



# Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa

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Protozoa species were identified in rumen contents of four domestic sheep (*Ovis aries*) from South Africa. All animals were fed a forage diet which consisted of 50% lucerne and 50% teff hay. Ten new host records were identified, bringing the total number of species and forms observed in sheep in South Africa to 30. The occurrence and geographic distribution of ciliate protozoa in both domestic and wild sheep from around the world are summarised. It was found that 15 genera and 131 species occur in domestic sheep globally.

## Introduction

Other than several early reports from South Africa on rumen ciliate protozoa in domestic sheep (Fantham 1920, 1921, 1926; Van der Wath & Myburgh 1941), no additional research in this respect has been published. These previous studies identified a total of only 12 species and forms. Studies from other areas of Africa are also limited (see, e.g. Selim *et al.* [1996] for Egypt and Selim *et al.* [1999] for Libya). To date only 17 species have been observed in domestic sheep across Africa.

## Materials and methods

During August 2009 samples of rumen contents were obtained from four fistulated male domestic sheep (*Ovis aries*), which were all housed together in 6 m x 10 m pens at the Department of Anatomy and Physiology, University of Pretoria (Onderstepoort), South Africa. Half of each pen was covered by a concrete floor, whilst the other half was an open-air dirt floor. The animals were rotated to a clean pen every week. The sheep were fed a 50:50 mixture of lucerne (*Medicago sativa*) and teff hay (*Eragrostis tef*) each morning, after which they were allowed free access to kikuyu grass (*Pennisetum clandestinum*) pasture for the rest of the day. Rumen samples of 200 mL each were collected through rumen fistulas and 200 mL warm saline was added immediately to each sample. This helped to extend the cilia of the protozoa for easier identification. The sample was then preserved by adding 70% alcohol (100 mL).

Each sample was washed in a Pitchford–Visser filter, similar to the one used for trematode egg counts. The outer sieve had an aperture of 37 µm, whilst apertures in the inner sieve were 110 µm. This procedure retained all the coarse material in the inner sieve and the protozoa were captured in the outer sieve. The sample was recovered from the outer sieve by means of a drain tap. The washed sample was drained into a container, allowed to stand and settle for 15 min and then most of the supernatant was decanted. This allowed concentration of the sample to a final volume of 40 mL. A measured volume of alcohol was added to preserve the sample. A few drops of methyl blue stain were added to stain the protozoa and nucleus (Booyse, Boomker & Dehority 2010).

A 0.1-mL aliquot of stained sample was transferred onto a glass microscope slide using a 'Finnpipette', commonly used in chemistry laboratories. The sample was covered with a glass cover slip and examined with a standard Nikon microscope fitted with a Panasonic digital camera. Photographs were taken to aid identification. Each sample was examined in triplicate.

Owing to the observed lack of *Entodinium* spp. in the washed samples, additional samples of rumen contents from the four sheep were obtained. Sub-samples (0.1 mL) of these samples were stained and examined under the microscope to verify the presence of *Entodinium* spp., which had been lost through the 37-µm filter.

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## Ethical considerations

Housing and care of fistulated animals in the Department of Anatomy and Physiology were approved on an ongoing basis by the University of Pretoria Animal Care and Use Committee, as sheep are routinely used as rumen fluid donors, both for experimental and for teaching purposes.



## Results and discussion

A total of 20 species and forms of protozoa were observed in the four sheep used in the present study. Of these species, 10 were identified in South Africa for the first time (Table 1). This brings the total number of species and forms reported from sheep in South Africa to 30. All *Entodinium* species listed in Table 1 were identified in whole rumen content (i.e. unfiltered samples). It is noteworthy that for these new host records in South Africa at least three of the *Entodinium* species are closely related or possibly similar to *Entodinium dubardi* (Dehority 1994). These are *Entodinium caudatum* f. *dubardi*, *Entodinium parvum* and *Entodinium simplex*. *Entodinium nanellum* would have been included in this group, but had been observed previously. Two of the other *Entodinium* species reported as a new host record, namely *Entodinium exiguum* and *Entodinium longinucleatum*, can occur on a variation line with *E. dubardi*. However, two rather distinctive features allow identification as a separate species: for *E. exiguum*, a straight oesophagus that does not curve towards the macronucleus, and for *E. longinucleatum*, a macronucleus extending the entire length of the cell.

The number of species and forms observed for other geographical locations range from fewer than 10 to 49, as shown in Table 2. The number found in the present study is about halfway between these extremes. In general, several reports where only a limited number of species were observed, appear not to be comprehensive studies; that is, only a few species were identified rather than a complete listing of all species present. Göçmen *et al.* (1999) observed that the protozoan fauna of sheep in Turkey and Far Eastern areas (e.g. China and Japan) appeared to be more diverse than in European and American sheep.

A number of the studies listed in Table 2 were reported between 1920 and 1985, before the most widely used classification scheme of Lee, Hutner and Bovee (1985) was published. Therefore, the older species names in the subfamily Diplodiniinae listed in the original reports have been corrected according to the more recent classification scheme. For example, *Eodinium* spp. are now classified under *Diplodinium* and *Eremoplastron* spp. under *Eudiplodinium*. *Diploplastron affine* is now classified as *Metadinium affine*. In more recent studies by Göçmen (1999a, 1999b), classification

**TABLE 1:** Rumen ciliate protozoa observed in domestic sheep (*Ovis aries*) in South Africa.

Species and forms	Present study	Fantham (1920)	Fantham (1921)	Fantham (1926)	Van der Wath and Myburgh (1941)
<i>Isotricha intestinalis</i>	+	+	-	-	-
<i>Isotricha prostoma</i>	+	+	-	-	-
<i>Dasytricha ruminantium</i>	+	+	-	-	-
<i>Entodinium bursa</i>	-	+	-	-	-
<i>Entodinium caudatum</i>	-	-	-	-	-
f. <i>caudatum</i>	+	-	+	-	-
f. <i>dubardi</i>	++	-	-	-	-
<i>Entodinium dubardi</i>	+	-	-	+	+
<i>Entodinium elongatum</i>	-	-	-	-	+
<i>Entodinium exiguum</i>	++	-	-	-	-
<i>Entodinium furca</i>	-	-	-	-	+
<i>Entodinium longinucleatum</i>	++	-	-	-	-
<i>Entodinium minimum</i>	-	-	-	+	-
<i>Entodinium nanellum</i>	+	-	-	+	+
<i>Entodinium parvum</i>	++	-	-	-	-
<i>Entodinium simplex</i>	++	-	-	-	-
<i>Diplodinium dentatum</i>	+	-	-	+	-
<i>Diplodinium polygonale</i>	-	-	-	+	-
<i>Ostracodinium crassum</i>	-	-	-	+	-
<i>Ostracodinium gracile</i>	++	-	-	-	-
<i>Ostracodinium trivesiculatum</i>	++	-	-	-	-
<i>Eudiplodinium neglectum</i>	-	-	-	+	-
<i>Enopoplastron triloricatum</i>	++	-	-	-	-
<i>Polyplastron multivesiculatum</i>	++	-	-	-	-
<i>Epidinium ecaudatum</i>	-	-	-	-	-
f. <i>ecaudatum</i>	-	+	-	-	-
f. <i>caudatum</i>	+	+	-	-	-
f. <i>bicaudatum</i>	-	+	-	-	-
f. <i>tricaudatum</i>	-	+	-	-	-
<i>Ophryoscolex caudatus</i>	+	-	-	+	-
<i>Ophryoscolex purkynjei</i>	-	-	-	-	-
f. <i>bicornutus</i>	+	-	-	+	-
f. <i>purkynjei</i>	++	-	-	-	-
<b>Total species and forms</b>	<b>20</b>	<b>8</b>	<b>1</b>	<b>9</b>	<b>4</b>

Note: Please see the full reference list of the article, Booysse, D. & Dehority, B.A., 2011, 'Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa', *Onderstepoort Journal of Veterinary Research* 78(1), Art. #307, 7 pages. doi:10.4102/ojvr.v78i1.307, for more information.  
A total of 30 species and forms have been observed in South Africa (+), of which 10 new ones (++) were observed in the present study.

TABLE 2: Compilation of the protozoan fauna reported for domestic sheep (*Ovis aries*) from numerous geographical locations around the world. The numbers in each locality refers to the references listed below the table.

Species or form	South Africa	Egypt	Libya	Iceland	Canada	China	Europe	India	Iran	Japan	Pakistan	Russia	Scotland	Siberia	Turkey	USA	Yugoslavia	Cyprus	Portugal	Alaska	France	USSR	Britain	
<i>Isotricha intestinalis</i>	1	2	3	-	4	-	-	-	-	5	-	-	-	-	-	-	30	6	7	-	-	-	-	
<i>Isotricha prostoma</i>	1	2	-	10	4	24	-	-	9	-	5	-	-	31	-	30	6	7	-	-	-	-	-	
<i>Dasytricha ruminantium</i>	1	2	3	10	4	6	-	-	9	-	5	-	-	31	-	30	6	7	-	-	-	-	-	
<i>Parostrichia colpoidea</i>	-	-	-	10	-	24	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	12	-	
<i>Charon ventriculi</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Buetschlia neglecta</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Buetschlia parva</i>	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	6	7	-	-	-	-	-	
<i>Entodinium acutum</i>	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Entodinium amphicostatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	
<i>Entodinium angustatum</i>	-	-	-	-	14	14	-	-	-	-	-	-	-	-	-	-	-	32	-	-	-	-	-	
<i>Entodinium anterouncinatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. dilobum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	8	-	-	-	-	
<i>f. laeve</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	8	32	33	-	-	-	
<i>Entodinium babici</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	31	-	-	-	-	-	-	-	-	-	
<i>Entodinium bicaudatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	-	33	-	
<i>Entodinium bicornutum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32	-	
<i>Entodinium biconcavum</i>	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	30	
<i>Entodinium bimastus</i>	-	-	-	4	24	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	
<i>Entodinium bursa</i>	1	-	-	-	4	-	-	-	9	-	5	-	-	-	-	-	30	-	7	34	24	-	-	
<i>Entodinium caudatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. caudatum</i>	15	2	3	10	4	24	-	-	9	-	5	17	-	35	-	30	22	7	34	32	-	-	-	
<i>f. dubardi</i>	TS	2	3	-	-	4	24	-	-	-	5	-	-	-	-	30	-	-	-	-	-	-	-	
<i>f. lobospinosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	31	-	30	-	-	34	-	-	-		
<i>Entodinium constrictum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	36	-	33	-	-	
<i>Entodinium costatum</i>	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	7	34	32	-	-	-	-	
<i>Entodinium cyriensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-	
<i>Entodinium dalli</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	
<i>f. radidorsospinatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	
<i>Entodinium damae</i>	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	
<i>Entodinium dilobum</i>	-	2	3	10	-	24	-	-	9	-	5	-	-	-	-	-	30	-	7	34	32	-	-	
<i>Entodinium dubordii</i>	38	2	3	10	-	24	-	13	9	-	5	-	-	-	-	31	-	30	6	7	34	32	-	
<i>Entodinium ekendiae</i>	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	34	32	-	-	
<i>Entodinium ellipsoidum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31	-	30	-	-	-	-	-	
<i>Entodinium elongatum</i>	16	-	-	-	-	-	-	-	-	-	9	-	5	-	-	31	-	30	-	-	-	-	-	
<i>Entodinium exiguum</i>	TS	2	3	10	4	-	-	-	13	-	-	-	-	-	-	-	31	-	30	-	-	36	32	-
<i>Entodinium furca</i>	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	7	34	-	-
<i>Entodinium imaii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-
<i>Entodinium lobospinosum</i>	-	5	3	10	4	-	-	-	9	-	-	17	-	-	-	-	-	-	7	34	-	-	-	-
<i>Entodinium longinucleatum</i>	-	2	-	10	4	24	-	13	9	-	5	-	-	31	-	30	6	7	36	32	-	-	-	-
<i>Entodinium minimum</i>	38	2	3	-	-	21	-	-	9	-	5	-	-	-	-	30	-	7	34	-	-	-	-	-

Note: Please see the full reference list of the article, Boysoye, D. & Dehority, B.A., 2011, 'Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa', *One Health Report* 7(1), Art. #307, 7 pages, doi:10.4102/ojvr.v7i1.307, for more information.

Ts: this study; USSR: Union of Soviet Socialist Republics (former federal union of 15 constituent republics).  
 1: Dehority and Purser 1970; 2: Grau 1966; 3: Selim et al. 1996; 4: Imai et al. 1989; 5: Inai and Ogimoto 1978; 6: Dehority 1978; 7: Wertheim 1935; 8: Göçmen et al. 2001; 9: Moriggi 1941; 10: De la Fuente, Skinner and Dehority 2006; 11: Dehority and Purser 1970; 12: Grau 1966; 13: Banerjee 1955; 14: Dogiel 1927; 15: Fantham 1941; 16: Van der Watt and Myburgh 1941; 17: Lubinsky 1957; 18: Dehority 1975; 19: Coleman and Hall 1972; 20: Coleman and Hall 1973; 21: Görgen 2003b; 22: Bush and Kofoed 1948; 23: Imai, Katsuno and Ogimoto 1979; 24: Hsung 1931; 25: Kofoid and Wacienniak 1932; 26: Ogimoto and Imai 1981; 27: Das Gupta 1955; 28: Göçmen 2003a; 29: Dehority and Potter 1974; 30: Oktem, Göçmen and Torun 1997; 31: Eadie 1957; 32: Marinho 1983; 33: Dehority 1974; 34: Göçmen and Gürelli 2009b; 35: Göçmen et al. 1999; 36: Göçmen and Gürelli 2009a; 37: Latteur 1969; 38: Fantham 1926.

Table 1 continues on the next page →

**TABLE 2 (Continues...)**: Compilation of the protozoan fauna reported for domestic sheep (*Ovis aries*) from numerous geographical locations around the world. The numbers in each locality refers to the references listed below the table.

Species or form	South Africa	Egypt	Libya	Iceland	Canada	China	Europe	India	Italy	Iran	Japan	Pakistan	Russia	Scotland	Siberia	Turkey	USA	Yugoslavia	Cyprus	Portugal	Alaska	France	USSR	Britain
<i>Entodinium minimum parvicauda</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium monolobum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium nanellum</i>	38	2	3	10	4	-	-	13	9	-	5	-	-	-	-	-	30	6	7	34	32	-	-	-
<i>Entodinium nanum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-	-
<i>Entodinium oektemae</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium ogimotoi</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium orbicularis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	-	33	-
<i>Entodinium ovinum</i>	-	2	-	4	24	-	-	-	5	-	-	-	-	-	-	-	30	-	7	34	32	-	-	-
<i>Entodinium ovoideum</i>	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium parvum</i>	TS	2	3	10	4	-	-	-	5	-	-	-	-	-	-	-	-	7	34	32	-	-	-	-
<i>Entodinium protuberans</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium quadricapsis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium rectangulatum</i>	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-	30	6	-	34	32	-	-	-
<i>Entodinium rectangularum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	-
<i>lobospinosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	-
<i>Entodinium rostratum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	7	34	-	-	-	-
<i>Entodinium semahatae</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	22	7	34	32	-	-
<i>Entodinium simplex</i>	TS	2	3	-	4	24	-	-	9	-	5	-	-	-	-	-	37	30	22	7	34	32	-	-
<i>Entodinium simulans</i>	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-	-	6	-	34	-	-	-	-
<i>Entodinium simulans caudatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	32	-	-	-
<i>Entodinium simulans dubardi</i>	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Entodinium simulans lobospinosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	-
<i>Entodinium triacum dextrum</i>	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-
<i>Entodinium williamsi</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	34	-	-	-	-
<i>Entodinium williamsi turicum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-	-	-
<i>Eodinium bilobum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	14	-	7	-	-	-	-
<i>Eodinium posterovesiculatum</i>	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-
<i>Eodinium rectangulatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-
<i>Diplodinium anacanthum</i>	-	2	-	10	-	24	-	-	-	-	26	-	-	-	-	-	21	-	7	-	-	-	-	-
<i>f. monocanthum</i>	-	-	10	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	7	-	-	-	-
<i>f. diacanthum</i>	-	-	10	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	7	-	-	-	-
<i>f. triacanthum</i>	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	7	-	-	-	-
<i>f. tetracanthum</i>	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	7	-	-	-	-
<i>f. pentacanthum</i>	-	-	-	-	-	-	-	-	24	13	-	-	-	-	-	-	-	-	-	7	-	-	-	-
<i>f. anisocanthum</i>	-	-	-	-	-	-	-	-	-	-	27	-	-	-	-	-	-	-	-	7	-	-	-	-
<i>Diplodinium costatum</i>	38	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-
<i>Diplodinium dentatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	-	-
<i>Diplodinium flabellum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	-	-
<i>Diplodinium flabellum aspiratum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	-	-
<i>Diplodinium flabellum monospinatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29	-	-	-	-

Note: Please see the full reference list of the article, Boyse, D. & Dehority, B.A., 2011, 'Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa', *Understepoort Journal of Veterinary Research* 78(1), Art. #307, 7 pages, doi:10.4102/ojvr.v78i1.307, for more information.  
 TS, this study; USSR, Union of Soviet Socialist Republics (former federal union of 15 constituent republics).  
 (1) Fantham 1920; (2) Selim et al. 1996; (3) Selim et al. 1999; (4) Ima and Ogimoto 1978; (5) Ima and Ogimoto 1989; (6) Dehority 1978; (7) Wertheim 1935; (8) Göçmen 1941; (9) Morigli 1941; (10) De la Fuente, Skirnisson and Dehority 2006; (11) Dehority and Plurser 1970; (12) Grain 1966; (13) Banerjee 1955; (14) Dogiel 1927; (15) Fantham 1921; (16) Van der Walt and Myburgh 1941; (17) Lubinsky 1957; (18) Dehority 2004; (19) Dehority 1975; (20) Coleman and Hall 1972; (21) Göçmen 2003b; (22) Bush and Kofoid 1948; (23) Imai, Katsumi and Ogimoto 1979; (24) Hsiung 1931; (25) Kofoid and Madleven 1932; (26) Özköprü and İma 1981; (27) Dasgupta 1935; (28) Göçmen 2003a; (29) Özköprü and Potter 1974; (30) Dehority and Özköprü 1974; (31) Ertürk and Torun 1997; (32) Marinho 1983; (33) Dehority 1959; (34) Göçmen and Gürelli 2009b; (35) Göçmen et al. 1999; (36) Göçmen and Gürelli 2009a; (37) Latteur 1969; (38) Fantham 1926.

Table 1 continues on the next page →

**TABLE 2 (Continues...)**: Compilation of the protozoan fauna reported for domestic sheep (*Ovis aries*) from numerous geographical locations around the world. The numbers in each locality refers to the references listed below the table.

Species or form	South Africa	Egypt	Libya	Iceland	Canada	China	Europe	India	Italy	Iran	Japan	Pakistan	Russia	Scotland	Siberia	Turkey	USA	Yugoslavia	Cyprus	Portugal	Alaska	France	USSR	Britain
<i>Diplodinium lobatum</i>	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium major</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium monolobosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium polygonale</i>	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium quinquecaudatum</i>	-	-	-	-	-	7	-	-	-	7	-	14	-	-	-	-	-	-	-	-	-	-	-	-
<i>Diplodinium rangiferi</i>	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eudiplodinium bovis</i>	-	-	10	-	24	-	-	-	-	5	-	14	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eudiplodinium dilobum</i>	-	-	10	-	24	-	-	-	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eudiplodinium monolobum</i>	-	-	-	-	-	-	-	9	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eudiplodinium neglectum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eudiplodinium rostratum</i>	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Eudiplodinium maggi</i>	-	-	10	-	24	-	-	9	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracocardinium cilioporum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracocardinium crassum</i>	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracocardinium gracile</i>	-	-	10	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracocardinium mammosum</i>	-	-	-	-	-	-	-	13	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracocardinium obtusum</i>	-	-	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracocardinium rugolosum</i>	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracocardinium trivesiculatum</i>	TS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Ostracocardinium venustum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Metadinium affine</i>	-	-	10	4	24	-	-	-	-	9	-	5	-	-	-	-	-	-	-	-	-	-	-	-
<i>Metadinium medium</i>	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Metadinium minorum</i>	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Metadinium touricum</i>	-	-	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Enoploplastron trilobatum</i>	TS	-	10	4	24	-	-	9	-	23	-	-	31	-	8	-	7	-	-	-	-	-	-	-
<i>Elytroplastron bubali</i>	-	-	10	-	-	-	-	25	-	-	-	-	31	-	-	-	-	-	-	-	-	-	-	-
<i>Polyplastron longitergum</i>	-	-	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Polyplastron multivesiculatum</i>	TS	2	-	-	4	24	-	-	-	5	-	-	-	-	-	-	35	6	7	-	-	-	-	20
<i>Epidinium cattanei</i>	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Epidinium eberleini</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Epidinium ecaudatum</i>	1	-	3	5	-	7	-	-	-	-	-	-	-	-	-	10	21	22	24	35	-	-	-	-
<i>f. caudatum</i>	1	-	2	3	-	-	-	-	8	-	9	-	-	-	-	21	-	-	35	-	-	-	-	-
<i>f. bicaudatum</i>	1	-	-	-	-	24	-	-	-	-	-	-	-	-	-	8	-	-	28	-	-	-	-	-
<i>f. tricaudatum</i>	1	-	-	-	-	-	-	-	9	-	-	-	-	-	-	8	-	-	-	-	33	-	-	-
<i>f. quadraudatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	22	7	35	-	-	-	-	-
<i>f. paricaudatum</i>	-	-	-	-	-	-	-	13	-	-	-	-	-	-	-	22	7	35	-	-	-	-	-	-
<i>Epidinium hamatum</i>	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-
<i>Epidinium graini</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: Please see the full reference list of the article. Bodyse, D. & Dehority, B.A., 2011, 'Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa', *Oversteepoort Journal of Veterinary Research* 78(1), Art. #307, 7 pages. doi:10.4102/ojvr.v78i1.307, for more information.

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Table 1 continues on the next page →



**TABLE 2 (Continues...):** Compilation of the protozoan fauna reported for domestic sheep (*Ovis aries*) from numerous geographical locations around the world. The numbers in each locality refers to the references listed below the table.

Species or form	South Africa	Egypt	Libya	Iceland	Canada	China	Europe	India	Iran	Japan	Pakistan	Russia	Siberia	Turkey	USA	Yugoslavia	Cyprus	Portugal	Alaska	France	USSR	Britain	
<i>f. grainii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. caudatiquadriconatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. caudatricoronaum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Ophryoscolex bicinctus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Ophryoscolex buissonii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Ophryoscolex caudatus</i>	38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Ophryoscolex purkyniei</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. bicoronatus</i>	TS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. bifidobicinctus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. bifidobicinctus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. purkyniei</i>	38	2	-	4	-	24	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. quadricoronaum</i>	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-	-	-	-	
<i>f. tricoronatus</i>	-	-	-	-	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	
<b>Total number of protozoa records per locality</b>	<b>30</b>	<b>19</b>	<b>17</b>	<b>29</b>	<b>35</b>	<b>3</b>	<b>6</b>	<b>25</b>	<b>2</b>	<b>34</b>	<b>6</b>	<b>10</b>	<b>12</b>	<b>4</b>	<b>45</b>	<b>39</b>	<b>49</b>	<b>47</b>	<b>18</b>	<b>10</b>	<b>1</b>	<b>2</b>	<b>1</b>

Note: Please see the full reference list of the article, Booyse, D. & Dehority, B.A., 2011, 'Rumen protozoa in South African sheep with a summary of the worldwide distribution of sheep protozoa', *Onderstepoort Journal of Veterinary Research* 78(1), Art. #307, 7 pages, doi:10.4102/ojvr.v78i1.307, for more information.  
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**TABLE 3:** Protozoa recorded in Bighorn (*Ovis canadensis*) and Dall (*Ovis dalli*) sheep. The numbers in each locality refers to the references listed below the table.

Protozoa listed per host	California	Scotland	Siberia	Alaska
<b>Bighorn sheep</b>	-	-	-	-
<i>Entodinium bicarinatum</i>	-	-	3	-
<i>Entodinium bicaudatum</i> †	1	-	-	-
<i>Entodinium chatterjeei</i>	1	-	-	-
<i>Entodinium exiguum</i> †	1	-	-	-
<i>Entodinium nanum</i> †	1	3	-	-
<i>Entodinium orbicularis</i> †	1	-	-	-
<i>Entodinium truncatum</i>	1	-	-	-
<i>Enoploplastron triloricatum</i> †	1	-	-	-
<i>Metadinium tauricum</i> †	1	-	-	-
<i>Polyplastron californiense</i>	1	-	-	-
<b>Dall sheep</b>	-	-	-	-
<i>Entodinium anteronucleatum</i> †	-	-	-	2
<i>Entodinium bicaudatum</i> †	-	-	-	2
<i>Entodinium constrictum</i> †	-	-	-	2
<i>Entodinium dalli</i>	-	-	-	2
<i>Entodinium nanum</i> †	-	-	-	2
<i>Metadinium tauricum</i> †	-	-	-	2
<i>Polyplastron alaskum</i>	-	-	-	2
<i>Ophryoscolex bicinctus</i> †	-	-	-	2
<i>Ophryoscolex buissoni</i> †	-	-	-	2
<i>Ophryoscolex purkyniei</i> †	-	-	-	-
<i>f. bicoronatus</i> †	-	-	-	2
<i>f. caudatus</i> †**	-	-	-	2
<b>Total number of species and forms</b>	<b>9</b>	<b>1</b>	<b>1</b>	<b>11</b>

†, Protozoa recorded in domestic sheep.

(1) Bush, M. & Kofoed, C.A., 1948, 'Ciliates from the Sierra Nevada bighorn (*Ovis canadensis sierrae* Grinnell)', *University of California Publications in Zoology* 53, 287–261; (2) Dehority, B.A., 1974, 'Rumen ciliate fauna of Alaskan Moose (*Alces Americana*), Musk-Ox (*Ovis moschatus*) and Dall Mountain sheep (*Ovis dalli*)', *Journal of Protozoology* 21, 26–32; (3) Latteur, B., 1969, 'Revision systématique de la Famille des *Ophryoscolecidae* Stein, 1858: sous-Famille des *Entodiniinae* Lubinsky, 1957, Genre *Entodinium* Stein, 1958', *Annales de la Societe Royal Zoologique de Belgique* 99, 3–25.

of both *Epidinium* spp. and *Ophryoscolex* spp. have been redefined and are used in Table 2. The total number of protozoa found in each of the localities indicated in Table 2 is summarised and listed at the end of the table.

Table 3 lists species and forms of protozoa observed in wild Bighorn and Dall sheep in the USA. Bighorn sheep are found in the Rocky Mountains from Colorado to Canada, whilst the Dall sheep live further north, reaching into Alaska. Many of the protozoa found in these two species (10 in Bighorn and 11 in Dall sheep) are also present in domestic sheep. Although not reported from domestic sheep, at least two species have been observed in Turkish cattle, namely *Entodinium dalli*, and a second form, *Entodinium dalli rudidorosospinatum* (Göçmen & Öktem 1996). Of particular interest is the presence of two new species of *Polyplastron*, neither of which has been observed elsewhere.

It is possible that as further in-depth studies are conducted, we will find a somewhat uniform distribution of protozoal species around the world.

## Conclusion

We identified 10 species of rumen ciliate protozoa that had not been previously observed in rumen contents of South



African sheep. This brings the total of species observed in this country to 30. The collection of protozoal fauna in South African sheep was compared to previous data reported for sheep worldwide and appeared to be somewhat less diverse.

## References

- Banerjee, K., 1955, 'Studies on parasitic ciliates from Indian ruminants', *Proceedings of the Zoological Society* 8, 87–101.
- Booyse, D.G., Boomker, E.A. & Dehority, B.A., 2010, 'Protozoa in the digestive tract of wild herbivores in South Africa, I: Warthogs (*Phacochoerus aethiopicus*)', *Zootaxa* 2492, 63–68.
- Bush, M. & Kofoed, C.A., 1948, 'Ciliates from the Sierra Nevada bighorn (*Ovis canadensis sierrae* Grinnell)', *University of California Publications in Zoology* 53, 287–261.
- Coleman, G.S. & Hall, F.J., 1972, 'Fine structural studies on the digestion of bacterial species in the rumen ciliate *Entodinium caudatum*', *Tissue and Cell* 4, 37–38. doi:10.1016/S0040-8166(72)80004-1
- Das Gupta, M., 1935, 'Preliminary observations on the protozoan fauna of the rumen of the Indian goat, *Capra hircus* Linn.', *Archiv für Protistenkunde* 85, 153–172.
- De la Fuente, G., Skirnisson, K. & Dehority, B.A., 2006, 'Rumen ciliate fauna of Icelandic cattle, sheep, goat and reindeer', *Zootaxa* 1337, 47–60.
- Dehority, B.A., 1974, 'Rumen ciliate fauna of Alaskan moose (*Alces Americana*), musk-ox (*Ovis moschatus*) and Dall Mountain sheep (*Ovis dalli*)', *Journal of Protozoology* 21, 26–32.
- Dehority, B.A., 1975, '*Diplodinium (Ostracodinium) minorum* sp.n., ciliate from the rumen of domestic sheep', *Journal of Protozoology* 22, 328–330.
- Dehority, B.A., 1978, 'Specificity of rumen ciliate protozoa in cattle and sheep', *Journal of Protozoology* 25, 509–513.
- Dehority, B.A., 1994, 'Rumen ciliate protozoa of the blue duiker (*Cephalophus monticola*), with observations on morphological variation lines within the species *Entodinium dubardi*', *Journal of Eukaryotic Microbiology* 41, 103–111. doi:10.1111/j.1550-7408.1994.tb01481.x, PMID:8167616.
- Dehority, B.A., 2004, 'In vitro determination of generation times for *Entodinium exiguum*, *Ophryoscolex purkynjei* and *Eudiplodinium maggi*', *Journal of Eukaryotic Microbiology* 5, 333–338. doi:10.1111/j.1550-7408.2004.tb00575.x, PMID:15218703.
- Dehority, B.A. & Potter, E.L., 1974, '*Diplodinium flabellum*: Occurrence and numbers in rumen of sheep with a description of two new subspecies', *Journal of Protozoology* 21, 686–693.
- Dehority, B.A. & Purser, D.B., 1970, 'Factors effecting the establishment and numbers of holotrich protozoa in the ovine rumen', *Journal of Animal Science* 30, 445–449. PMID:5436455
- Dogiel, V.A., 1927, 'Monographie der Familie Ophryoscolecidae', *Archiv für Protistenkunde* 59, 1–288.
- Eadie, J.M., 1957, 'The mid-winter rumen microfauna of the seaweed-eating sheep of North Ronaldshay', *Proceedings of the Royal Society of Edinburgh Series B* 66, 276–287.
- Fantham, H.B., 1920, 'Some parasitic protozoa found in South Africa III', *South African Journal of Science* 17, 131–135.
- Fantham, H.B., 1921, 'Some parasitic protozoa found in South Africa IV', *South African Journal of Science* 18, 164–170.
- Fantham, H.B., 1926, 'Some parasitic protozoa found in South Africa. IX', *South African Journal of Science* 23, 560–570.
- Göçmen, B., 1999a, 'Morphological and taxonomical investigations on the genus of *Ophryoscolex* Stein, 1858 (Protozoa: Ciliophora: Entodiniomorphida)', *Turkish Journal of Zoology* 23, 397–427.
- Göçmen, B., 1999b, 'Morphological and taxonomical investigations on the genus *Epidinium* Crawley, 1923 (Protozoa: Ciliophora: Entodiniomorphida)', *Turkish Journal of Zoology* 23, 429–463.
- Göçmen, B., 2003a, 'The Rumen ophryoscolecid (Entodiniomorphida) ciliate, *Ophryoscolex purkynjei* Stein, 1858 (Sensu Göçmen, 1999) of domestic sheep (*Ovis ammon aries*) from Cyprus', *Türkische Parazitologische Zeitschrift* 27, 273–279.
- Göçmen, B., 2003b, 'Rumen Ophryoscolecid (Entodiniomorphida) ciliate genus *Epidinium* (Crawley, 1923) living in the domestic sheep from Cyprus', *Türkische Parazitologische Zeitschrift* 27, 280–286.
- Göçmen, B. & Gürelli, G., 2009a, 'The occurrence of the rumen ciliate *Entodinium constrictum* Dehority, 1974 (Entodiniidae, Entodiniomorphida) from sheep (*Ovis ammon aries*) in Northern Cyprus', *North-Western Journal of Zoology* 5, 301–306.
- Göçmen, B. & Gürelli, G., 2009b, 'Rumen entodiniid ciliated protozoan fauna (Entodiniomorphida: Entodiniidae) of domestic sheep (*Ovis ammon aries* L.) from Northern Cyprus, with a description of a new species, *Entodinium cypriensis* sp. nov.', *Turkish Journal of Zoology* 33, 169–180.
- Göçmen, B. & Öktem, N., 1996, 'New rumen ciliates from Turkish domestic cattle (*Bos taurus* L.): The presence of *Entodinium dalli* Dehority, 1974 with a new forma, *Entodinium dalli ruditordorsinatum* n. f. and comparisons with *Entodinium williamsi* n. sp.', *European Journal of Protistology* 32, 513–522.
- Göçmen, B., Torun, S. & Öktem, N., 1999, 'A preliminary study on the rumen ciliate fauna of Turkish domestic sheep (*Ovis ammon aries*): Family Ophryoscolecidae (Entodiniomorphida)', *Turkish Journal of Zoology* 23, 473–490.
- Göçmen, B., Dehority, B., Talu, D.H. & Rastgeldi, S., 2001, 'The rumen ciliate ophryoscolecid (Entodiniomorphida) and isotrichid (Trichostomatida) fauna of domestic sheep (*Ovis ammon aries*) from the Turkish Republic of Northern Cyprus', *Journal of Eukaryotic Microbiology* 48, 455–459. doi:10.1111/j.1550-7408.2001.tb00179.x, PMID:11456322
- Grain, J., 1966, 'Etude cytologique de quelques ciliées holotriches endocommensaux des ruminants et des équides', *Protistologica* 2, 59–141.
- Hsiung, T.-S., 1931, 'The protozoan fauna of the rumen of Chinese sheep', *Bulletin of the Fan Memorial Institute of Biology* 2, 29–41.
- Imai, S., Han, S.S., Cheng, K.J. & Kudo, H., 1989, 'Composition of the rumen ciliate population in experimental herds of cattle and sheep in Leithbridge, Alberta, Western Canada', *Canadian Journal of Microbiology* 35, 686–690. doi:10.1139/m89-112, PMID:2504472
- Imai, S., Katsuno, M. & Ogimoto, K., 1979, 'Type of the pattern of the rumen ciliate composition of the domestic ruminants and the predator-prey interaction of ciliates', *Japanese Journal of Zootechnical Science* 50, 79–87.
- Imai, S. & Ogimoto, K., 1978, 'Scanning electron and fluorescent microscopic studies on attachment of spherical bacteria to ciliate protozoa in ovine rumen', *Japanese Journal of Veterinary Science* 40, 9–19. PMID:417206
- Kofoid, C.A. & MacLennan, R.F., 1932, 'Ciliates from *Bos indicus* Linn. II. A revision of *Diplodinium Schuberg*', *University of California Publications in Zoology* 37, 53–152.
- Latteur, B., 1969, 'Révision systématique de la Famille des Ophryoscolecidae Stein, 1858: sous-Famille des Entodiniinae Lubinsky, 1957, Genre *Entodinium* Stein, 1958', *Annales de la Socieite Royal Zoologique de Belgique* 99, 3–25.
- Lee, J.J., Hutner, S.H. & Bovee, E.C., 1985, *An Illustrated Guide to the Protozoa*, Society of Protozoologists, Lawrence.
- Lubinsky, G., 1957, 'Studies on the Evolution of the Ophryoscolecidae (Ciliata: Oligotricha) A new species of *Entodinium* with "caudatum", "lobospinosum" and "dubardi" forms, and some evolutionary trends in the genus *Entodinium*', *Canadian Journal of Zoology* 35, 111–128. doi:10.1139/z57-007
- Marinho, A.A., 1983, 'Protozoários ciliados no rumen de ovinos em pastoreio', *Revista Portuguesa Ciencias Veterinarias* 78, 157–165.
- Moriggi, M., 1941, 'Ricerche sugli infusori dei Ruminanti Italiani', *Archivio Zoologico Italiano Pubblicato Sotto gli Auspicj della Unione* 29, 396–412.
- Ogimoto, K. & Imai, S., 1981, *Atlas of Rumen Microbiology*, Japan Scientific Societies Press, Tokyo.
- Öktem, N., Göçmen, B. & Torun, S., 1997, 'Türkiye evcil koyun (*Ovis ammon aries*)' larının işkembe Siliyat (Protozoa: Ciliophora) Faunası Hakkında Bir Ön Çalışma: I- FAMILYA Isotrichidae (Trichostomatida) ve Entodiniidae (Entodiniomorphida)', *Turkish Journal of Zoology* 21, 475–502.
- Selim, H.M., Imai, S., Yamato, O., El Kabbany, A., Kiroloss, F. & Maede, Y., 1996, 'Comparative study of rumen ciliates in buffalo, cattle and sheep in Egypt', *Journal of Veterinary and Medical Science* 58, 799–801. doi:10.1292/jvms.61.303
- Selim, H.M., Imai, S., Sheik, A.K., Attia, H., Okamoto, E., Miyagawa, E. et al., 1999, 'Rumen ciliate protozoal fauna of native sheep, Friesian cattle and dromedary camel in Libya', *Journal of Veterinary and Medical Science* 61, 303–305.
- Van der Wath, J.G. & Myburgh, S.J., 1941, 'Studies on the alimentary tract of merino sheep in South Africa. VI. The role of infusoria in ruminal digestion with some remarks on ruminal bacteria', *Onderstepoort Journal of Veterinary Science and Animal Industry* 17, 61–85.
- Wertheim, P., 1935, 'Infusorien aus dem Widerkauermagen von Gebiete Jugoslawiens nebs einer Übersicht dieser Tierchen von Balkanhalbinsel Bereich und ein kurzer Bericht über die Pferdedarminfusorien, zugleich Revision der Familie Ophryoscolecidae', *Veterinär Archiv* 5, 386–537.