THE INTESTINAL PROTOZOA OF THE GUINEA-PIG*

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INTRODUCTION

The domestic guinea-pig, or cavy, **Cavia cobaya** Pallas, 1766, has been a household pet and laboratory animal throughout the civilized world for so long that its ancestry is uncertain. It was introduced from South America into Europe soon after the discovery of the Western Hemisphere and was known to the naturalist Gesner (1551). Leunis (1860) recognized nine species of guinea-pigs, including five extinct ones and four living species. These latter include the wild guinea-pig of Brazil, **Cavia aperea** (the aperea or preá); the domestic guinea-pig of Brazil, **C. porcella** (cobaio); the guinea-pig of Peru, **C. cutleri,** which was domesticated by the Incas, and the cosmopolitan **C. cobaya** (cobayo, conejillo de Indias, cobaye, cochon d'Inde, Meerschweinchen). Most naturalists regard **C. porcella** as the ancestral stock from which **C. cobaya** was derived, although Brehm (1890) considered **C. cutleri** to be the more probable antecedent.

Closely related rodents of the family Caviidae are the capybara **(Hydrochoerus capybara),** the agouti **(Dasyprocta aguti),** the mara **(Dolichotis patagonica)** and the paca **(Coelogenys paca).** Like the guinea-pigs, all of these animals are indigenous to South America.

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A considerable number of internal parasites have been described for the guinea-pig. Some of these were undoubtedly autochthonous to the animal in its wild state and appear to be relatively specific for the genus **Cavia.** Others have been acquired under conditions of domestication. Still other microörganisms described as parasites are probably not true parasites but are coprozoic organisms capable of living temporarily in the digestive tract of the guinea-pig and other vertebrates. Finally, the guinea-pig has been found to be a susceptible laboratory host for several parasitic helminths and a few protozoa which are normally parasitic in man, simians and other domestic animals.

During an investigation of the parasite-host relationship of **Endamoeba histolytica** of human origin in the guinea-pig (Carrera and Faust, 1949) a number of intestinal protozoa were encountered and studied. This lead to a survey of the species of parasitic protozoa described for this host. As a result of this undertaking it has seemed worthwhile to record the accumulated information in word and picture, since it is not readily available to the average worker.

The Protozoa of the Guinea-Pig's Digestive Tract

Four Class groups of Protozoa have been found in the digestive tract of the guinea-pig, viz., Rhizopoda, Mastigophora, Ciliata and Sporozoa. The species belonging to each group will be considered in the above-named sequence.

RHIZOPODA

This Class is represented by **Endamoeba cobayae** and **Endolimax caviae.**

Endamoeba cobayae (Walker, 1908) Holmes, 1923

Endamoeba cobayae was described by Walker (1908) from the intestinal tract of **Cavia cobaya** and has been considered subsequently by Chatton (1917), Leger (1918), Holmes (1923), Hegner and Taliaferro (1924) and Wenyon (1926). The sparceness of the records suggest that it is not a common parasite, although in small numbers

it may have been overlooked. The normal habitat of the trophozoite, like that of **Endamoeba coli** of man, is the lumen of the cecum. There is no evidence that this ameba is pathogenic or is a tissue invader.

The trophozoite of **E. cobayae,** as studied by the present investigator (Fig. **1 a**), corresponds for the most part to Walker's original description: "Amoeboid stage circular in outline when at rest, oval, oblong, ligulate, less frequently irregular when in motion; 15.5-25 microns in diameter in the resting condition; pseudopodium normally single, lobose; ectoplasm hyaline, extensive; entoplasm coarsely granular; nucleus circular in outline, but plastic, surrounded by a hyaline halo, otherwise homogeneous; a single contractile vacuole". The nucleus is almost an exact counterpart of that of **E. coli.**

In the cecal feces the active organism feeds on bacteria of various types. The vegetative stage grew in **Endamoeba histolytica** culture medium in our laboratory for 24 to 48 hours, but died out on subculture.

Holmes (1923) made a special study of the encysted stage, which he found to vary in size from 11 to 17 microns diameter (average 14 microns). Walker's cysts ranged from 7.5 to 14 microns. This stage is spherical or somewhat subspherical, has coarsely granular cytoplasm and one to eight nuclei, each with a relatively large eccentric karyosome and relatively coarse marginal chromatin. Some cysts have a large glycogen vacuole (Fig. **1 b**), while others appear to be glycogen-free (Fig. **1 c**). The chromatoidal bodies differ from those of **E. histolytica** and **E. coli,** in that they are rather broad, short, compact bundles of chromophilic filaments with rounded or squarish ends, and at times have a slight constriction towards their mid-longitudinal plane. The writer has seen mature cysts in the cecal feces, as has Holmes (l. c.), who at times also recovered "fair numbers of cysts" from feces collected from the guinea-pig's cages. Walker (l.c.) reported that cysts developed early in his cultures.

Holmes l.c) was unable to infect white rats with **E. cobayae,** either by exposure of the rats to evacuated cysts or by introducing trophozoites directly into the cecum, and concluded that the rat was not a susceptible host.

Endolimax caviae Hegner, 1926

This species was described by Hegner from trophozoites obtained from two laboratory guinea-pigs, in association with **Endamoeba cobayae,** trichomonads, ciliates and Blastocystis. The level of the

intestine from which they were recovered was not recorded, but there is considerable likelihood that they were from the cecal area. The organisms (Fig. **2 a-d**) were identical with the common **E. nana** of man except for their smaller size, i.e., 5.5 to 6.6 microns vs. 8 microns average. No cysts were seen.

The present investigator is inclined to regard these organisms as **E. nana** resulting from the guinea-pig's exposure to human excreta containing cysts of this ameba. The smaller size can possibly be explained on the basis of a somewhat unfavorable environment in an abnormal host. He does not regard size **per se**, or recovery of the organism in a host different from the type host, as sufficient warrant for erecting a new species.

MASTIGOPHORA

This Class is represented by the following species; **Chilomastix intestinalis, Trichomonas caviae, T. flagelliphora, Eutrichomastix caviae, Enteromonas caviae, Embadomonas intestinalis, Oikomonas termo, Sphaeromonas communis, Spiromonas angusta, Globomonas parasitica, Chilomitus caviae, Selenomonas ruminantium** and **Giardia caviae.**

Chilomastix intestinalis Kuczynski, 1914

This organism is rather common in domestic guinea-pigs and is frequently found in greatest abundance in the cecal feces. **C. intestinalis** (Fig. **3a, 3b**) conforms closely to the characteristics of the genus **Chilomastix** Alexeieff, 1912. The body is generally pyriform. It possesses an anterior vesicular nucleus, three anterior flagella, a large cytostome which is narrowly dumbbell-shaped and contains internally a fourth flagellum, a pair of fibrous filaments which encompass the cytostome, and a group of blepharoplasts which are medial in position between the anterior face of the nucleus and the anterior margin of the organism and constitute the sites of origin of the motor organelles. The cyst is symmetrically pyriform to lemon-shaped.

The trophozoites studied by the present investigator varied in size from 20 x 15 microns to those which were less than half these dimensions. As in **C. mesnili**, the trophozoite is posteriorly twisted on its axis but in fresh, living material from the cecum of the guinea-pig the torsion

was found to be confined to the posterior tip, whereas in **C. mesnili** a posterior tongue-like extension may be nearly as long as the anterior rounded part or may be completely absorbed into he latter. Moreover, the cyst of the guinea-pig **Chilomastix** (Fig. **3b**) has a much thicker wall than that of **C. mesnili.** This is one of the few types of cysts which has been observed by the writer in evacuated guinea-pig's feces.

In commenting on the many specific names given to **Chilomastix** in different host species, Wenyon (1926) states that "it is very doubtful if they can be distinguished from one another." However, the present study indicates that at least **C. intestinalis** can be readily differentiated from **C. mesnili** on the basis of its shape and the thickness of its cyst wall.

Trichomonas caviae Davaine, 1875

All species of **Trichomonas** in the active stage are characterized by having a contour which is oval or biconvex, a relatively narrow, crescentic cytostome, an anteriorly disposed vesicular nucleus, a semi-rigid axostyle which extends through the axis and frequently protrudes beyond the posterior margin of the ectoplasm, three to five free flagella arising from the blepharoplast at the anterior end, an undulating membrane originating at the blepharoplast and extending down one side of the organism, with an additional flagellum on the margin of the undulating membrane, and an axoneme (or costa) within the ectoplasm, paralleling the undulating membrane.

T. caviae is a relatively common parasite of the domestic guinea-pig. In an examination of 41 animals the writer found it in 13, or approximately 32 per cent. When present its most common habitat is the cecum, in which it may be large (22 x 15 microns) and very active, or dwarfed (4 x 1.5 microns) and relatively inactive. The anterior flagella are typically three in number and subequal, while the free extension of the fourth flagellum, posterior to its attachment to the undulating membrane, is typicaly not greater than the posterior protrusion of the axostyle. The nucleus is characteristically ovoidal (Kuczynski, 1914; Wenyon, 1926; present study, fig. **4a).** Not infrequently the undulating membrane is lacking and in this condition the active **Trichomonas** is easily confused with **Eutrichomastix (vide infra).** As in a few other species of this genus, but not those producing human infection, encystation occurs in **T. caviae.** The organism retracts its free flagella and undulating membrane, coils on itself and secretes a thin, firm, hyaline cyst wall which is spherical in outline (Fig. **4b).**

Trichomonas flagelliphora Faust, 1921

This organism has been observed only once, when the writer found myriads of very active trophozoites in the ileum and cecum of a laboratory guinea-pig at autopsy in Peking, China (Faust, 1921). The diagnostic features of this species (Figs. **5a, 5b)** are the spherical nucleus, the greater length of one of the three anterior flagella, the characteristic protrusion of the axostyle for a considerable distance beyond the posterior end of the organism's cytoplasm and the long, trailing flagellum beyond the posterior attachment of the undulating membrane. As in **T. caviae,** the undulating membrane and its associated flagellum may be lacking in **T. flagelliphora;** or the membrane and flagellum may be partly or completely free of attachment except at the site of insertion. No cysts were discovered in examination of this material.

Eutrichomastix caviae (Grassi, 1882)

Species of this genus resemble **Trichomonas** except that they lack an undulating membrane, so that the long, posteriorly directed flagellum is free and trailing. Several species have been described, including those from the intestine of insect larvae, fishes, snakes, turtles, lizards and frogs, birds and several species of mammals.

E. caviae was originally described by Grassi (1882) from the cecum of the guinea-pig, and later by Yakimoff, Wassilewsky, Korniloff and Zwietkoff (1921) from the same species of host. Meanwhile da Fonseca (1916) recorded this parasite from **C. porcella,** as well as from the wild guinea-pig **(C. aperea)** and the agouti **(Dasyprocta aguti)** in Brazil. The trophozoite (Fig. 6) is elongated pyriform in outline, has three subequal anterior flagella and a long, trailing posterior flagellum, and looks like a small, compact **Trichomonas** without an undulating membrane. Cysts have been described for several species of **Eutrichomastix** but apparently have not been reported for **E. caviae.**

Enteromonas caviae Lynch, 1922

Species of the genus **Enteromonas** are characterized by their globular contour, a small spherical nucleus near the anterior end, no apparent cytostome, an axoneme between the nucleus and the anterior face of the organism terminating in a blepharoplast, and three free flagella originating from the blepharoplast.

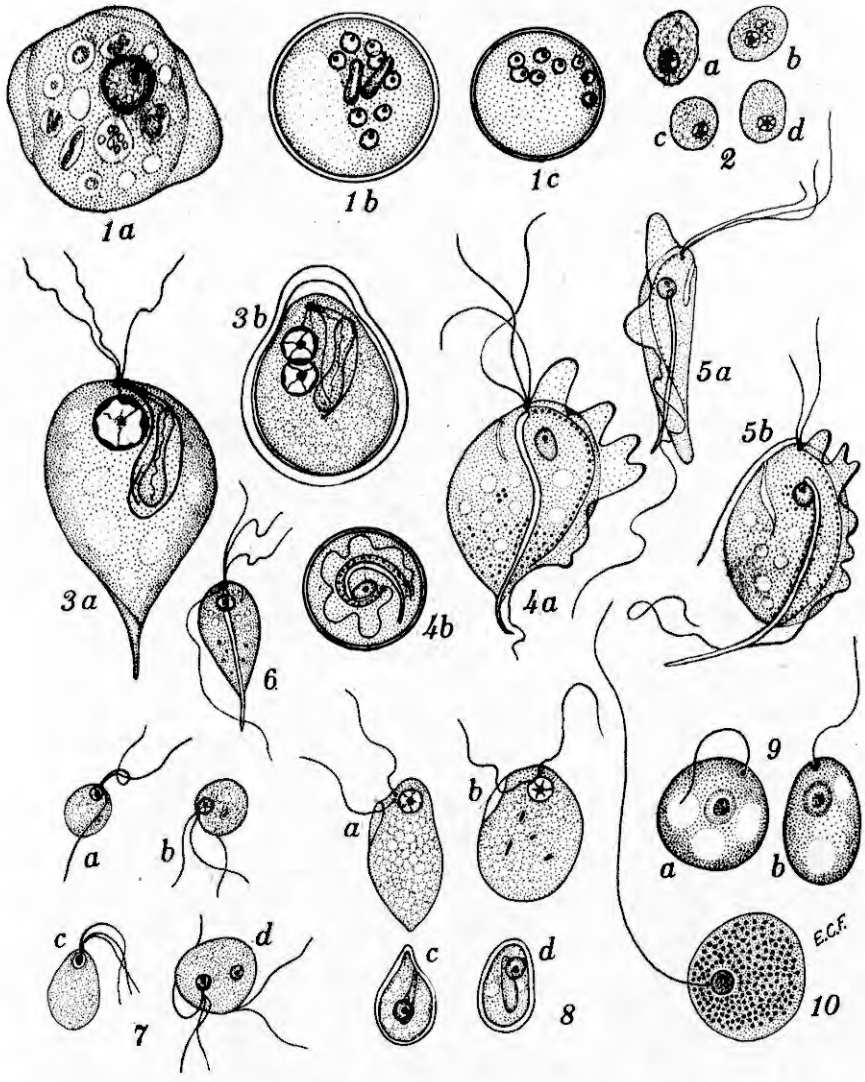

PLATE I. 1. **Endamoeba cobayae. a,** trophozoite, **b, c,** mature cysts. × 1160. (Original.) 2. **Endolimax caviae. a-d,** trophozoites. × 1160. (Adapted from Hegner.) 3. **Chilomastix intestinalis. a,** trophozoite; **b,** cyst. × 1740. (Original.) 4. **Trichomonas caviae. a,** trophozoite; **b,** cyst. × 1740. (Original.) 5. **Trichomonas flagelliphora. a, b,** trophozoites in different phases of activity. × 1740. (After Faust.) 6. **Eutrichomastix caviae,** trophozoite. × ca. 1740. (Adapted from da Fonseca.) 7. **Enteromonas caviae. a-d,** trophozoites in different phases of activity. × ca. 1740. (Adapted from Lynch.) 8. **Embadomonas intestinalis. a, b,** trophozoites; **c, d,** cysts. × ca. 1740. (Adapted from Wenyon and O'Connor, Jepps, and Hegner and Taliaferro.) 9. **Oikomonas termo. a, b,** trophozoites. × ca. 1740. (Adapted from Martin, in Wenyon.) 10. **Sphaeromonas communis,** trophozoite. × ca. 1740. (Adapted from da Fonseca.)

Lynch (1922) has described **E. caviae** from the domestic guinea-pig (cecum?). It closely resembles **Tricercomonas,** but differs specifically in that the posteriorly-directed flagellum is definitely unattached (Fig. **7a, b)** and at times (Fig. **7c)** is associated with the two anterior flagella. Multiplication is by longitudinal binary fission (Fig. **7d).** Yakimoff (1925), apparently unaware of Lynch's publication, named the species found in the guinea-pig **E. fonsecai,** but this must be considered a synonym of **E. caviae.** Moreover, it is not improbable that the species found in the guinea-pig is identical with that reported from man, in which case its correct designation would be **Enteromonas hominis** da Fonseca, 1915.

Embadomonas intestinalis (Wenyon and O'Connor, 1917) Chalmers and Pekkola, 1918

Species of the genus **Embadomonas** vary in shape from elongated pyriform to subspherical. There is a vesicular nucleus in the anterior, slightly enlarged portion of the body, lateral and slightly posterior to which is a relatively conspicuous cytostome. There are two blepharoplasts near the nuclear membrane, and from each of these there arises a single flagellum.

Embadomonas intestinalis is a relatively common parasite recovered from human feces in various parts of the world. It varies considerably in shape and size but is generally pyriform to ovoidal, with a slight concavity on one side just behind the nucleus and a cytostomal convexity on the opposite side (Figs. **8a, 8b).** One of the two flagella is directed anteriad while the one which arises more posteriorly appears to emerge through the cytostome. Cysts of this organism (Figs. **8c, 8d)** may be pyriform or irregularly ovidal. Wenyon (1926) states that "a form identical in every way with **E. intestinalis** was seen by the writer in the caecum of a guinea-pig which had been sent to Macedonia from Egypt in 1918, while he has cultivated the flagellate on three occasions from guinea-pigs, and once from a wild rat in England".

Wenrich (1932) considers that the appropriate generic name for **E. intestinalis** is **Retortamonas** Grassi, 1879.

Oikomonas termo (Ehrenberg, 1838)

Species of the genus **Oikomonas** have a globoidal or regularly ovoidal body, a nucleus with a large, densely-staining karyosome, a

blepharoplast nearby, and a single flagellum which has its origin in the blepharoplast. The organism typically occurs in stagnant water and in contaminated feces, conjugates and encysts.

Liebetanz (1910) created the species **O. communis** and **O. minima** for certain forms recovered from the rumen of cattle. Yakimoff, Wassilewsky, Korniloff and Zwietkoff (1921) isolated **O. termo** from agar plates after inoculation with feces of the guinea-pig and of mice. The free-living forms recovered from soil have been studied by Martin (1912) and are illustrated in figs. **9a** and **9b.**

Sphaeromonas communis Liebetanz, 1910

Species of this genus, as defined by Liebetanz, 1910, have a globoidal, oval or pyriform body, a non-vesicular, dense nuclear mass, a single, long flagellum arising from near the nucleus, and many densely-staining granules in the cytoplasm. Liebetanz (l.c.) created three species **(S. communis, S. minima** and **S. maxima),** which are probably identical and should be resolved into the first species named, i.e., **S. communis.** Da Fonseca (1916) has reported finding this organism in cattle, goats and **Cavia porcella** in Brazil (Fig. 10), while Yakimoff, Wassilewsky, Korniloff and Zwietkoff (1921) record this same flagellate in the guinea-pig under the name **S. rossica.**

Spiromonas angusta (Dujardin, 1841)

Species of this genus are typically elongated oval, with a counterclockwise spiralling of the body up to 720 degrees; but they may be elongated without torsion, ovoidal, pyriform or subspherical. A vesicular nucleus is found in the anterior third of the body. From the anterior aspect of the nuclear membrane an axoneme extends up to the small, distinct cytostome, which lies on one side near the anterior extremity of the body. Two thread-like flagella arising from a twinned blepharoplast extend through the cytostome as free locomotor organelles. **Spiromonas** is usually an inhabitant of stagnant fresh water.

The species **S. angusta** (Fig. **11a-f)** has been studied from cultures of goat's and pig's feces. In the latter material Wenyon (1926) has described encystation, with division of the nuclei and then of the entire organism into two or even four daughter organisms.

The writer has apparently for the first time found **S. angusta** as a parasite of the guinea-pig. It was identified in 26 of 41 animals studied

(approximately 63 per cent). The organisms varied in size from 20 x 4 microns to dwarfed forms not over 5 microns in length. They were always of the elongated spiral type, usually very active and most abundant in cecal feces. Encystation was never observed, even in hard-formed fecal pellets in the rectal portion of the intestine. At times thousands of very active organisms were present in a single coverglass preparation of diluted cecal feces. Only occasionally were they present in the terminal ileum. It would seem, therefore, that this organism can adjust itself to endoparasitism, although its presence, even in almost uncounted numbers, produces no demonstrable irritation to the intestinal mucosa.

Globomonas parasitica da Fonseca 1918

Da Fonseca (1918) created the genus **Globomonas** for a minute globoid protomonad with two equal, anterior flagella, designated as **G. parasitica,** which he found in the cecal feces of **C. porcella** in Brazil. The organism is described as regularly spherical, 3-5 microns in size, without trace of axostyle or cytostome. The nucleus lies near the flagellar pole, contains a comparatively large, dense karyosome and is surrounded by a halo. The two flagella, which are of equal length and are somewhat longer than the diameter of the organism, arise from a single distinct blepharoplast situated just within the limiting membrane of the organism. (See fig. **12.**)

Chilomitus caviae da Fonseca, 1915

This genus was created by da Fonseca (1915) for the species **caviae,** recovered from the cecum of **Cavia porcella** and **C. aperea** in Brazil. The body is described as elongated, with a rigid periplast, a sac-like cytostome on one side of the anterior end, a non-vesicular, anteriorly disposed nucleus composed of a mass of granules, and four equal flagella arising from a common center between the nucleus and cytostome and emerging through the latter organelle. (See fig. **13.**) **C. caviae** is stated to be dimorphic, a longer form measuring 12-17 x 4 microns and a shorter form measuring 8-10 x 4-5 microns. There is no description of cyst formation.

Monocercomonas caviae da Cunha and Muniz, 1921

Species belonging to this genus are small, globoidal, ovoidal or pyriform protomonad flagellates, possessing two pairs of flagella,

each pair (?) arising from a distinct blepharoplast near the anteriorly situated nucleus, and, in addition, a filamentous axostyle. Da Cunha and Muniz (1921) state that their species, found in the cecum of **Cavia porcella,** is at times rounded, at other times pyriform or slightly elongated, varying in size from 4 x 3 microns to 8 x 7 microns. No cytostome has been observed. The nucleus, which is in the anterior part fo the body, is rounded or ovoidal and has a centrally-placed karyosome and peripheral chromatin lining the nuclear membrane. There are four flagella of equal length, from one to one and one-half times the body length. They arise from blepharoplasts grouped in pairs, and at times the blepharoplasts of the same pair appear as a single basal body. From one of the two blepharoplast pairs there arises a chromophilic filament (axostyle), which passes around the nucleus and extends to the posterior end of the organism. (See fig. **14.**) Rounded organisms without evident flagella and axostyle have been interpreted as cysts.

Selenomonas ruminantium (Certes, 1889) von Prowazek, 1913

Species of this genus are characterized by having a rigidly crescentic body measuring 6.8-9.1 x 1.8-2.3 microns, and a bunch of several flagella arising from the hollow on the ventral side of the crescent, near which is a deeply stained mass (nucleus?). (Fig. **15**). There is considerable likelihood that **S. palpitans,** described by Simons (1921) from the cecum of guinea-pigs, is identical with **S. ruminantium,** originally described from the rumen of cattle by Certes (1889). Da Fonseca (1915) identified this parasite from **C. porcella** and **C. aperea** and da Cunha (1915) from **C. porcella** in Brazil, while Boskamp (1922) has studied its structure and biology. However, there is much to be learned about this organism and its host relationships.

Giardia caviae Hegner, 1923

The genus **Giardia** is relatively unique morphologically and its characteristics are sufficiently understood, so that no generic description is required in this account. Hegner (1923) described **G. caviae** as a distinct species on the basis of the size and shape of the trophozoite (mean length, 10.7 microns; mean breadth, 7.2 microns), with its greatest breadth across the center of the lateral shields, and the pair of long, slender parabasal bodies (as distinguished from the

ovoidal shape of these bodies in **G. muris),** situated dorsal to the axostyles but oblique in position with reference to the dorso-ventral plane. (See fig. **16.)** Pinto (1938) reports that da Cunha and Muniz have also recovered this parasite from **C. porcella.** Neither of these workers indicates the level of the intestine from which the giardias were recovered but, on the basis of analogy with other species of giardia in mammals, it seems probable that the optimum habitat is the duodenal-jejunal level.

CILIATA

The genera of ciliates reported from the guinea-pig are **Balantidium, Cyathodinium, Enterophrya** and **Cunhaia.**

Balantidium caviae Neiva, da Cunha and Travassos, 1914

In the original description of this species Neiva, da Cunha and Travassos (1914) characterized the trophozoite as an ovoidal object with a narrower anterior end, beset with cilia arranged in longitudinal lines; with a peristome in the form of an oblique cleft at the anterior end, extending only one-fourth to one-fifth of the body length and beset with cilia longer than those of the body proper; with a rounded macronucleus in the equatorial region or somewhat more posterior in position and a micronucleus nearby, and with a contractile vacuole near the posterior end. Although the peristome resembles that of **Balantidium coli,** the spherical macro-nucleus and the presence of a single contractile vacuole are species distinctive. The organism was first described from the large bowel of the wild guinea-pig **(Cavia aperea).** It was almost invariably present in each animal examined, although it was never abundant. The size measurements were stated to be 60-90 x 50-70 microns.

In the present investigator's study **Balantidium** was observed in 23 of 42 domestic guinea-pigs (56 per cent). At times only a few balantidia were found, usually in the trophozoite stage; at other times they were so numerous that hundreds of them were present in a single 22 mm. square coverglass preparation. When they were found in appreciable numbers they were most abundant in the cecal feces or in the cecal crypts. Structurally they agreed with the description of Neiva, da Cunha and Travassos (1914) except that their variation in size was much greater **(Fig. 17a, 17b).** At times the large forms were present at the cecal level and dwarfed forms at lower levels of the colon. Encystation was observed occasionally in association with

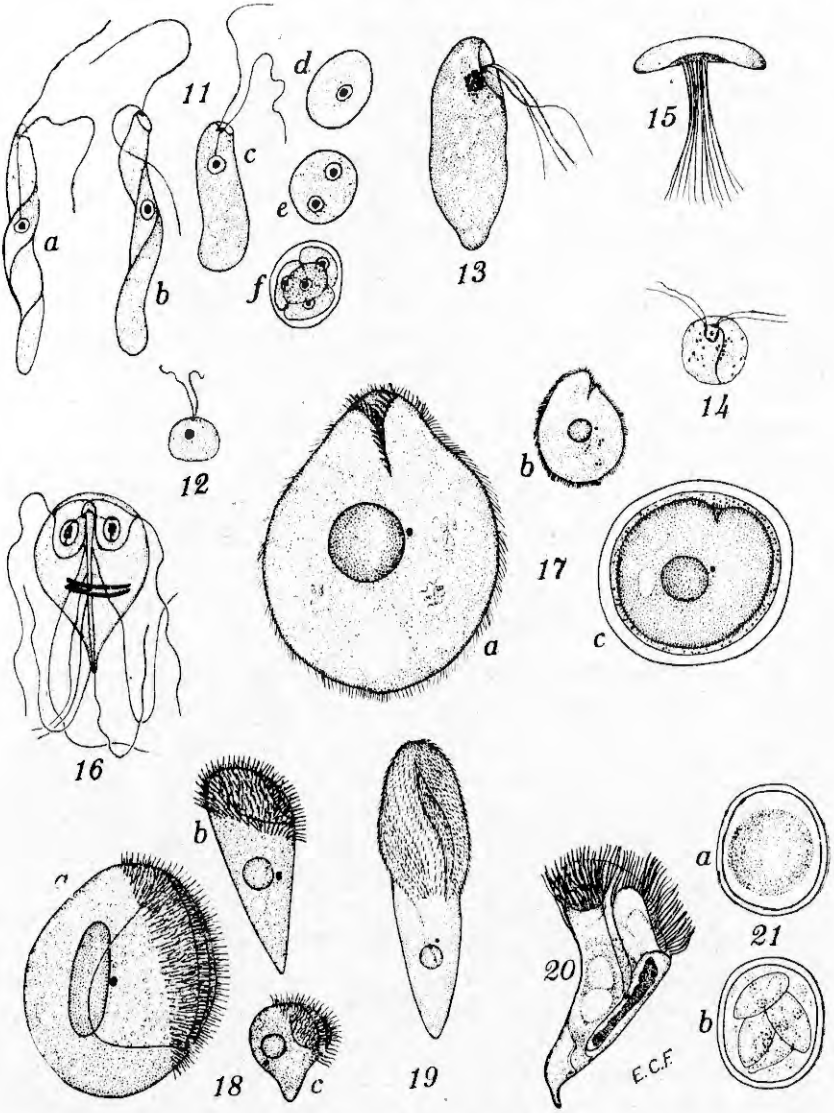

PLATE II. 11. **Spiromonas angusta. a-c,** trophozoites in different phases of activity; **d-f,** cysts in progressive stages of maturity. × 1740. **(a-c,** original; **d-f,** adapted from Wenyon.) 12. **Globomonas parasitica,** trophozoite. × ca. 1740. (Adapted from da Fonseca.) 13. **Chilomitus caviae,** trophozoite. × ca. 1740. (Adapted from da Fonseca.) 14. **Monoercomonas caviae,** trophozoite. × ca. 1740. (Adapted from da Cunha and Muniz.) 15. **Selenomonas ruminantium,** trophozoite. × ca. 2345. (Adapted from da Fonseca.) 16. **Giardia caviae,** trophozoite. × ca. 2000. (Adapted from Hegner.) 17. **Balantidium caviae. a, b,** large and dwarfed trophozoites; **c,** cyst. × 580. (Original.) 18. **Cyathodinium** spp., trophozoites. **a, C. vesiculosum; b, C. conicum; c, C. piriforme.** × ca. 385. (Adapted from da Cunha.) 19. **Enterophrya elongata,** trophozoite. × 368. (Adapted from description by Hasselmann.) 20. **Cunhaia curvata,** trophozoite. × ca. 385. (Adapted from Hasselmann.) 21. **Eimeria caviae,** oocysts. **a,** immature, **b,** mature oocyst. × 868. (Original.)

numerous trophozoites in thick gruelly cecal feces, but more commonly cyst formation occurred in the colon. From time to time, but not regularly enough to constitute an accurate index of infection, cysts were recovered from evacuated fecal pellets. The cyst invariably corresponded in size to the large-sized individuals. A particular characteristic of these cysts, which possibly constitutes an additional species criterion, is the very thick, hyaline cyst wall (Fig. **17c).** Rarely two balantidia were observed within one cyst wall, suggesting that encystation may have occurred during conjugation.

The writer can not agree with Scott (1927), that **"Balantidium** from the guinea-pig is **Balantidium coli,** the form found in the pig and in man". It is true that the illustrations in Doctor Scott's monograph indicate that she was dealing with a **B. coli**-like organism, but this is certainly not the species described by Neiva, da Cunha and Travassos (1914) from **C. aperea** nor that which the present writer has studied from stock guinea-pigs in New Orleans.

Cyathodinium species

In 1914 da Cunha created the genus **Cyathodinium** for species of protozoa having the following common characteristics: "Ciliates provided with a peristome in the form of a deep depression, the opening of which occupies the anterior face and part of the ventral side. The inner surface of this depression is invested with delicate, uniform cilia arranged linearly. The outer surface lacks cilia, except for the zone around the peristome, which is provided with cilia similar to those within the depression. The cilia which invest the internal surface are continuous with those of the exterior... The form of the macronucleus is not constant; nearby is the micronucleus. There are one or more contractile vacuoles, which are close to the dorsal side of the body." Da Cunha (l.c.) described three species, all new, viz., **Cyathodinium conicum,** with an inverted coneshaped body, measuring 50-80 x 20-30 microns, and with a spherical macronucleus, in the cecum of **Cavia aperea; C. piriforme,** body pyriform and laterally flattened, narrowest posteriorly and inclined dorsally, measuring 30-40 x 20-30 microns, and with a spherical macronucleus, frequently present in the cecum of **C. aperea** and seldom in the cecum of **C. porcella,** and **C. vesiculosum,** with an ellipsoidal, laterally flattened body, having a depressed peristome which occupies the greater part of the body and extends internally to a depth two-thirds that of the body

breadth, measuring 80-100 x 60-80 microns, with an elongated macronucleus, in the cecum of **C. aperea.** The three species are illustrated in fig. **18 (a, b, c).**

Fantham (1925) reported the finding on rare occasions of **C. conicum** from the cecum of **Cavia porcella** in Johannesburg, South Africa, while Lucas (1932) redescribed **C. piriforme** from 73 per cent of 55 adults and 32 per cent of 59 young individuals of the domestic guinea-pig in the United States. These were the same animals from which this investigator had previously studied **Balantidium** (Scott, 1927). Lucas (l.c.) concluded that the ciliate is a commensal, and, although it has certain characteristics of a flagellate, it justifiably is placed in the Class Ciliata, Order Holotricha.

Enterophrya species

This genus was created by Hasselmann (1918) for two species of ciliates, **E. elongata** and **E. piriforme,** which he obtained from the cecum of the wild guinea-pig, **Cavia aperea,** in Brazil. The organisms are elongated, pearshaped (measuring 30-50 x 3-10 microns for **E. elongata** and 35 x 8 microns for **E. piriforme),** have cilia only on the anterior portion of the body, a ciliated groove originating at the anterior extremity, a spherical macronucleus with associated micronucleus in the posterior region and nearby a single contractile vacuole. (See fig. **19.)** Pinto (1938) states that da Cunha has also recovered **E. elongata** from **C. porcella.** It seems probable that the two species are actually different forms of a single species.

Cunhaia curvata Hasselmann, 1918

The monotypical genus **Cunhaia** was created by Hasselmann in 1918 for a ciliate related to the **genus Entodinium,** recovered from the cecum of the wild guinea-pig, **Cavia aperea,** in Brazil. **C. curvata,** as described and figured by Hasselmann, 1924, (Fig. 20) has an irregularly curved conical body, with the apex of the cone in the posterior position. It measures 60-80 microns long by 30-40 microns broad. The dorsal surface is convex and the ventral surface concave. Anteriorly there is a spiral row of cirri, while a zone of cilia extends along the anterior third of the dorsal surface. Internally on the dorsal side there is an elongated macronucleus with a micronucleus nearby, and two contractile vacuoles, one anterior and one posterior in position.

SPOROZOA

Although **Toxoplasma (T. caviae** Carini and Migliano, 1916), **Klossiella (K. cobayae** Seidelin, 1914) and **Pneumocystis (P. carinii** Delanoë, 1912) have been recovered from the guinea-pig, in cells of the reticulo-endothelium and endothelial lining of blood-vessels, the only intestinal sporozoön which has been identified from this host is **Eimeria caviae.**

Eimeria caviae Sheather, 1924

This coccidian sporozoön was apparently first seen in the guinea-pig in 1899 by Labbé, who regarded it as **E. perforans** (Leuckart, 1879), an intestinal parasite described for the rabbit. Strada and Traina (1900) claimed that this organism also parasitizes the guinea-pig's liver. Bugge and Heinke (1921) stated that the oöcysts measure 15.9-24.6 x 12.2-17.4 microns, while Dieben (1924) found that they can be distinguished from **E. nieschulzi** of the rat. Sheather (1924) studied the various stages of the guinea-pig's coccidium, found that they closely resemble **E. perforans** and are confined to the large bowel, and created the specific name **E. caviae.** Pinto (1938) reports that Souza has observed this coccidium in **C. porcella** in Brazil.

E. caviae oöcysts have been encountered only twice in the present investigation, once in sparce numbers in cecal feces and once in evacuated fecal pellets. Those obtained from the former material (Fig. **21a)** were in the unsegmented stage, while those which had remained overnight in passed feces showed ripening, including a few which were mature (Fig. **21b).** There was no evidence in representative sections of the ileum, cecum and colon of the infected animals, indicating where the schizogonous and gametogonous stages of the parasite are located.

The Guinea-pig as Experimental Host for Endamoeba histolytica

In the concurrent investigation by Carrera and Faust (1949) 35 laboratory guinea-pigs were inoculated with cultures of **E. histolytica** of human origin. The organism had been grown in culture for approximately a year and a half in Balamuth's (monophasic) medium and in diphasic media, in association with five alcaligenes-type gram negative bacilli and a gram-positive micrococcus. The inoculum was

introduced into the terminal ileum under nembutal anesthesia. Five animals were sacrificed on each of seven successive days following inoculation. Tissue invasion with typical amebic lesions was demonstrated in the cecum of 33 of the animals. One other animal, which had died a few hours before autopsy, had post-mortem changes in the bowel wall and was therefore not studied histopathologically, contained numerous active trophozoites of **E. histolytica** in the lumen of the cecum and ascending colon. In the additional animal of the series (seven days incubation) there was no gross or microscopic evidence of tissue invasion, although two semi-active trophozoites of **E. histolytica** were found in a film prepared from the cecal feces. This study has demonstrated conclusively that the domestic guinea-pig is highly susceptible to infection with **E. histolytica.**

Discussion

In most instances the protozoa which have been reported for the guinea-pig have been found to be parasites of **Cavia porcella** and **C. aperea** in Brazil, even though in some instances the parasites were first observed and described from the domestic guinea-pig (**C. cobaya**) in other parts of the world. In a few instances the only records of infection are from Brazil. Again, there is evidence that some of these protozoa also occur in other rodents closely related to the guinea-pig, while a few are probably only incidental parasites of the guinea-pig, acquired from contamination with feces of other animals, particularly ruminants, which are the usual hosts (viz., **Sphaeromonas communis** and **Selenomonas ruminantium**), or man (viz., **Embadomonas intestinalis**).

A considerable number of the protozoa reported from the guinea-pig are, strictly speaking, not true parasites, or at least they are not obligate parasites. In a comprehensive review on coprophilic protozoa, Watson (1946) has discussed the bionomics of this group of organisms. Although Watson considers primarily the environment suitable for these organisms in the voided stool, much of his thesis applies to the cecal menstruum within the large bowel. These protozoa, particularly the flagellates, are tolerant of a wide range in pH, tonicity, aerobiasis, and bacterial and cellular contents of the intestinal tract, but they are usually fairly sensitive to dehydration.

Among the flagellates described from the guinea-pig the following should be regarded as coprozoic forms which frequently flourish in the

semi-liquid cecal feces: **Enteromonas caviae, Oikomonas termo, Sphaeromonas communis, Spiromonas angusta, Globomonas parasitica, Monocercomonas caviae,** and possibly also **Eutrichomastix caviae** and **Embadomonas intestinalis.** From the relatively scant biological data which have been accumulated concerning the above-named organisms it seems likely that they live typically in stagnant water wich is contaminated, and therefore enriched, with feces; that in an encysted or rounded-up state they can gain entry to the guinea-pig's digestive tract in contaminated food, water or even air, will frequently survive passage down to the cecal level, where they become activated and multiply, at time in tremendous numbers. Of the species studied by the present investigator **Spiromonas angusta** has been observed most frequently and has been found to flourish under a wide range of conditions.

Microscopic examination of the voided feces constitutes a very poor technic for discovery of the protozoan parasites of the guinea-pig's intestine. Probably culture of the feces would provide a much more dependable gauge. The considerable degree of dehydration in the feces as they are formed into pellets and pass down the colon possibly occurs too rapidly to allow encystation of most of the species, with sporadic exceptions in **Balantidium caviae, Chilomastix intestinalis, Eimeria caviae,** and possibly other species.

None of the natural intestinal protozoa other than **Balantidium caviae** and **Eimeria caviae** have been found to invade the intestinal mucosa of the guinea-pig, and there is no evidence that any of the other species are pathogenic for their host.

Summary and Conclusions

1. The present study was carried out in connection with an investigation of experimental amebiasis in the domestic guinea-pig, in which **Endamoeba histolytica** of human origin was used as inoculum.
2. The domestic guinea-pig **(Cavia cobaya)** is generally considered to have been derived from **C. porcella** of Brazil. It has been under domestication in Europe since the early part of the sixteenth century and is almost universally bred as a household pet and for laboratory experimentation. Closely related extant species are the wild guinea-pig or preá **(C. aperea),** of Brazil, and the domesticated **C. cutleri,** of Peru.

3. A considerable number of protozoa and several species of helminths have been described as natural parasites of the genus **Cavia.** In an examination of the intestinal feces of the animals in an experimental amebiasis series a number of protozoa have been encountered and studied. This lead to a survey of the literature to correlate the present observations with those of previous investigators. A review has been prepared which includes all of the species of protozoa described from the intestinal tract of the several species of **Cavia.**

4. The list of natural protozoan parasites of the intestinal tract of the guinea-pig includes the following:

RHIZOPODA. — **Endamoeba cobayae, Endolimax caviae.**

MASTIGOPHORA. — **Chilomastix intestinalis, Trichomonas caviae, T. flagelliphora, Eutrichomastix caviae, Enteromonas caviae, Embadomonas intestinalis, Oikomonas termo, Sphaeromonas communis, Spiromonas angusta** (reported for the first time from the guinea-pig), **Globomonas parasitica, Chilomitus caviae, Monocercomonas caviae, Selenomonas ruminantium, Giardia caviae.**

CILIATA. — **Balantidium caviae, Cyathodinium vesiculosum, C. conicum, C. piriforme, Enterophrya elongata, E. piriforme, Cunhaia curvata.**

SPOROZOA. — **Eimeria caviae.**

5. Several of the described protozoa are native to **C. porcella** and **C. aperea** in Brazil, even though some of them were first reported from **C. caviae** in other parts of the world. A few are also parasitic in the intestine of other rodents closely related to the guinea-pig, as the agouti, capybara, mara and paca. Some of these protozoa have previously been reported from ruminants, which are probably their natural hosts. A number of the protomonad flagellates are coprophilic in their biology and are only fortuitously facultative inhabitants of the intestinal tract of the guinea-pig or any other animal.

6. Except for **Eimeria caviae,** which is described from the wall of the large bowel of the guinea-pig, and **Balantidium caviae,** which is capable of invading the cecal mucosa but apparently produces

no appreciable inflammatory reaction, none of the species of protozoa described from the intestine of the guinea-pig are tissue invaders and none are of pathologic importance.

7. The guinea-pig has been found to be highly susceptible to infection with **Endamoeba histolytica** of human origin. In 33 of 35 inoculated animals typical amebic lesions were demonstrated in the cecal wall, in most instances with colonies of amebae in the lesions. In one of the other two animals amebae were found in the lumen feces but not in the tissues, while in the remaining animal, which died a few hours before it was to be sacrificed and was not studied in histologic section, a large number of active **E. histolytica** were found in the contents of the cecum and ascending colon.

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