cell proper; without attachment organelle or vaginal tube; syzygy absent; oocysts with 0, 1, 2, 4, or more sporocysts, each with 1 or more sporozoites, homoxenous or at least without asexual multiplication in non definitive host; merogony within host, sporogony typically outside; microgametes with 2 or 3 flagella; without metrocytes, in vertebrates; about 1500 named species.

**Genus: Cyclospora** (Schneider, 1881)
Oocyst with 2 sporocysts, each with 2 sporozoites, about 9 named species.

**Genus: Caryospora** (Leger, 1911)
Oocysts with one sporocysts containing 8 sporozoites;

**Genus: Eimeria** (Schneider, 1875)
Oocysts with 4 sporocysts each with 2 sporozoites, in vertebrates and a few invertebrates. More than 1000 named species.

**Genus: Isospora** (Schneider, 1881)
Oocysts with 2 sporocysts, each with 4 sporozoites; usually in vertebrates; about 200 named species.

**Genus: Tyzzeria** (Allen, 1936)
Oocysts without sporocysts with 8 naked sporozoites; in vertebrates, about 9 named species

**Genus : Mantonella** (Vincent, 1936)
Oocysts with 1 sporocysts containing 4 sporozoites, about 3 named species.

**Genus: Diaspora** (Leger, 1898)
Oocysts unknown, sporocysts each with 1 sporocysts; sporocysts without bivalved wall, without longitudinal dehiscense suture; in vertebrates; about 1 named species.

**Genus: Dorisa** (Levine, 1979)
Oocysts with variable number of sporocysts, each with 8 sporozoites; about 9 named species.

**Genus : Wenyonella** (Hoare, 1933)
Oocysts with 4 sporocysts each with 4 sporozoites, about 15 named species.

**Genus: Hoarella** (Arcay de Peraza, 1963)

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Oocysts with 16 sporocysts, each with 2 sporozoites, about 1 named species.

**Genus: Sivatoshella** (Ray and Sarker, 1968)
Oocysts with 2 sporocysts, each with 16 sporozoites, about one named species.

**Genus: Pythonella** (Ray and Das Gupta, 1937)
Oocysts with 16 sporocysts, each with 4 sporozoites, about 2 named species.

**Genus: Barrouxia** (Schneider, 1885)
Oocysts with many sporocysts, each with one sporozoites, sporocysts with bivalved wall, with a longitudinal dehiscence suture, about 10 named species.

**Genus: Gousseffia** (Levine and Ivens, 1980)
Oocysts with 8 sporocysts, each with many sporozoites, about 1 named species.

**Genus: Skrjabinalla** (Machulískii, 1949)
Oocysts with 16 sporocysts, each with 1 sporozoite, about 1 named species.

**Family: Cryptosporidiidae** (Leger, 1911)
Development just under surface membrane of host cell within its brush border and not in the cell proper syzygy absent, oocysts and meronts with a knob-like attachment, organelle at some point on their surface; oocysts without sporocysts, with 4 naked sporozoites; microgametes without flagella; homoxenous; about 10 named species.

**Genus: Cryptosporidium** (Tyzzer, 1907)

**Family: Sarcocystidae** (Poche, 1913)
Heteroxenous, producing oocysts following syngamy, syzygy absent; oocysts with 2 sporocysts, each with 4 sporozoites, in intestine of a definitive host; with asexual stages in an intermediate host; about 105 named species.

**Subfamily: Sarcocystinae** (Poche. 1913)
Obligatorily heteroxenous; asexual multiplication in intermediate (prey) host; last generation meronts (Sarcocysts) in intermediate host form metrocysts, which give rise to bradyzoites, which are infectious for definitive host (Predator); oocysts sporulate in predator host tissues; sporulated sporocysts in faeces.

**Genus: Frankelia** (Biocca, 1968)

**Genus: Arthrocystis** (Levine, Beamer and Simon, 1970)

**Genus: Sarcocystis** (Lankester, 1882)

**Subfamily: Toxoplasmatinae** (Biocca, 1956)
Complete life cycle obligatorily heteroxenous but asexual stages usually transmissible from 1 intermediate host to another; metrocytes not formed; oocysts do not sporulate in host tissues; about 14 named species.

**Genus: Besnoitia** (Henry, 1913).
**Genus: Hammondia** (Frenkel, 1974).
**Genus: Neospora** (Dubey, 1988).

**Genus: Toxoplasma** (Nicolle and Manceaux, 1908).

**Suborder 3: Haemospororina** (Danilewsky, 1885).
Macrogamete and microgamont develop independently; conoid ordinarily absent; syzygy absent microgamont produces about 8 flagellated microgametes; zygote motile (ookinete); sporozoites naked, with 3 membraned wall; endodyogeny absent,; heteroxenous, with merogony in vertebrate host and sporogony in invertebrate, pigment (hemozoin) visible with the light microscope may or may not be formed from host cell haemoglobin ; transmitted by blood-sucking insects; about 460 named species.

**Subclass 3: Piroplasmasina** (Levine, 1961).
Piriform, round, rod-shaped or amoeboid, without conoid; without oocysts, spores, or pseudocysts; flagella absent; most genera without subpellicular microtubules; with polar ring and rhoptries, locomotion by body flexion, gliding or in sexual stages (in Babesiidae and Theileriidae) by large axopodium-like ìstrahlenî; asexual and probably sexual reproduction present; parasitic in erythrocytes and sometimes also in other circulating and fixed cells; heteroxenous, with merogony in vertebrate and sporogony in invertebrate; sporozoites with 1-membraned wall; the vectors are thought to be tick; about 150 named species [4,5,7,8].

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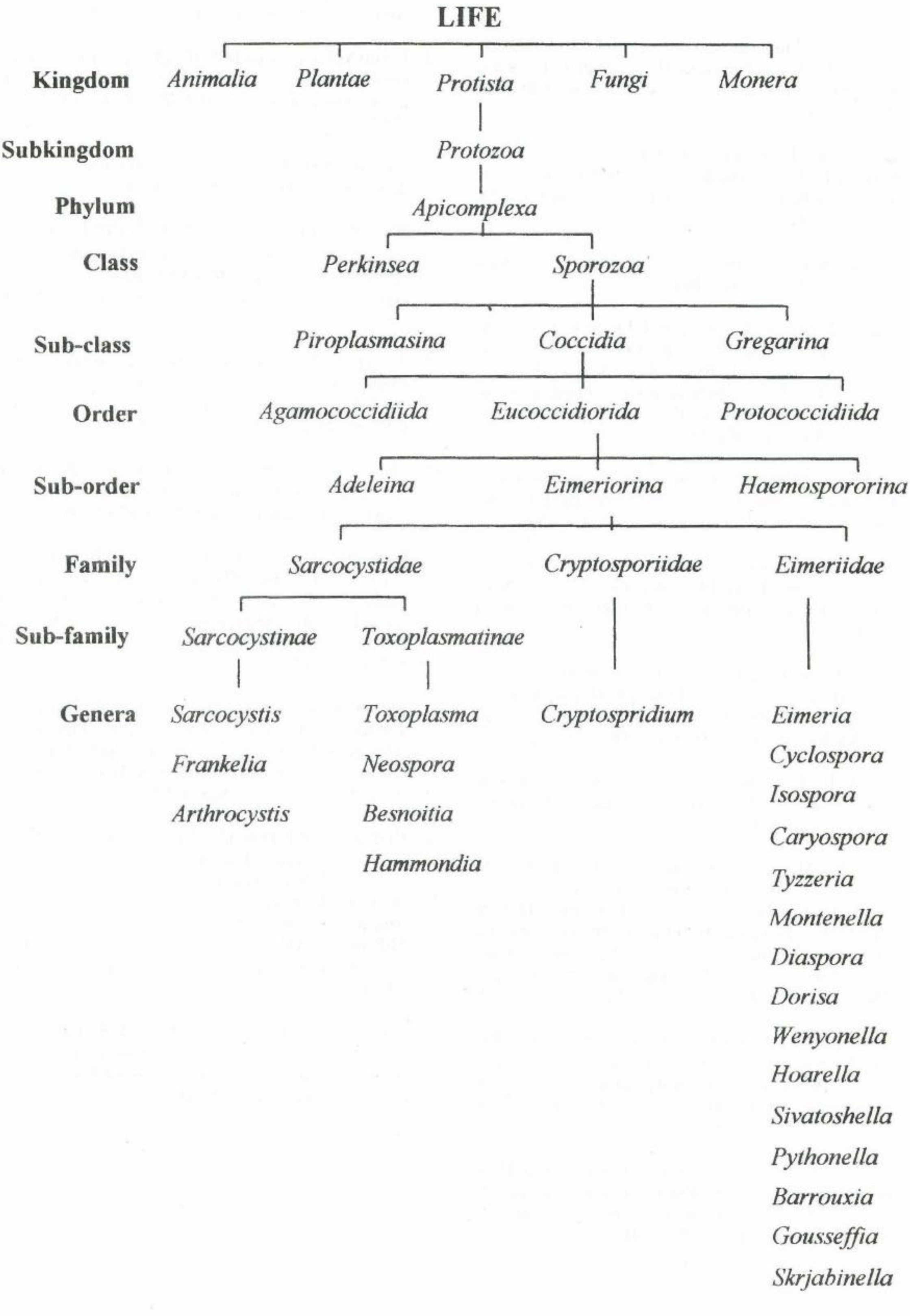
**Figure 1.** Diagrammatic classification of the family Eimeriidae.
**Şekil 1.** Eimeriidae ailesi sınıflama şeması



## REFERENCES


1. Levine ND: Taxonomy of sporozoa. *J of Para*, 56, 208-209, 1970.
2. Levine ND: Introduction, history and taxonomy. In: Long, PL (Ed): The coccidia: Eimeria, Isospora, Toxoplasma and related genera, 1-22, University Park Press, 1973.
3. Levine ND: Taxonomy and life cycles of coccidia. In: Long, PL (Ed.): The Biology of the Coccidia, 1-34, University Park Press, Baltimore and Adward Arnold, London, 1982.
4. Levine ND: Veterinary Protozoology, Iowa State University Press, Ames, 1985.
5. Eckert J, Taylor M, Catchpole J, Licois D, Coudert P and Buclar H: Identification of Eimeria species and strains, In: Eckert J, Braun R, Shirley MW and Coudert P (Eds): Biotechnology; Guidelines on Techniques in Coccidiosis Research, COST, 103-119, Brussels, Luxembourg, 1995.
6. Ball SJ and Pittilo RM: Structure and ultrastructure, In: Long, P.L.(Ed): Coccidiosis of Man and Domestic Animals, 17-41, CRC Press, Boston, USA, 1990.
7. Current WL, Upton SJ and Long PL: Taxonomy and Life Cycle. In: Long PL (Ed.): Coccidiosis of Man and Domestic Animals, 1-16, CRC Press, Boca Raton, Florida, 1990.
8. Vivier E and Desportes I: Phylum Apicomplexa. In: Margulis L, Corlis JO, Melkonian M and Chapman DJ (Eds.): Handbook of Protoctista, 549-573, Jones and Bartlett Publishers, Boston, 1990.
9. Sogin ML: Evolution of eukaryotic micro-organisms and their small subunit rRNAs, American Zoologist, 29, 487-499, 1989.
10. Barta JR, Martin DS, Liberator PA, Dashkevicz M, Anderson JW, Feighner SD, Elbrecht A, PerkinsBarrow A, Jenkins MC, Danforth HD, Ruff MD, ProfousJuchelka, H: Phylogenetic relationships among eight Eimeria species infecting domestic fowl inferred using complete small subunit ribosomal DNA sequences. *J of Para*, 83, 262-271, 1997.
11. Johnson AM, Murray PJ, Illana S and Baverstock PJ: Rapid nucleotide-sequence analysis of the small subunit rRNA of Toxoplasma gondii-evolutionary implications for the Apicomplexa. *Mol and Biochem Para*, 25, 239-246, 1987.
12. Baverstock PR and Johnson AM: Ribosomal RNA nucleotide sequence: A comparison of newer methods used for its determination and its use in phylogenetic analysis. *Aust Syst Bot*, 3, 101-110, 1990.
13. Unnasch TR and Zimmerman PA: Systematics: Questions and approaches for the molecular parasitology. In: Boothroyd JC and Komuniecki R (Eds.): Molecular Approaches to Parasitology, 5-20, New York, Chichester, Wiley-Liss, 1995.
14. Dixon MT and Hillis DM: rRNA secondary structure: compensatory mutations and implications for phylogenetic analysis. *Mol Biol Evol*, 10, 256-67, 1993.
15. Johnson AM: Phylogeny and evolution of protozoa. *Zoological Science*, 1990, 7, 179, 1990.
16. Barta JR, Jenkins MC and Danforth HD: Evolutionary relationships of avian Eimeria species among other apicomplexan protozoa-monophyly of the Apicomplexa is supported. *Mol Bio and Evol*, 8, 345-355, 1991.
17. Tenter AM, Baverstock PR and Johnson AM: Phylogenetic relationships of Sarcocystis species from sheep, goat, cattle and mice based on ribosomal RNA sequences. *Int J for Para*, 22, 503-513, 1992.
18. Ellis J, Luton K, Baverstock PR, Brindley PJ, Nimmo KA and Johnson AM: The phylogeny of Neospora caninum. *Mol and Biochem Para*, 64 303-311, 1994.
19. Escalante AA, Goldman IF, DeRijk P, DeWachter R, Collins WE, Qari SH and Lal AA.: Phylogenetic study of the genus Plasmodium based on the secondary structure-based alignment of the small subunit ribosomal RNA. *Mol and Biochem Para*, 90, 317-321, 1997.
20. Ellis J, Luton K, Baverstock PR, Withworth G, Tender AM and Johnson AM: Phylogenetic relationship between Toxoplasma and Sarcocystis deduced from a comparison of 18S rDNA sequences. *Parasitology*, 110,521-528, 1995.
21. Holmdahl OJM, Ellis TJ, Harper PAW and Morrison DA: Phylogenetic relationships based on small subunit rRNA sequences from two isolates of Besnoitia besnoiti and other cyst-forming coccidian parasites, Control Of Coccidiosis Into The Next Millennium, VII. International Coccidosis Conference and European Union COST820 Workshop, Oxford, UK. 73-74, 1997.
22. Tenter AM, Baverstock PR and Johnson AM: Phylogenetic relationships of Sarcocystis species from sheep, goat, cattle and mice based on ribosomal RNA sequences. *Int J for Para*, 22, 503-513, 1992.