RUMEN CILIATE FAUNA OF THE SPRINGBOK (*ANTIDORCAS MARSUPIALIS*) IN SOUTHERN AFRICA

R. C. WILKINSON* AND W. VAN HOVEN
Mammal Research Institute, University of Pretoria

ABSTRACT

Springbok were sampled in Angola, South West Africa, the Kalahari, the Cape Province and Eastern Transvaal between July 1973 and July 1974. All the ciliates found in the twenty rumens investigated belonged to a single genus, *Entodinium* (family Ophryoscolecidae). Eight species were identified and two new species are described, *E. kalaharicus* and *E. lucii*.

INTRODUCTION

The importance of rumen micro-organisms in ruminant nutrition has long been recognized (Doetsch & Robinson 1953; Bryant 1959; Hungate 1960). However, most studies have dealt with rumen organisms in domestic animals and until recently little has been known about the kinds and quantities of micro-organisms present in wild ruminants.

Much of the early work has resulted in taxonomical confusion especially in the genus *Entodinium*. This is because the emphasis was laid on external rather than internal characteristics. It has since been shown how much variability occurs in these external characters, especially caudal spination (Lubinsky 1957).

Three species of springbok in Southern Africa were recognized by Ansell (1971):

Antidorcas marsupialis marsupialis (Zimmerman 1780) which is the South African range of the species.
Antidorcas marsupialis hofmeyri (Thomas 1929) which is found in the southern part of South West Africa and Botswana.
Antidorcas marsupialis angolensis (Blaine 1922) which occurs in northern South West Africa and Angola.

Rumen samples were collected from animals shot in all three regions over a period of a year for this study.

The intention of this investigation was to obtain quantitative and qualitative (taxonomic) information about the rumen ciliate fauna of springbok living under natural conditions. The quantitative data on these micro-organisms is required for a better understanding of their exact functions and the reasons for the specific variability found.

*Present address: National Institute of Water Research, CSIR, Box 395, Pretoria 0001.

Zoologica Africana 11(1): 1–22 (1976)

METHODS AND MATERIALS

Samples of rumen fluid from 20 springbok were collected from various parts of the Republic of South Africa, South West Africa, Botswana and Angola between June 1973 and July 1974. The methods used in collecting and treating the protozoa are described in Van Hoven (1974).

Identification of the genera and species of ciliate Protozoa was based mainly on the descriptions of Dehority (1974), Dogiel (1927), Kofoid & Christenson (1934), Kofoid & MacLennan (1930), Latteur (1969), Lu binsky (1957, 1958), Wertheim (1935) and Zielyk (1961).

Drawings of all species were made with the aid of a Zeiss drawing apparatus at 1 000× magnification. Cell measurements were done with a calibrated ocular micrometer.

Terminology used in describing the morphology is according to the system proposed by Lubinsky (1958). This system appears to be the most practical for general usage since the same terms are used for all genera of Ophryoscolecidae. Briefly, if the protozoal cell is orientated with the oral end towards 12 o'clock and with the micronucleus situated to the left of the macronucleus, the right side is towards 3 o'clock and the left side towards 9 o'clock. The body surface closest to the observer is the upper side, while the opposite body surface is termed the lower side.

RESULTS

Only Protozoa of the genus *Entodinium* were found in all the springbok sampled. This is a fact of particular interest since a wide variety of genera usually occur in the rumen of other animals. This relatively unique occurrence has however been observed in the past by Pearson (1965), who found only the genus *Entodinium* present in the rumen of white-tailed deer (*Odocoileus virginianus*) from Texas. U.S.A., and by Dehority (1974), who found the same in the Alaskan moose (*Alces americana*) from the vicinity of Cantwell, Alaska.

Ten species of the genus *Entodinium* were found in this study but one, *E. longinucleatum* Dogiel, 1925, was only found in insignificant numbers in one host animal. The other nine species were well represented in all the springbok sampled (see section on population structure). An account of the various species follows.

Entodinium parvum Buisson, 1923
Figure 1

This species has always been a problem due to frequent confusion with *E. dubardi*, *E. simplex*, *E. nanellum*, *E. exiguum* and *E. ovinum* (Dogiel 1927; Wertheim 1935; Lubinsky 1958; Latteur 1969). This appears to be due to the fact that separation of these species depends mainly on size relationships of both the body and the macronucleus and that both these characters are intraspecifically variable.

Latteur (1969) suggests combining all the species mentioned above under the name *Entodinium furca* du Cunha, 1914, forma *nanellum* Dogiel, 1923, based on the position of the contractile vacuole. This, however, could be very unsatisfactory and may possibly lead to even greater confusion. First, a great deal of variability in the position of the contractile vacuole within a species has been observed in this study. Secondly, the use of the subdivision 'forma' in ciliate taxonomy has already proved very confusing, with the result that work has been done to alleviate the situation by raising many of these forms to subspecies level (Kofoid & MacLennan 1930). Thus it is considered best to adhere as closely as is possible to the division of species given by Dogiel (1927). A point midway between his size and proportion characteristics must be used to divide the species.

Specimens regarded as *E. parvum* were those with an average body length greater than 30 μm, the macronucleus lying close to the anterior end of the body and extending to the beginning

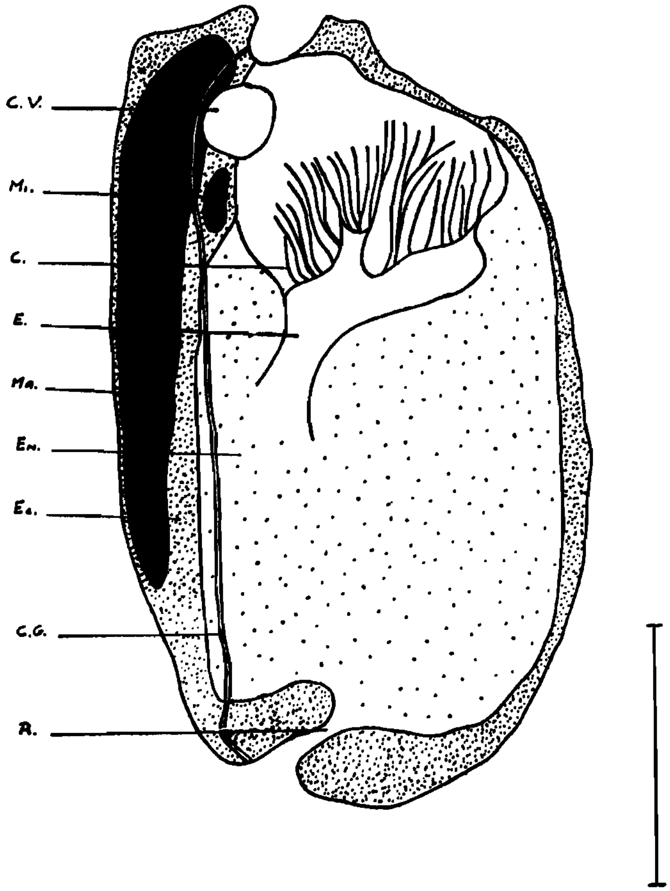

FIGURE 1

Entodinium parvum.

KEY: C.V. Contractile Vacuole, Mi. Micronucleus, C. Cilia withdrawn into oral cavity, E. Esophagus, Ma. Macronucleus, En. Endoderm, Ec. Ectoderm, C.G. Cuticular Groove, R. Rectum. Scale: 10 μm.

of the last third of the body. It differs from *E. ovinum* by the fact that the left and right sides are flat and more or less parallel and the average body length is less than 40 μm.

There are two aspects of the original description of *E. parvum* which have to be revised in the light of evidence from this study:

1. Dogiel (1927) states that the cuticle is smooth with no longitudinal groove. A marked cuticular groove was found in this study, running parallel to and just to the left of the macronucleus from the oral region to the tip of the posterior end on both the upper and lower surfaces.

2. According to Dogiel (1927) the range of body length known was 30–35 μm but he does note evidence of very much larger forms. The mean value in this study was 32,5 μm which concurs (Table 1). However, the range must be extended slightly to include all organisms found in the springbok. The range found was 22,9–43,9 μm. Due to the fact that Dogiel has noted forms larger than the original description only the lower limit of the known size range must be extended down to 22 μm. The lower limit of the range in width must be similarly lowered.

TABLE 1

Dimensions of 10 specimens of *Entodinium parvum* found in the springbok, in μm.

	Body Mean	*Observed limits of variation*	*Macronucleus Mean*	*Observed limits of variation*
Length	32,5	22,9 –43,9	20,2	13,4 –29,6
Width	20,3	13,4 –31,5	3,5	2,9 – 4,9
L/W ratio	1,64	1,18– 2,01	5,84	4,62– 7,79

Entodinium dubardi Buisson, 1923, forma *dubardi* Dogiel, 1925

Figure 2

This species is separated from those similar to it (see *E. parvum*) by the fact that the anterior end of the macronucleus does not adhere closely to the anterior body wall. Thus it only has to be separated from *E. simplex*. Although the length/width ratio lies between that given by Dogiel

(1927) for *E. dubardi* f. *dubardi* (1,5–1,6) and *E. simplex* (1,7–1,74) it is still regarded as *E. dubardi* f. *dubardi* because the distance between the macronucleus and the anterior body wall is relatively great. With respect to this Dogiel (1927) states 'Im Vergleich mit *E. simplex* ist bei *E. dubardi* der abstand zwischen dem vorderen Köperende und dem vorderen Ende des Ma etwas grösser'. This results in the macronucleus of *E. simplex* being generally situated in the anterior half of the body while in *E. dubardi* f. *dubardi* it usually lies midway between the anterior and posterior halves.

Dogiel (1925) found *E. dubardi* to range from 28 to 35 μm long by 18 to 25 μm wide whereas Lubinsky (1958) found 36 to 54 μm long by 24 to 33 μm wide. Thus the mean body measurements found in this study concur with those of Dogiel (1925) but the range must be extended to cover Dogiel (1925), Lubinsky (1958) and the present study. However, due to the fact that in Lubinsky's study on the reindeer (1958) *E. dubardi* f. *dubardi* was present in only one reindeer where it constituted 0,5 per cent of the ophryoscolecid ciliates, his whole range fell right outside that of other workers (Buisson 1923; Dogiel 1925; Fantham 1926). The advisability of extending the range to include his extremes is questionable. The range could be limited to 23–43 μm long and 15–29 μm wide.

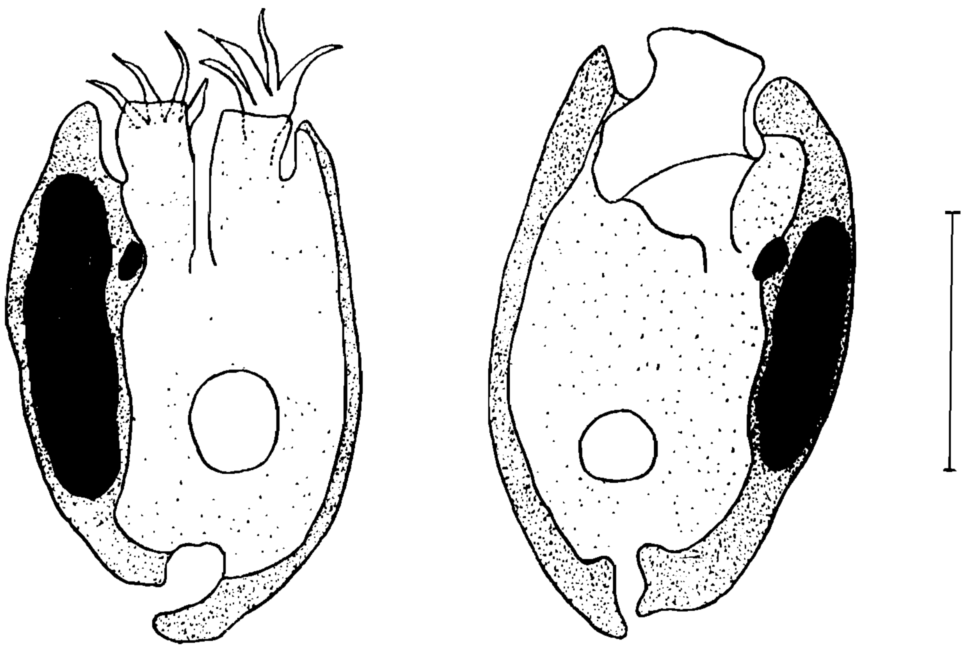

FIGURE 2

Entodinium dubardi f. dubardi. Scale: 10 μm.

TABLE 2

Dimensions of 10 specimens of *Entodinium dubardi* f. *dubardi* found in the springbok, in μm.

	Body Mean	*Observed limits of variation*	*Macronucleus Mean*	*Observed limits of variation*
Length	34,1	23,9 –43,9	18,8	11,5 –30,6
Width	20,6	15,3 –29,6	3,8	2,9 – 7,1
L/W ratio	1,66	1,48– 2,00	5,34	2,68– 8,55

Entodinium longinucleatum Dogiel, 1925
Figure 3

This species, described by Dogiel from reindeer, is very common in cattle, water-buffalo, sheep and goats. It was present in only one of the springbok samples (No. 11) where it constituted 0,3 per cent of the total ciliate population.

Although of little importance to this study due to its insignificant representation in the springbok, it is of interest because it concurs exactly with Dogiel's description except that it is half the size. Where both Dogiel (1925) and Kofoid & MacLennan (1930) found the dimensions to be 44–64 μm long and 29–46 μm wide, this species in the springbok measured 18,5 μm long and 11,2 μm wide. The ratio of length to width is similar to that found by both the above authors.

Entodinium kalaharicus sp. nov.
Figure 4

Diagnosis

The body shape is ovoid with the left side more convex than the right. Posteriorly there are no lobes or spines. The macronucleus is wedge-shaped and the anterior end of it is cleft, giving it a forked appearance.

Description

From above the body is roughly ovoid although the left side is more convex than the right side.

This convexity results in the greatest diameter occurring in the middle of the body although it does not taper markedly either anteriorly or posteriorly. Both left and right body sides are smooth.

The adoral membranelle zone is not slanted, but perpendicular to the longitudinal axis of the body.

A pronounced longitudinal cuticular fold on the right upper surface runs from the base of the outer adoral lip extending from one-third to two-thirds of the body length It does not run parallel to the macronucleus but from left to right across the anterior part of it and ending some distance to the left of it. On the lower body surface there is either no cuticular fold or occasionally

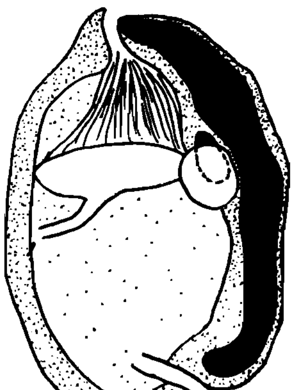

FIGURE 3

Entodinium longinucleatum.

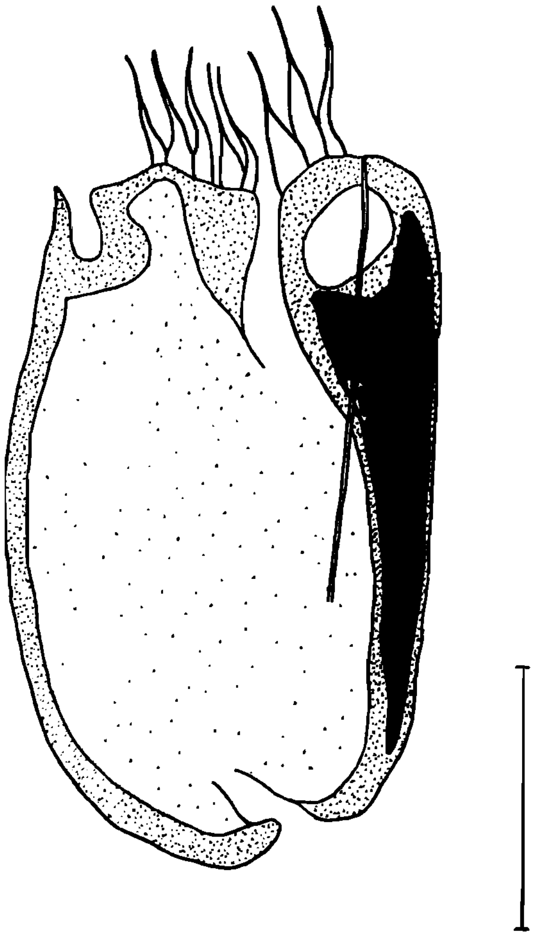

FIGURE 4

Entodinium kalaharicus.

Scale: 10 μm.

a short one which never exceeds one-third of the body length. The posterior end of the cell is rounded and has no caudal appendages.

The macronucleus is closely applied to the right body wall, beginning some distance, i.e. about one-quarter of the body length, from the anterior end of the body. It is wedge-shaped with a very wide anterior end and tapers to a point posteriorly. The anterior end is split by a V-shaped cleft giving the whole wedge a forked to heart-shaped appearance. Its length varies from one-third to two-thirds of the total body length but the width (measured in the middle) does not vary as much, so that the overall shape varies from short and fat to long and narrow. The micronucleus lies, completely obscured, in an indentation in the left side of the anterior part of the macronucleus.

The contractile vacuole lies anterior to the macronucleus.

The oesophagus is inclined slightly towards the macronucleus terminating in the region of the micronucleus.

The endoplasmic sac is bounded by a fairly distinct boundary layer. It is surrounded by a thin layer of ectoplasm which thickens markedly in the region of the anterior end of the macronucleus. The ectoplasm at the posterior end of the body is not thickened, in sharp contrast to most species of this genus. The rectum is a wide tube, slanted at an angle of 45° away from the macronucleus, terminating slightly to the right of the posterior pole of the body.

Measurements of 20 specimens of *Entodinium kalaharicus* taken randomly from samples representing all areas studied are given in Table 3.

TABLE 3

Dimensions of 20 specimens of *Entodinium kalaharicus* found in the springbok, in μm.

	Body Mean	*Observed limits of variation*	*Macronucleus Mean*	*Observed limits of variation*
Length	31,8	25,8 –47,4	19,9	11,9 –30,8
Width	19,9	16,6 –23,7	4,6	3,9 – 6,0
L/W ratio	1,6	1,33– 1,89	4,41	2,53– 6,92

Variation

This species shows morphological variation in only two features – the macronucleus varies considerably in length and proportion. However, as the basic shape remains the same and all the intermediate stages between short and fat, and long and thin are represented this does not appear to be of enough significance to affect species designation.

Occurrence (Figure 12)
Entodinium kalaharicus constituted between 20 and 50 per cent of the total ciliate populations in the rumens 11, 12, 13 and 15. It constituted between 10 and 20 per cent of the populations in samples 7, 14 and 16 and was present in significant numbers in all other samples except 18 and 19 where although present its numbers were low.

Relationships
As far as the shape of the anterior end of the macronucleus is concerned, which is the most distinguishing feature in *E. kalaharicus*, it most closely resembles *E. gibberosum* Kofoid & MacLennan, 1930. However it differs in almost all characteristics, *e.g.* in *E. gibberosum*:

(a) the macronucleus is more convex and not as tapered,
(b) the micronucleus is not imbedded in the macronucleus but lies against the left-hand side of it,
(c) caudal appendages are present and the endoplasmic sac does not penetrate them so that the ectoplasmic layer is considerably thickened in this region,
(d) the oral apparatus is slanted away from the macronucleus.

Entodinium kalaharicus appears to be most closely related to *E. caudatum* Stein, 1859, forma *dubardi* Lubinsky, 1957. Designation as a new species, separate from the above, is based on the following characteristics:

(a) The macronucleus is considerably wider in *E. kalaharicus* having a mean width of 4,6 μm (3,9 μm–6,0 μm) whereas *E. caudatum* f. *dubardi* as found in this study has a mean width of 3 μm (2,4 μm – 4,0 μm). In addition the macronucleus is never as short as it may be in *E. kalaharicus*.

(b) *In E. caudatum* f. *dubardi*:

(i) the micronucleus is not embedded in the macronucleus
(ii) the ectoplasm is thickened posteriorly
(iii) the macronucleus does not have the characteristic cleft of *E. kalaharicus*.

Entodinium alces Dehority, 1974
Figure 5

This species was described by Dehority from the Alaskan moose (*Alces americana*). It was found in all the springbok sampled forming from 0,4 to 20 per cent of the populations.

The body is ovoid, generally widest in the anterior half; the posterior end has two short lobes of appıoximately equal length but these are not as triangular as described by Dehority. The dimensions arɩ slightly smaller than those found in the moose (Tabl͏ɜ 4).

TABLE 4

Dimensions of 10 specimens of *Entodinium alces* found in the springbok, in μm.

	Body Mean	*Observed limits of variation*	*Macronucleus Mean*	*Observed limits of variation*
Length	27,5	23,9 –30,8	14,0	11,5 –16,2
Width	17,8	16,3 –22,0	2,9	1,9 – 4,0
L/W ratio	1,53	1,30– 1,77	4,83	3,26– 7,53

There is a definite difference in the position of the contractile vacuole. Dehority describes it as being situated to the left of the anterior portion of the macronucleus. In this study it was

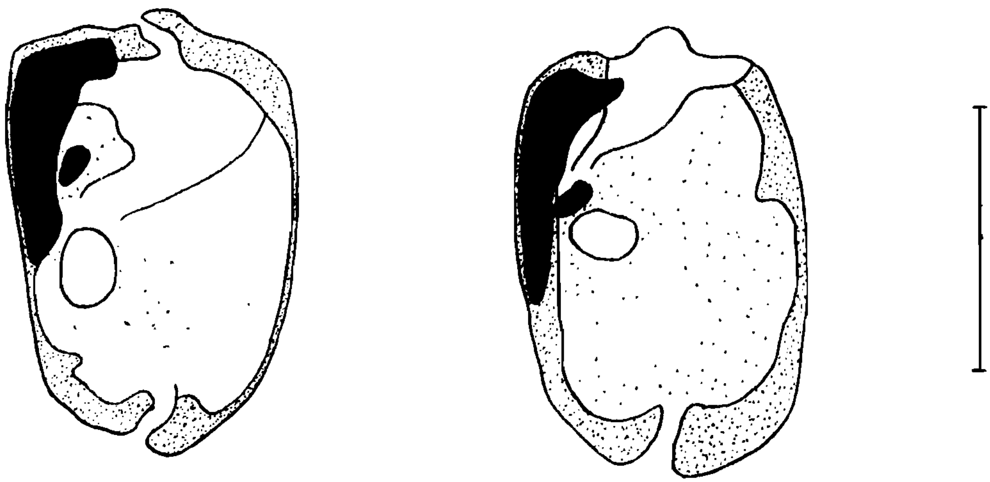

FIGURE 5

Entodinium alces. Scale: 10 μm.

usually found to be situated to the left of the posterior portion of the macronucleus. However, although there is general acceptance amongst workers in this field of the constancy of the position of the contractile vacuole in *Entodinia* (Latteur 1969) it was found in this study that a degree of variability does occur. It does appear as if the region in which the contractile vacuole is situated is limited but the exact position is by no means definitive. In *E. alces* as observed in this study there was a considerable amount of variability about the vacuolar position indicated above and that indicated by Dehority. An examination of over 50 specimens from all the springbok sampled showed a distribution as indicated in Figure 11.

In all other characters this species concurs exactly with Dehority's description of *E. alces* in the moose.

Entodinium caudatum Stein, 1859, forma *dubardi* Lubinsky, 1957
Figure 6

Entodinium caudatum is characterized exclusively on the basis of its caudal spination. However, the taxonomic value of caudal spination became limited when Poljanksy & Strelkow (1938) showed that in *E. caudatum* spination is environmentally plastic. The range of food-induced variability embraces forms of spination, previously believed to be characteristic of different species of this genus.

Lubinsky (1957) showed that in material collected in Pakistan three different species of *Entodinium* with the '*caudatum*' type of caudal spination were present. In each species three

TABLE 5

Dimensions of 10 specimens of *Entodinium caudatum* forma *dubardi* found in the springbok, in μm.

	Body Mean	*Observed limits of variation*	*Macronucleus Mean*	*Observed limits of variation*
Length	32,0	26,1 –40,3	19,2	14,2 –30,8
Width	20,6	16,6 –28,4	3,0	2,4 – 4,0
L/W ratio	1,56	1,42– 1,72	6,57	3,76– 9,88

different types were found showing varying degrees of spination. These are the '*caudatum*', '*loboso-spinosum*' and '*dubardi*' forms, the latter totally lacking caudal spines.

Thus the species found in the springbok material are *E. caudatum* by virtue of their internal characteristics and are classified as forma *dubardi* because of their lack of any caudal spination.

Measurements of 10 individuals from the springbok are given in Table 5 and these concur with those given by Lubinsky (1957) who states, 'the body length varied from 28 to 65 μm, but that of the tailed classes only was from 38 to 65 μm. The tailed individuals were thus on an average slightly larger than the tailless forms. The relation of length to depth varied from 1,1 to 1,7 μm".

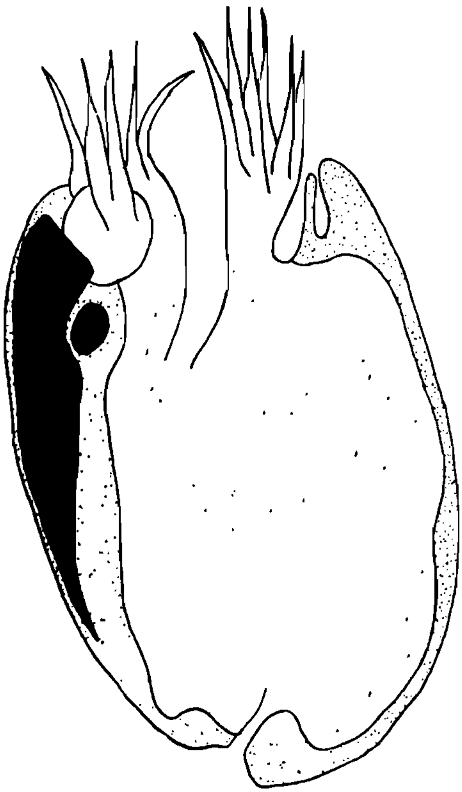

FIGURE 6

Entodinium caudatum f. dubardi.

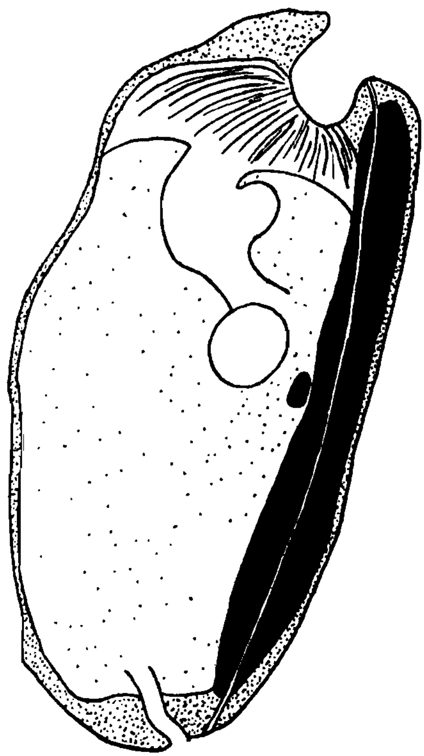

FIGURE 7

Entodinium lucii.

Scale: 10 μm.

Entodinium lucii sp. nov.
Figure 7

Diagnosis

Body is elongated, oval to rectangular. The posterior end is smoothly rounded with no caudal appendages. The macronucleus extends the whole length of the body and is completely straight.

Description

From above, the body is roughly rectangular, sometimes tending slightly to an oval shape. The body is generally elongated, 35 μm long and 19 μm wide with a length to width ratio of 1,88. These measurements were taken from a mean of 20 specimens taken randomly, from all areas sampled and the observed limits of variation are given in Table 6. The left and right body sides are smooth but where the left side is generally parallel to the body axis the right side may be slightly convex. The adoral membranelle zone is slanted slightly toward the maconucleus. There are pronounced longitudinal cuticular grooves on both the upper and lower surfaces. These run from the adoral lip, parallel to and above the macronucleus, extending the entire length of the body. The posterior end of the body has no appendages and is smoothly rounded.

The macronucleus is closely applied to the right body wall extending from the basal region of the adoral lip, down the entire length of the body to the posterior wall of the endoplasmic sac, *i.e.* it does not enter the caudal lobe. It is relatively narrow (3,4 μm) and in length (27,5 μm) is only shorter than the total body length by the length of the adoral lips and caudal lobes.

The micronucleus is situated close to the left of the macronucleus. It lies midway, or slightly anterior to midway, down the length of the macronucleus which generally has a slight indentation in this region.

TABLE 6

Dimensions of 20 specimens of *Entodinium lucii* found in the springbok, in μm.

	Body Mean	*Observed limits of variation*	*Macronucleus Mean*	*Observed limits of variation*
Length	35,3	26,7 –40,3	27,5	20,1 –35,6
Width	18,9	16,2 –23,9	3,4	2,4 – 4,8
L/W ratio	1,89	1,48– 2,18	8,64	4,58–12,13

The contractile vacuole is situated to the left of the middle portion of the macronucleus between it and the longitudinal mid-line of the body.

The oesophagus bends very sharply towards the macronucleus, terminating in the region of the contractile vacuole and anterior to the micronucleus.

The endoplasmic sac does not penetrate the caudal lobes so there is a slight ectoplasmic thickening posteriorly. The rectum is a wide tube terminating slightly to the left of the posterior pole of the body. It is slanted at about 45° away from the macronucleus.

Variation

This species shows very little significant variation in morphologic characters. The contractile vacuole may vary in position from close to the left side of the macronucleus to the midline of the body. The macronucleus was sometimes observed to taper posteriorly. These variations do not, however, appear to be of enough significance to affect species designation. There are no significant variations in the proportions of the body or macronucleus.

Occurrence (Figure 12)

Entodinium lucii constituted 18 per cent of the total ciliate population in the rumen of Sample 9 and between 10 and 15 per cent in Samples 1, 2, 6, 8 and 11. They constituted between 3 and 10 per cent in all the rest of the samples except for Samples 18 and 19 from the Ermelo district. In these they were present in insignificant numbers only.

Relationships

Of previously described species, *E. lucii* appears most closely related to *E. longinucleatum* Dogiel, 1925, *E. parvum* Buisson, 1923, and *E. ovoideum* Kofoid & MacLennan, 1930.

Entodinium lucii is more elongated than either *E. parvum* or *E. longinucleatum* having a length/width ratio of 1,89 compared to *E. longinucleatum* (1,45) and *E. parvum* (1,64). In this respect it is similar to *E. ovoideum* which has a length/width ratio of 1,42–2,10.

Entodinium parvum and *E. ovoideum* are both characterized by the macronucleus lying in the anterior two-thirds of the body whereas in *E. lucii* it extends the full length of the body cavity resembling *E. longinucleatum*.

The macronucleus in *E. longinucleatum* is curved and extends into the left caudal lobe ending close to the rectum. In *E. lucii* it is straight and stops short of the caudal lobe.

In all three of these species the contractile vacuole is situated to the left of the anterior end of the macronucleus while in *E. lucii* it is found to the left of the middle region of the macronucleus.

Entodinium anteronucleatum forma *laeve* Dogiel, 1925

Figure 8

This species as found in the springbok concurs with the description given by Dogiel (1925) and Lubinsky (1958) except that it is smaller in size.

Dogiel (1927) gives the body size of this species as 63 μm (51–80 μm) long by 43 μm (39–49 μm) wide and Lubinsky (1958) observed dimensions of 60 μm (48–72 μm) long by 39 μm (30–45 μm) wide. The average dimensions of 10 specimens from the springbok listed in Table 7 prove them to be about half the size.

The length/width ratio of the body is given by Dogiel as 1,45. Lubinsky found this to be 1,5 (1,1–1,7). These are consistent with the figure of 1,44 found in this study. Lubinsky gives dimensions of the macronucleus as well and from these a length/width ratio of 2,78 can be calculated. This also compares favourably with the ratio of 2,71 found in this study.

As this species concurs in all other features with the original description it cannot be viewed as different to it on the basis of size alone. This is especially so in view of the fact that the proportions are consistent with those of earlier descriptions.

It is thus only necessary to note that the size range of *E. anteronucleatum* f. *laeve* is much wider than originally described.

TABLE 7

Dimensions of 10 specimens of *Entodinium anteronucleatum* f. *laeve* found in the springbok, in μm.

	Body Mean	*Observed limits of variation*	*Macronucleus Mean*	*Observed limits of variation*
Length	30,1	22,9 –43,0	11,4	6,7 –14,3
Width	21,4	13,4 –32,5	4,5	2,4 – 7,1
L/W ratio	1,44	1,20– 1,71	2,71	1,68– 4,96

Entodinium fyferi van Hoven (in press)
Figure 9

This species has recently been described by van Hoven (in press) from the tsessebe (*Damaliscus lunatus lunatus*). Concurrence in the following characters indicate that the species found in the springbok was *E. fyferi*:

(a) the shape of the nucleus with its anterior hook and the protuberance towards the left;
(b) the position of the contractile vacuole;
(c) the longitudinal cuticular folds on both left and right sides terminating in the posterior half of the body;
(d) the large size and the position of the micronucleus;
(e) the fact that the rectum is slanted at an angle of 55° away from the left side;
(f) the position of the oesophagus;
(g) the presence of flanges on both sides.

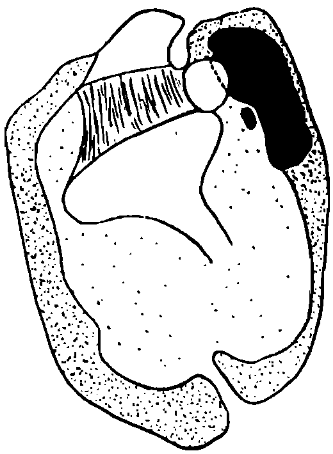

FIGURE 8

Entodinium anteronucleatum.

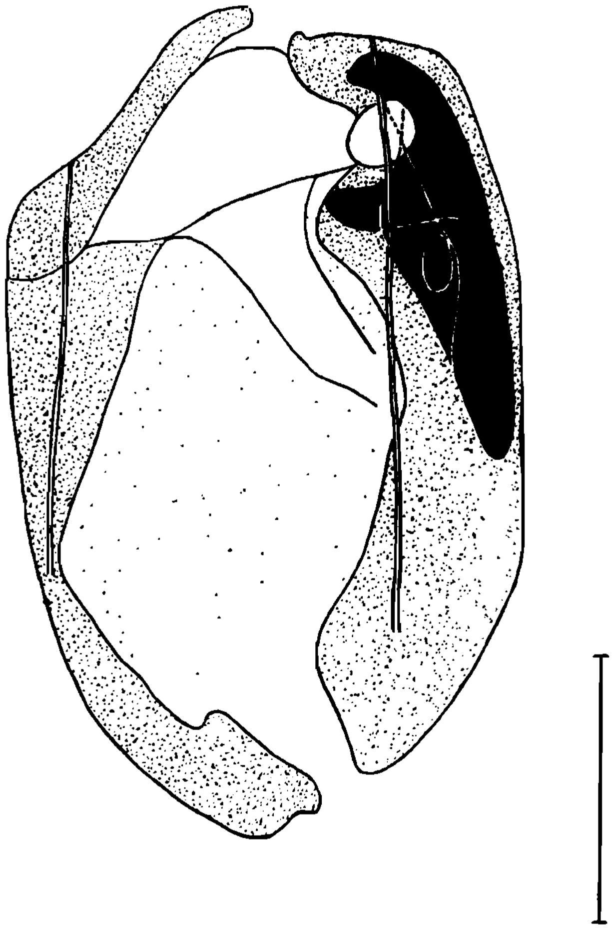

FIGURE 9

Entodinium fyferi.

Scale: 10 μm.

A degree of variation between the specimens observed in this study and those described from the tsessebe was seen. This was, however, not considered sufficient to affect the classification of this species as *E. fyferi*.

These variations are given below as an amendment to the original description:

(a) van Hoven describes the macronuclear protuberance as arising from the posterior half of the macronucleus. It was found in this study to be more anterior.
(b) In the specimens from the springbok the anus opens slightly to the left of the posterior pole. In the tsessebe it was described as opening in the centre of the posterior end.
(c) The original description gives the dimensions of *E. fyferi* as follows:

Length	24,7 μm (20,2–28,8 μm)
Width	20,6 μm (17,1–24,0 μm)
L/W ratio	1,15.

Table 8 gives the dimensions observed in 10 specimens from the springbok taken at random from all areas sampled. These were considerably larger than those found in the tsessebe thus making the size range of *E. fyferi* more in the order of 20,2–43,0 μm long and 17,1–29,9 μm wide.

TABLE 8

Dimensions of 10 specimens of *Entodinium fyferi* found in the springbok, in μm.

	Body Mean	*Observed limits of variation*	*Macronucleus Mean*	*Observed limits of variation*
Length	40,1	39,1 –43,0	20,1	16,6 –26,2
Width	28,7	26,5 –29,9	3,8	2,9 – 6,0
L/W ratio	1,4	1,31– 1,5	5,29	4,15– 5,92

Entodinium bovis Wertheim, 1935
Figure 10

Only one variation from the original description was observed in this species from the springbok. Where Wertheim described the macronucleus as tapering posteriorly, the specimens from the springbok generally had a constant macronuclear diameter for the whole length. The posterior end of the macronucleus was rounded.

Dimensions of ten specimens of *E. bovis* found in the springbok are given in Table 9.

TABLE 9

Dimensions of 10 specimens of *Entodinium bovis* found in the springbok, in μm.

	Body Mean	*Observed limits of variation*	*Macronucleus Mean*	*Observed limits of variation*
Length	32,4	25,1 –40,3	16,6	13,1 –21,4
Width	29,8	21,5 –36,0	3,1	2,9 – 4,0
L/W ratio	1,2	1,13– 1,36	5,38	4,14– 5,92

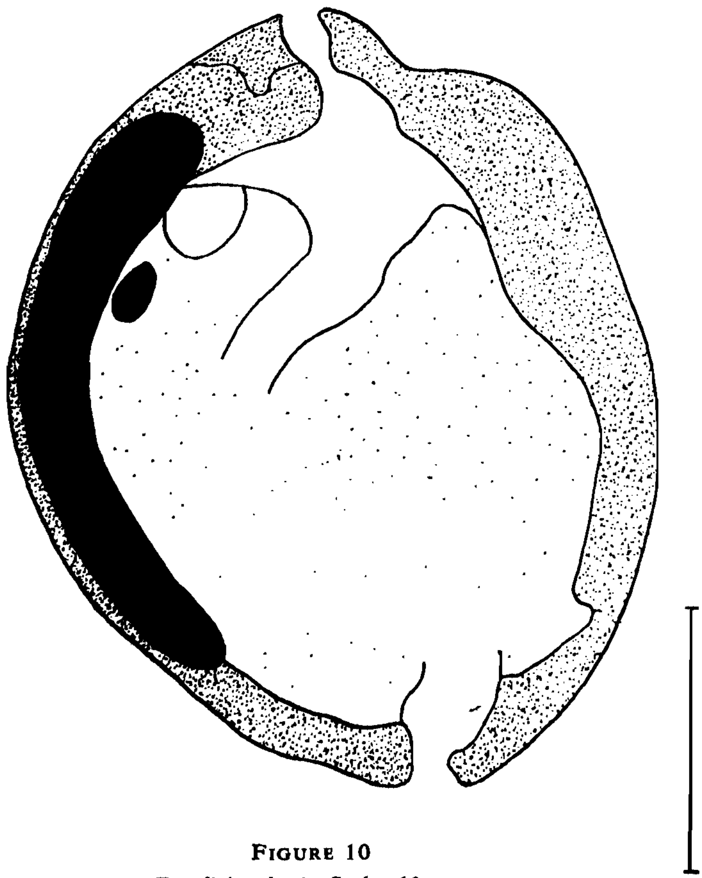

FIGURE 10
Entodinium bovis. Scale: 10 μm.

DISCUSSION

Entodinium is structurally the simplest genus of the family Ophryoscolecidae. Apart from the fact that all ruminal protozoa in the springbok belong to the genus *Entodinium*, only the species devoid of caudal appendages are represented.

Although this '*Entodinium* only' condition was found by Dehority (1974) in the Alaskan moose, both he and Kraschennikow (1955) cite Dogiel (1927) as having found other genera in the moose in an earlier investigation. These included *Ostracodinium*, *Epidinium* and *Eudiplodinium*. This discrepancy could be due to the fact that Dehority's study was done on only three moose sampled at the same time. It has been shown that populations may vary from season to season (Pearson 1965; Westerling 1970).

The investigation of the white-tailed deer (Pearson 1965) and the present study on the springbok both incorporate samples over a longer period and from different areas. Thus the '*Entodinium* only' condition in these animals appears to be constant.

A possible explanation for this condition could be the pH of the rumen contents. According to Hungate (1966) the rumen protozoa are sensitive to acidity and do not survive extended exposure to acidities outside the pH range of 5,5–8,0. However, the *Entodinium* are somewhat

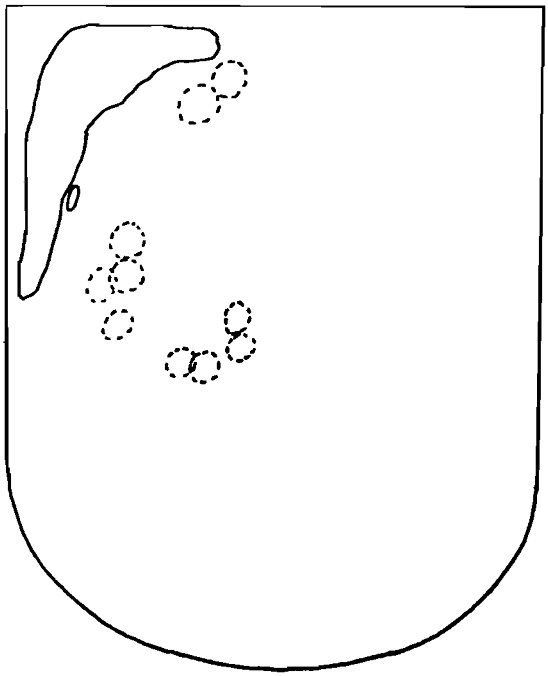

FIGURE 11

A diagrammatic representation of *E. alces* showing the observed positions of the contractile vacuole.

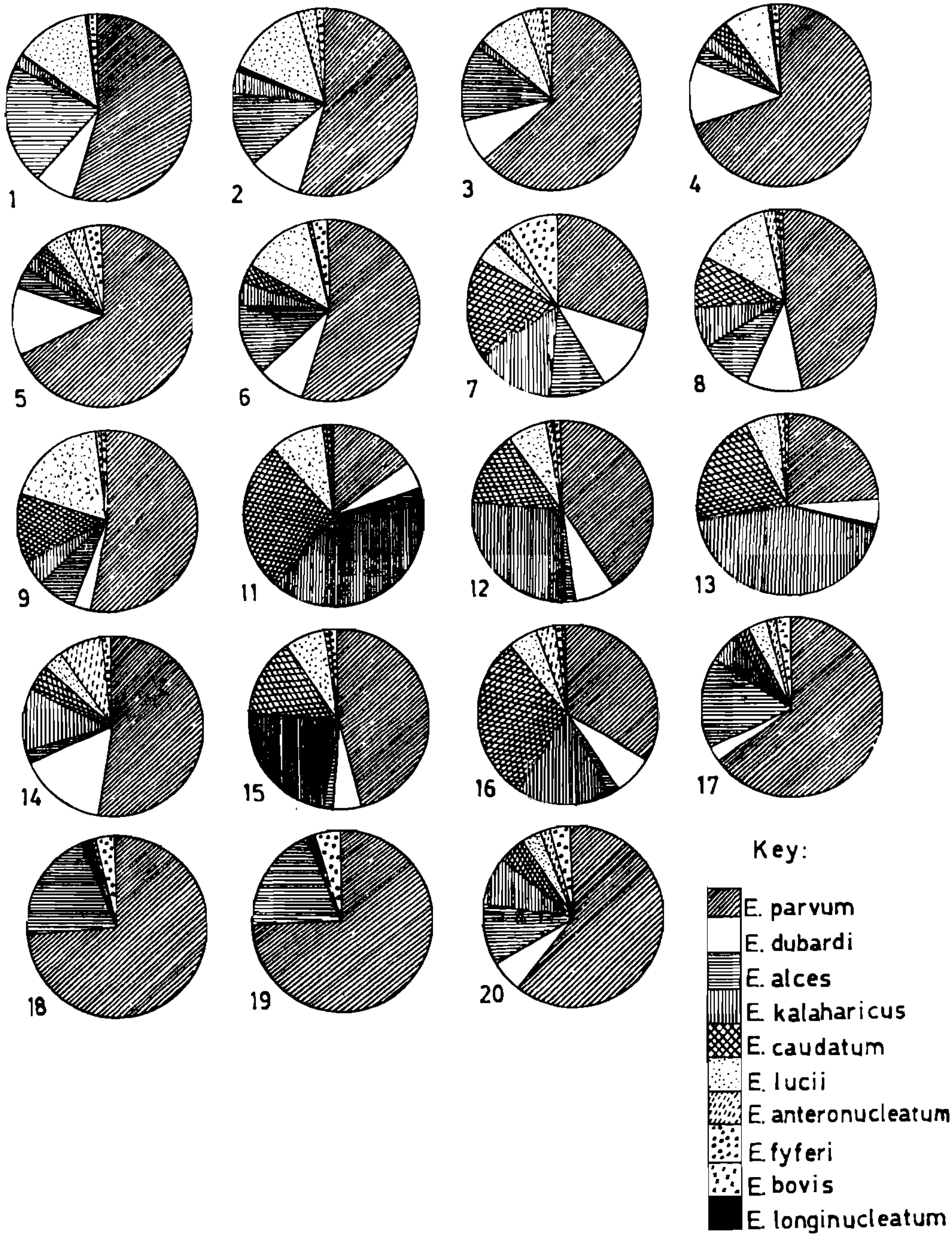

FIGURE 12

Population composition of the ciliate fauna of each sample.

more resistant to acid than are other genera. Thus it is possible that the pH of the rumen contents of the springbok tends towards the limits of the pH range, making it habitable to *Entodinium* only. Unfortunately pH values were not taken in the present study so this point remains speculative.

The lack of caudal appendages can be explained by the extremely low starch values found in the digesta. Lubinsky (1957) found that when animals were fed a low starch diet, forms with reduced caudal spination predominated in the population; when food was rich in starch, forms with well-developed caudal spination became predominant.

Most of the species found in this study which had been previously described had to be revised slightly to incorporate the variations seen in the ciliate fauna of the springbok. Most of the revisions were due to variations in the dimensions of the organisms. The fact that only the smallest species of the entodiniomorphs were represented and that specimens of these species were smaller than has hitherto been observed suggests a correlation with an ecological factor. This is possibly the vegetation type from which the host's food is derived. Hungate (1966) shows that species which ingest starch become swollen with it. Thus the low starch content of the springboks' feed may, to a certain extent, account for the small organisms observed. Hungate's observation that some of the very small species of *Entodinium* do not actively ingest and digest starch suggests that they make use of some other energy source. They would therefore be at an ecological advantage in the relatively starch-free conditions of the springbok rumen. This may be the reason for the success of the small *Entodinia* as opposed to other species in this environment.

ACKNOWLEDGEMENTS

We thank Professor J. D. Skinner and Mr T. Robinson for collecting certain samples. The National Parks Board, Serviços de Veterinária, Angola, and the owners of private nature reserves are thanked for supplying the springbok.

REFERENCES

ANSELL, W. H. F. 1971. Order Artiodactyla. In *The Mammals of Africa: an identification manual*, ed. J. Meester & H. W. Setzer. Washington D.C.: Smithsonian Institution.

BECKER, E. R. & TALBOT, M. 1927. The protozoan fauna of the rumen and reticulum of American cattle. *Iowa St. Coll. J. Sci.* 1: 345–371.

BRYANT, M. P. 1959. Bacterial species of the rumen. *Bact. Rev.* 23:125–153.

BUISSON, J. 1923. *Les infusoires ciliés du tube digestif de l'homme et des mammifères*. Paris: A. Legrand.

DEHORITY, B. A. 1974. Rumen ciliate fauna of Alaskan moose (*Alces americana*), musk-ox (*Ovibos moschatus*) and Dall mountain sheep (*Ovis dalli*). *J. Protozool.* 21:26–32.

DOETSCH, R. M. & ROBINSON, R. Q. 1953. The bacteriology of the bovine rumen. *J. Dairy Sci.* 36:115–142.

DOGIEL, V. A. 1925. Nouveaux infusoires de la famille des Ophryoscolecides parasites d'antilopes africaines. *Ann. Parasit.* 3:116–142.

DOGIEL, V. A. 1927. Monographie der familie Ophryoscolecidae. *Arch. Protistenk.* 59:1–288.

FANTHAM, H. B. 1926. Some parasitic Protozoa found in South Africa. *S. Afr. J. Sci.* 23:560–570.

HUNGATE, R. E. 1960. Microbial ecology of the rumen. *Bact. Rev.* 24:353–364.

HUNGATE, R. E. 1966. *The rumen and its microbes.* New York: Academic Press.

KOFOID, C. A. & CHRISTENSON, J. F. 1934. Ciliates from *Bos gaurus* H. Smith. *Univ. Calif. Publs. Zool.* 39:341–392.

KOFOID, C. A. & MACLENNAN, R. F. 1930. Ciliates from *Bos indicus* Linn. 1. The genus *Entodinium* Stein. *Univ. Calif. Publs. Zool.* 33:471–544.

KOFOID, C. A. & MACLENNAN, R. F. 1932. Ciliates from *Bos indicus* Linn. 11. A revision of *Diplodinium* Schuberg. *Univ. Calif. Publs. Zool.* 37:53–152.

KOFOID, C. A. & MACLENNAN, R. F. 1933. Ciliates from *Bos indicus* Linn. III. *Epidinium* Crawley, *Epiplastron* gen. nov. and *Ophrysoscolex* Stein. *Univ. Calif. Publs. Zool.* 39:1–34.

KRASCHENINNIKOW, S. 1955. Observations on the morphology and division of *Eudiplodinium neglectum* Dogiel (Ciliata Entodimomorpha) from the stomach of a moose (*Alces americana*). *J. Protozool.* 2:124–134.

LATTEUR, B. 1969. Revision systematique de la famille des Ophryoscolecidae Stein, 1898 sous-famille des Entodiniimae Lubinsky, 1957 genre *Entodinium* Stein, 1858. *Annls. Soc. r. zool. Belg.* 99:1–41.

LUBINSKY, G. 1957. Studies on the evolution of the Ophryoscolecidae (Ciliata: Oligotricha). 1. A new species of *Entodinium* with 'caudatum', 'loboso-spinosum' and 'dubardi' forms, and some evolutionary trends in the genus *Entodinium*. *Can. J. Zool.* 35:111–133.

LUBINSKY, G. 1958. Ophryoscolecidae (Ciliata: Entodiniosmorphida) of reindeer (*Rangifer tanandus* L.) from the Canadian Arctic. *Can. J. Zool.* 36:819–835.

PEARSON, H. A. 1965. Rumen organisms in white-tailed deer from South Texas. *J. Wildl. Mgmt.* 29:493–496.

POLJANSKY, G. & STRELKOW, A. 1938. Etude experimentale sur la variabilité de quelque Ophryoscolecides. *Archs. Zool. exp. gén.* 80:1–123.

VAN HOVEN, W. 1974. Ciliate protozoa and aspects of the nutrition of the hippopotamus in the Kruger National Park. *S. Afr. J. Sci.* 70:107–109.

WERTHEIM, P. 1935. A new ciliate, *Entodinium bovis* sp. n. from the stomach of *Bos taurus* L., with the revision of *Entodinium exiguum*, *E. nanellum*, *E. simplex*, *E. dubardi* and *E. parvum*. *Parasitology* 27:226–230.

WERTHEIM, P. 1937. La faune des infusoires de l'estomac des ruminants domestiques dans le Jardins Zoologiques. *Annls Parasit. hum. comp.* 1937:248–252.

WESTERLING, B. 1970. Rumen ciliate fauna of semi-domestic reindeer (*Rangifer tarandus* L.) in Finland: composition, volume and some seasonal variations. *Acta zool. fenn.* 127:1–75.

ZIELYK, M. W. 1961. Ophryoscolecid fauna from the stomach of the white-tailed deer (*Odocoileus virginiancus borealis*), and observations on the division of *Entodinium dubardi* Buisson 1923 (Ciliata: Entodiniomorpha). *J. Protozool.* 8:33–41.