mm. without distinct ectosarc and endosarc. Plasma coarsely granular, with very small nucleus (or nucleolus?), demonstrable only by staining. Movement more rapid than in *Entamœba coli*. Usually only one or a few pseudopodia, long, digitate and rapid in formation. Reproduction not observed.

This species was found by Kartulis in Alexandria, where it occurred in an Arabian, in a tumor the size of an orange, on the right mandible. In the thick pus and on fragments of extracted bone the amœbæ occurred together with numerous bacteria. They had been feeding on blood and pus corpuscles. Although apparently distinct from *Entamœba coli*, Doflein inclines to regard their connection as not impossible, and views as even more probable this interpretation of the amœbæ from an abscess in the oral cavity reported by Flexner. These were described as larger than leucocytes, with granular vacuolated plasma and a nucleus demonstrable only with some uncertainty. Although in both these cases the presence of *Entamœba coli* in the host had not been shown by any antecedent dysentery or fæcal examination, it has already been stated that this species may be present in the normal intestine, and its occurrence outside the canal in abscesses is abundantly demonstrated by other cases. It is less probable this form may have been *Entamœba histolytica*, though the description is not distinctive, as the absence of lesions in the canal can hardly be explained if the pathogenic species was present.

*Amœba urogenitalis* Baelz 1883.—Diameter 0.022–0.05 mm. Plasma coarsely granular, containing one or several nuclei, excretory products, and erythrocytes. Movement slow, by formation of short pseudopodia. Encysted forms possibly occur.

Originally found in numbers in the bloody urine and vaginal mucus of a Japanese female, twenty-three years old, who shortly before her demise from tuberculosis manifested hæmaturia with strong cystic tenesmus. (*Cf.* Vol. I., p. 233, HANDBOOK.) Similar cases have been reported by many authors. In Jürgens' case chronic cystitis was associated with small mucous cyst filled with amœbæ; these were also present in the entire vagina. The descriptions are scanty and do not render a differentiation between these forms and *Entamœba coli* and *E. histolytica*, either structurally or clinically easy at present. Pathogenic characteristics are certainly not distinctly shown, and in so far this case belongs more probably to *E. coli* if to either. Better knowledge of the species and more careful examination of the reports of previous observers may make it possible to refer some such cases to a definite species; but many will always remain uncertain.

*Amœba buccalis* Sternberg 1862; *Amœba dentalis* Grassi 1879; *Amœba gingivalis* Grassi 1849.—All these species were discovered in tartar scraped from the surface of human teeth. They have not been reported a second time, and Celli and Fiocca state specifically that they have failed to find amœboid organisms in the oral cavity. Grassi himself suggested the possibility of confusion with salivary corpuscles.

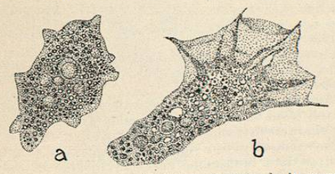


FIG. 5167.—*Leydenia gemmipara*; *a*, at rest; *b*, in movement. Magnified. (From Doflein after Schaudinn.)

*Amœba pulmonalis* Artault 1898.—In an examination of the contents of a large pulmonary cavity a small number of amœbæ were found among the leucocytes, which were distinguishable by firm contour, much finer and more uniform granulation, and a distinct nucleus or vacuole. In appearance like the epithelial cells found in sputum they manifested changes in form and position through the slow formation of pseudopodia. They were also more highly refractive, and resisted methylene blue or fuchsin longer than leucocytes, but when preserved they stained readily and were indistinguishable from the latter. Despite the conjectures of the discoverer their real nature remains entirely unknown.

*Leydenia gemmipara* Schaudinn 1896.—Irregularly spherical or polygonal in form when resting (Fig. 5167, *a*), surface with prominent verrucosities. Ectosarc and

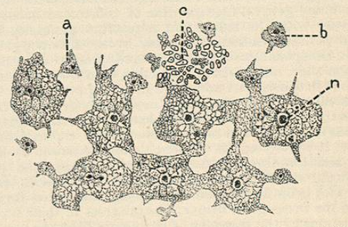


FIG. 5168.—*Leydenia gemmipara*. *a*, *b*, *c*, Young individuals formed by gemmation. *n*, nucleus. Magnified. (From Doflein after Schaudinn.)

endosarc not distinctly limited, but pseudopodia more hyaline than the opaque body with numerous highly refractive yellowish granules. Diameter of body, 0.003–0.036 mm. Nucleus single, spherical, distinct in life, and in the preserved specimen regularly one-fifth the diameter of the body; movement very slow, produced by formation of a broad, hyaline lamella at the anterior margin; streams of granular endosarc extend to the margin of this lamella (Fig. 5167, *b*), and may even project beyond it as pointed pseudopodia. The endoplasm contains granules, crystalline bodies, interpreted as excretory, and numerous vacuoles which increase in size toward the centre. A pulsating vacuole is present and contracts at intervals of about fifteen minutes.

Two or more individuals frequently unite without fusion of the nuclei, and plasmodia are formed by the union of many single individuals. Both division and gemmation occur. In the former the size of the resulting amœbæ may be very different, but is always proportional to the size of the nuclei (5:1). The nucleus divides directly, and the bud which originates as a protuberance from the surface of the amœba gradually works free and becomes an independent individual, which may at once undergo multiple division, giving rise to a mass of small spore-like forms (Fig. 5168).

Many years ago Lieberkühn observed in ascites fluid associated with malignant tumors peculiar cells; and similar structures were seen later by others. In 1896 Leyden and Schaudinn, on the basis of an exact investigation of these bodies in a particular case, determined them as a new parasitic rhizopod. Leyden had found them in the ascitic fluid of two patients in whom positive evidence of gastric carcinoma and of tumors in the peritoneal cavity was furnished. The amœbæ appeared in numbers in fluid drawn off from the cavity, and could be kept alive in fluid preserved several days under aseptic conditions. Schaudinn studied the amœbæ carefully and pronounced them to be unmistakably parasitic forms. Some later critics have inclined to reject this view, and regard them as descendants of the human tissue cells or pathologic neoplasms. L. Pfeiffer especially has maintained that similar large amœboid cells ("exudate cells") occur in variola, vaccinia, varicella, herpes zoster, etc., and yet the contractile vacuole, peculiar nuclear structure, and reproductive processes of *Leydenia* indicate unmistakably an independent organism, as well as many other features in which it resembles various related free-living forms.





Originally Leyden and Schaudinn were inclined to connect this form with carcinoma, but expressed no positive opinion on this point. Unfortunately it has not been studied by subsequent investigators, and in fact has been found but twice since then, although often sought for under similar circumstances. Recently Schaudinn has advanced the view that this form is probably an accidental commensal.

The class of the Mastigophora includes a great variety of organisms, having in common hardly more than the possession of vibratile organs of locomotion known as flagella, which by greater length, lesser number, and type of movement are easily distinguishable from cilia. The group shows relationships in many directions, and affords an almost unbroken line of transition to forms which are typically plant organisms. Here, again, as in the last class (Sarcodina) the uniformity of structure, coupled with an even smaller average size and very insufficient acquaintance with the life history, render it difficult to speak positively regarding many of the organisms. Of the sub-classes, which are founded upon the number and arrangement of the flagella, the character of the cell body and general habits of life, only one, Flagellata, is of importance here, as the others contain no parasitic forms.

The general form of the body, the number and position of flagella, and the precise method of reproduction serve to distinguish in the sub-class Flagellata five orders. Only two of these embrace human parasites and demand consideration here, namely: Protomonadina and Polymastigina.

The Protomonadina are small forms, often tending to form colonies. They have at the anterior end one flagellum, two similar flagella, or two or three dissimilar flagella. In many parasitic species an undulating membrane accompanies a single flagellum. Doflein gives the following key for the determination of those families which include parasitic species:

1. A single flagellum on anterior end ..... 2
   Two flagella on anterior end ..... Bodonidæ
2. An undulating membrane along the side of the body ..... Trypanosomidæ
   No undulating membrane present.. Cercomonadidæ

*Cercomonas.*—The species in this genus are rather uncertain. Many forms have been assigned to it which later studies have shown to belong to other genera. Confusion is possible both with plant organisms and with mere developmental stages of other groups. The species are small and colorless; in form round or oval, with a very large flagellum, which is projected ahead in locomotion. Many of the forms reported from the human body and assigned to this group are imperfectly known, often found but a single time, and in many cases probably pseudoparasites of various degrees. One or two of the more distinct forms need brief mention here.

*Cercomonas hominis* Davaine 1854.—Body pyriform, pointed posteriorly, with single flagellum at anterior end. Length 0.01–0.012 mm. Movement rapid, capable of attaching themselves by posterior tip. Smaller variety 0.008 mm. long.

Found in the dejecta of a cholera patient, the smaller variety in typhoid dejecta. Various later reports may be assigned to this species, including that of Lambl in 1875, which has often been erroneously identified as the same as the species described under the same name by this author in 1859. The latter will be discussed under its present name of *Lamblia duodenalis*. Some authors have assigned the former species to *Trichomonas*, forgetful of the fact that it possesses but a single flagellum.

It would be hazardous to assert that all typical cercomonads thus far described from the human host fall unquestionably into the limits of a single species; yet in the absence of contradictory evidence they may for practical purposes be considered as such. These forms have been found in the alimentary canal, the bronchial system, in pleural exudate, and in an *Echinococcus* cyst. Encysted forms have also been described. All investigators have not been equally careful to demonstrate the intestinal origin of such forms as were found in fæces, and which may have been due to secondary contamination of the fæcal material. Among numerous records only those of Councilman and Lafleur and of Dock concerning the occurrence of such forms in this country need be mentioned.

*Monas pyophila* R. Blanchard 1895. (Syn.: *M. pyophyla* Neveu-Lemaire 1902.) Form similar to large spermatozoa, 0.03–0.06 mm. in diameter of body, with long filament from rounded pole, resembling a flagellum, yet capable of retraction when the form becomes nearly spherical. Outside a cuticular (?) layer, which extends through the body in partitions, dividing it into three regions. Movement rapid, accompanied by change of form.

Found by Grimm in sputum and pus of abscesses in lung and liver of patient in Japan.

The Trypanosomidæ are parasitic forms with a chief flagellum directed anteriad, usually two-edged, with more or less of a spiral twist in the body, and with one edge of the body provided with an undulating membrane. The numerous species are hæmatozoa in vertebrates, though some live in the body cavity and alimentary canal of both vertebrates and invertebrates. Those forms of importance here all fall in the genus *Trypanosoma* s. str. Much difference of opinion prevails as to the number of species and their limits. Most of them are very poorly known, although several so-called species were discovered as much as sixty years ago; indeed of no form is even an approximately complete account of the life history at hand. Various species are recognized in various parts of the world as the cause of specific diseases among domesticated animals, which have assumed economic importance of the first rank. The most prominent of these are the following, together with the range and host of each species listed.

*Trypanosoma Lewisi*, in rats and (?) the hamster, reported from Europe, Asia, Africa, and North America, and causing at times fatal epidemics.

*Trypanosoma Brucei*, in cattle, horses, mules, and wild animals, gives rise to the *nagaña* or Tsetse-fly disease in Africa south of the Sahara.

*Trypanosoma equiperdum*, in horse, ass, and other domesticated species by inoculation, causes *dourine* in the circum-Mediterranean region.

*Trypanosoma Evansi*, in mammals, especially domestic, where it causes the *surra* in India, China, Burmah, and the Philippines.

*Trypanosoma equinum*, in horses, causing *mal de caderas* in South America.

*Trypanosoma Theileri*, in cattle, producing the *galziektè* in South Africa.

Although but little evidence is at hand, the weight of opinion is against any possibility of the transmission of these species to man.

Some structural features of the genus *Trypanosoma* s. str. need brief mention. The lancet-shaped body (Fig. 5169, *a*) shows a finely granular endoplasm and a distinct

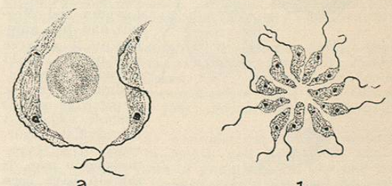


FIG. 5169.—*Trypanosoma Lewisi*. *a*, Adults with erythrocyte, from stained preparation. × 1,000. *b*, Multiplication rosette, less highly magnified. (After Francis.)

though very delicate hyaline ectoplasmic layer. The single flagellum arises near the posterior end in connection with the highly refractile granule variously denom-

inated centrosome, micronucleus, and nucleolus. The flagellum continues along the body as the thickened outer margin of the undulating membrane, and projects free from the anterior end of the animal. The prominent

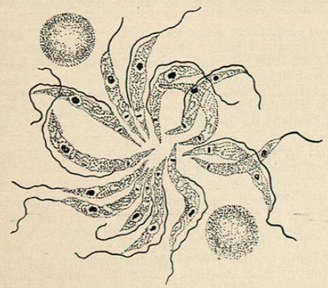

FIG. 5170.—*Trypanosoma Lewisi*. Auto-agglutination. Highly magnified. (After Francis.)

nucleus occupies a slightly different position in different species; it is rich in chromatin and stains deeply in prepared specimens.

Three types of reproduction are imperfectly known: a typical longitudinal division, a budding said by Senn to be more common, and a segmentation or multiple division into numerous spores (?) arranged in rosettes (Fig. 5169, *b*). The rosette formation is regarded by some authors as the result merely of the successive division of an ordinary individual of the species. These rosettes of enormous size, embracing several thousands of individuals, occur characteristically in cultures of *Trypanosoma Lewisi* (Fig. 5170). Such cultures have been recently successfully obtained by McNeal and Novy in a strictly pure form, and have been maintained for somewhat over a year. The great importance of this step for the study of the pathogenic activity of the organism and of the possible protective measures in combating the disease is evident at once. The species found in man is

*Trypanosoma gambiense* Dutton, 1902. (Syn.: *T. hominis* 1903; *T. Nepveu* Sambon 1903.) Length in stained preparation (Fig. 5171), including flagellum 0.018–0.025 mm., width 0.002–0.0028 mm. Free part of flagellum about one-third of total length. Anterior end attenuated along flagellum, posterior end roughly conical, very blunt. Oval macronculeus just anterior to centre of body, occupying entire width of animal. Near posterior end dark spot, the micronucleus (the centrosome of Laveran and Mesnil), and just anterior to it a large vacuole well marked. The flagellum ends at the upper edge of this vacuole. The first record of the occurrence of a trypanosome in man is said to have been published by Nepveu in 1891, and again in 1898. The description given, however, is too scanty to admit of any opinion regarding its general character, though many are inclined to interpret it as a member of the genus *Trypanosoma*. This species was discovered in 1901 by Dutton in the

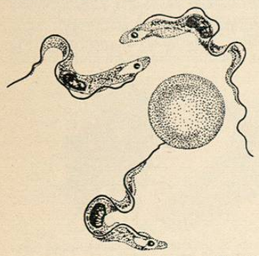

FIG. 5171. — *Trypanosoma gambiense*, with erythrocyte, drawn from stained preparation. × about 1,900. (After Dutton.)

blood of an Englishman in government employ on the Gambia River. The case was under observation some time, namely, until the patient died in January, 1903, and manifested the following clinical features: general weakness, irregular lapsing fever lasting one to four days with apyrexial periods of two to five days, some œdema, injection of the skin, enlargement of the spleen, constant frequent pulse, and hurried breathing. These symptoms were associated with no definite organic lesions.

In many prepared slides and fresh blood mounts there were found no malarial organisms. The number of trypanosomes present varied from one to fifteen, but in apyrexial periods none were detected in the blood. The parasite usually progressed with the flagellum in front, but occasionally reversed direction for a short distance. In slow progression wave-like motions start in the flagellum and are communicated to the undulating membrane; in rapid motion the body rotates on its longitudinal axis so that the undulating membrane appears as if spirally arranged. In one instance a mononuclear leucocyte was observed which had partially engulfed a trypanosome, only the flagellum and a small part of the anterior end of the body remaining free.

In films of blood taken from a child three years old the parasite was discovered again and associated with it malarial organisms. Annett points out that the chronic character of the disease, the rarity of the parasites, their apparent absence at long periods from the peripheral circulation, and the occasional rise in temperature favor confusion with malaria in diagnosis.

Later further cases of the malady have been identified by Dutton, Manson, and others, making in all six cases on the Congo River and seven on the Gambia, which are nearly equally divided between natives and Europeans. It is thus evidently not rare in tropical Africa, as Dutton found his seven cases in somewhat more than one thousand examinations in Senegambia. Two investigators seem to have identified it in India also, and it may be expected to occur in other countries as well, as do the corresponding affections of domestic animals.

A final most recent contribution of great importance to this subject has been made by Castellani, who found *Trypanosoma* in the cerebro-spinal fluid of natives afflicted with the so-called "sleeping sickness." This hitherto entirely unexplained disease, epidemic in certain regions of Africa, attacks only natives, and is characterized by a drowsy condition culminating in deep coma, with an all but universally lethal outcome in from three to twelve months. Hyperæmia of the arachnoid vessels is the only known pathological feature. Bacteriological investigations have remained without result, and the theory of Manson that the cause of the malady lay in the presence of *Filaria perstans* has already been referred to in another article (*Nematoda*). Castellani's hypothesis has been greatly strengthened by the communication of Bruce to the Royal Society that *Trypanosoma* was present in the cerebro-spinal fluid in every one of thirty-eight cases of sleeping sickness investigated in Ugunda, and occurred also in the blood in twelve out of thirteen cases tested on this point.

This species, which has been named *Trypanosoma Castellanii* (see Sambon in *Journal of Tropical Medicine*, July 1st, 1903), closely resembles *Trypanosoma Brucei*, but is said to differ in the following morphological peculiarities: a more or less rounded anterior extremity (posterior extremity of most authors, but this species moves with the more rounded extremity foremost), the centrosome outside the vacuole and much closer to the extremity, the larger vacuole placed before (?) the centrosome, the longer free portion of the flagellum and fewer granules at the posterior extremity.

The transference of the parasite is probably due to some blood-sucking insect, as has been demonstrated for other species of *Trypanosoma;* and in the case of the sleeping sickness, *Glossina morsitans*, the Tsetse fly has been declared responsible by Brumpt. In an illuminating discussion of the subject he shows that the disease is extraordinarily widespread among fishermen on the Congo, and almost unknown among people in the vicinity, who yet do not visit the stream. This accords with the habits of the Tsetse fly, which occurs on the river in immense swarms and is not found a short distance away from it. The freedom from this disease enjoyed by the whites can only be explained on the basis of present knowledge as a type of racial immunity. Recent observations, however, serve to arouse suspicion as to the correctness of the assumption itself.





Although the morphological differentiation of the various species of *Trypanosoma* is difficult, not to say impossible at present, there are sufficient grounds in the clinical features of the diseases caused by them, and in other physiological data, such as the immunity of various host species to certain forms, to justify the acceptance of their specific distinctness. One may well recall the earlier view, that only one form of malarial organism existed, and may find in the transport by *Anopheles* of different species of *Plasmodium* a case parallel to that of the Tsetse fly. Whether the latter host affords the opportunity for the development of a special phase in the life cycle of the trypanosome is as yet purely a matter of conjecture.

The family of the Bodonidæ would not call for any discussion here were it not for the frequence with which certain species have been assigned a rôle as parasites of man. The form which has most frequently been mentioned in this connection is

*Cystomonas urinaria* (Künstler 1883).—(Syn.: *Bodo urinarius* Künstler 1883; *Cystomonas urinaria* Blanchard 1886; *Plagiomonas urinaria* Künstler of Braun 1895.) Shaped like a beet root (Fig. 5172), 0.01 mm. long, 0.004–0.005 mm. broad, the broad anterior end notched, the posterior end in the form of a long slender filament. Nucleus anterior; two similar flagella originate from anterior notch.

In 1856 Hassall described an infusorian which he had observed in alkaline urine that had stood some time open to the air. It was subsequently found in fifty samples of urine from various sources left open similarly, sufficient proof of the contamination. In 1883, however, Künstler reported a form under the same name from fresh urine, which was accordingly attributed to the urinary passages. Blanchard held this to be in reality a new species and renamed it, bringing it in connection with a form described by Salisbury as *Trichomonas irregularis*. Braun regards the latter as rather *Tr. vaginalis*, and distinct from the former, for which he inclines to the view that it was actually a contamination. This is the more probable, as Th. Barrois found many flagellates in "freshly voided" urine in Lille, when subsequent examination yielded no trace of these parasites in urine of the same patients. Evidently the presence of such forms in human urine is beyond question, but their origin from the human urinary passages is yet to be demonstrated. That all such cases require the most searching examination is evinced by a recent experience of my own, in finding objects which were probably much contracted rotifers in preparations made from "absolutely fresh" urine.

FIG. 5172.—*Cystomonas urinaria*. Magnified. (From Braun, after Künstler.)

The order Polymastigina includes small forms, always non-colonial, with three similar flagella, or with four to eight flagella dissimilar in size and differently located. Two families contain parasitic forms and are distinguished as follows:

Body with three or four flagella, all at anterior end ..... Tetramitidæ

Body with four to six flagella on anterior end; posterior end either with two flagella, or prolonged into one to three lobes ... ..... .....Polymastigidæ

In the Tetramitidæ are included species of elongated form with usually pointed posterior end. They have no cuticula, or pellicle, hence may also manifest amœboid movements. One of the flagella may be represented by an undulating membrane. Only one of the genera, *Trichomonas*, embraces human parasites. The diagnosis of the genus may be given briefly as follows:

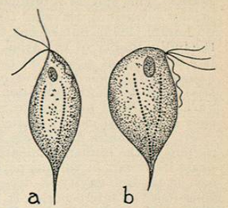

FIG. 5173. — *Trichomonas vaginalis*. *a*, From osmic-acid preparation; *b*, living. Magnified. (After Blochmann.)

*Trichomonas* Donné.—Generally pyriform, with anterior end rounded or almost pointed. Posterior end moderately pointed. Nucleus near anterior end, vacuoles near posterior, no contractile vacuole. Either three equal flagella from anterior tip, and also an undulating membrane (*Trichomonas* s. str.), or with three equal flagella directed anteriad, and one much longer extending posteriad from the same point of insertion (sub-genus *Trichomastix*).

*Trichomonas vaginalis* Donné 1837.—Body very mobile, usually pyriform or spindle-shaped (Fig. 5173), with posterior end sharply pointed and anterior end more or less rounded. The posterior tip is half as long as the rest of the body. Total length 0.015–0.025 mm. At anterior pole originate three flagella (four according to other investigators) of equal length, and an undulating membrane which winds spirally about the body to the base of the posterior tip. Plasma finely granular, nucleus near anterior end; posterior to it according to Blochman two longitudinal rows of prominent granules. Division has been reported; encystment is as yet unobserved.

This species is present in females where vaginal catarrh is associated with an acid reaction of the secretion. It has been found in girls of six or seven years and in aged women; and other conditions affect its presence as little as age save that menstruation, alkaline injections, or other conditions which alter the reaction of mucus result in its disappearance temporarily at least. A low temperature (15° C. or less) is also fatal to its existence. Dock and others have demonstrated the presence of this species in the urine of males; the infection doubtless resulted from intercourse and was made possible by an already abnormal condition of the male urethra, as was shown in the cases under discussion. Dock was unsuccessful in infecting guinea-pigs and dogs, and the means of transference from one female to another is unknown. According to Hausmann thirty to forty per cent. of females are infected. The parasites are easily demonstrated in the vaginal mucus, where they move slowly about among epithelial fragments and mucous corpuscles; but for successful demonstration the urine must be examined as soon as passed. Whether their relation to the vaginal catarrh is primary or secondary remains entirely undecided.

*Trichomonas intestinalis** (R. Leuckart 1879).—(Syn.: *Protoryxomyces coprinarius* Cunningham 1881; *Monocercomonas hominis* Grassi 1882; *Cimænomonas hominis* Grassi 1882; *Trichomonas hominis* Grassi 1888; *Cercomonas coli hominis* May 1891; *Monocercomonas hominis* Epstein 1893.)

Very similar to *Tr. vaginalis* but smaller, measuring 0.004–0.015 mm. in length and 0.003–0.004 mm. in breadth, without rows of granules; posterior end more sharply set off and measuring only one-third the length of the body. Three flagella, the free edge of the undulating membrane has sometimes been interpreted as a fourth. Otherwise as in *Tr. vaginalis*, although the species has not been carefully investigated. Kruse and Pas

* This form of the name is probably incorrect, but as the synonymy is badly confused I have retained it pending revision by some specialist.

quale observed groups of individuals which may have arisen by division. Before copulation this species loses its flagella and creeps about with bluntly lobose pseudopodia. This species is ordinarily identified as the *Cercomonas hominis* of Davaine (1854) and the *C. intestinalis* of Lambl (1875), but recent studies have demonstrated the individuality of this from the two cited. There also is a tendency at present to reduce this form to *Tr. vaginalis*, with which it agrees closely, and only an exact study can decide the question. In the uncertainty I regard it as more practical to retain both species, though they are at least closely related.

*Tr. intestinalis* parasitizes in the anterior and middle regions of the human alimentary canal, and has been repeatedly found in various parts of the world. It occurs also in the oral cavity in decaying teeth, where it nourishes itself on micrococci. It has been reported also frequently from diseased conditions associated with diarrhœa, such as typhoid, cholera, intestinal catarrh, gastric carcinoma, and once in pulmonary gangrene. The species lives only in fluids of an alkaline reaction. Its occurrence in the dejecta of healthy adults has been taken to indicate a commensal rather than a parasitic habit; but it at least multiplies rapidly in connection with morbid processes, and this may exercise an important influence on the progress of the disease. An etiological significance cannot, in the present state of knowledge, be attributed to this species; yet the experiments of Epstein showed that an infection is apparently produced by drinking-water and followed by diarrhœa in children. Experimental infection of animals has not yet succeeded, and the presence of this species in the oral cavity, both in health and in disease, points to possible transport of unknown encysted forms by the air.

Some accounts referred to supposable new species more probably concern this. Such are the forms described by Steinberg from the oral cavity as *Tr. elongata*, *Tr. caudata*, *Tr. flagellata*, as well as perhaps also *Cercomonas biflagellata*, together with the *Tr. pulmonalis* of Schmidt and Artault from sputa or contents of a pulmonary cyst.

The family Polymastigidæ contains small biaxial or bilateral forms with two or three flagella on either side or near the anterior end, while the posterior end is lobed or provided with two further flagella. Only one genus contains human parasites.

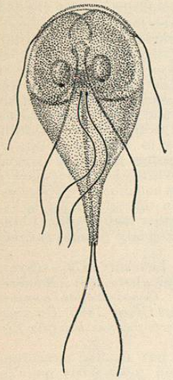

Fig. 5174.—*Lamblia duodenalis*, Living, from Rabbit Intestine. Magnified. (Combined sketch. After Metzner.)

*Lamblia* Blanchard.—At anterior tip one flagellum on each side, and near the centre two on either side; posterior end with two additional flagella. A concave sucking disc (?) on ventral surface near anterior end. Nucleus dumbbell shaped.

*Lamblia duodenalis* (Davaine 1875).—(Syn.: *Cercomonas intestinalis* Lambl 1859, nec 1875 nec Perty 1852; *Hexamitus duodenalis* Davaine 1875; *Dimorphus muris* Grassi 1879; *Megastoma entericum* Grassi 1881; *M. intestinale* R. Blanchard 1886; *Lamblia intestinalis* R. Bl. 1888; *L. duodenalis* Stiles 1902.)

Length 0.01–0.016 or 0.021 mm.; maximum breadth 0.005–0.007 or even 0.012 mm., with eight flagella nearly equal in length (0.009–0.014 mm.). In form bilaterally symmetrical (Fig. 5174). In ventral aspect it is rounded anteriorly and prolonged posteriorly into a very mobile steering tail flattened in the frontal plane. A shallow cordiform excavation of the ventral surface near the anterior end corresponds to the peristome and serves as an organ of attachment; its margin is raised and contractile, but is interrupted posteriorly; all flagella point posteriad; the anterior pair follow the margin half-way around before leaving the body; the lateral pair originate near the anterior margin in the peristome, but are bound to the body until they come to project beyond the contour of the animal; the median pair originate in the notch of the peristome margin and are vibratile through their entire length, being the chief organs of locomotion; the caudal pair are inserted at the tip of the body. The dumbbell-shaped nucleus lies dorsal to the peristome. Contractile vacuole and cytostome are wanting. Division has not been observed; the encysted form is oval, with heavy transparent wall, and measures 0.01 mm. in length by 0.007 mm. in breadth. Schaudinn reports that copulation has been observed and is followed by encystment.

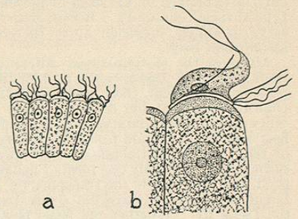


Fig. 5175.—*Lamblia duodenalis*. *a*, On epithelial cells of intestinal villus. × 370. *b*, single cell and parasite. × 1,070. (After Grassi and Schewiakoff.)

This species was first reported by Lambl from the dejecta of children in Prague. It has been reported from Germany, Italy, Russia, Sweden, Egypt, and the United States from the human host in which it seems to be a frequent parasite. It also occurs in rat, mouse, dog, cat, rabbit, sheep, and certain wild species, and is undoubtedly a common and widely distributed parasite.

Its normal seat is the duodenum or jejunum, rarely other parts of the canal, where it sits with the peristome applied to the curved outer face of an epithelial cell (Fig. 5175) on the villi. Although often in such numbers that apparently every cell is occupied, yet no pathological effect has been demonstrated to be exercised by these parasites. Normally only cysts occur in the colon and fæces, but in diarrhœic conditions the free living forms are torn loose and reach the exterior.

Grassi determined by experimental auto-infection that the cysts are the means of infection, and was unable to detect in himself any symptoms incident to the parasitism of the species. It is probable that cereals, or prepared food which becomes contaminated by rats or mice, constitute the ordinary avenue by which the infection of man is brought about.

The class Sporozoa embraces a series of groups of Protozoa of a consistent parasitic habit, which have in common the production at some point in their life cycle of numerous descendants, which are usually covered by a firm shell and accordingly denominated "spores." The enclosed young forms may be single or manifold, and in special cases the cyst wall may be lacking. These young forms always start the life cycle as cell parasites, and in all but rare cases alternation of generations appears in the course of the life history. All forms are true parasites, and all subsist only on fluid nourishment obtained by osmosis.

The class was made by Leuckart in 1879, when he brought together under the heading Sporozoa the imperfectly known and somewhat isolated groups of gregarines (Gregarinida), the psorosperm sacs of Müller (Myxosporidia), the oval or spherical psorosperms of Eimer (coccidia), and Rainey's or Miescher's corpuscles (Sarcosporidia). Later investigators have added the Microsporidia, Amœbosporidia, and Hæmosporidia, and have been able to fill up the gaps in the knowledge of the older groups, so that the association of these forms stands on a much clearer and firmer basis. This is especially true by virtue of the recent discoveries concerning the life cycles of various forms which have revealed an entirely unsuspected complexity and interrelation of the development with the parasitic habit.





In the majority of cases two types of reproduction alternate in the life history of the organism, and this alternation is associated with different factors in the biology of the parasite. The first type subserves the rapid multiplication of the parasite within the host, and is appropriately designated by Doflein multiplicative reproduction; when highly developed it will evidently transform an organism harmless because insignificant into an abundant destroyer of tissue and the exciter of disease. This may be observed again and again in the account of this group. The other type of reproduction is connected with the spread of the species, the infection of new hosts, and may be denoted after Doflein the propagative reproduction. Spore formation is here associated with all sorts of secondary or collateral structures which assist in the transport of the spores, their protection during this period, and their attainment of the new host. The morphology of the propagative reproduction constitutes the means of characterizing the major subdivisions of the Sporozoa; the multiplicative reproduction varies often widely among closely related forms.

The two sub-classes, Telosporidia and Neosporidia, are distinguished by the fact that the former produces spores only at the close of the vegetative period, while the latter do so during the entire period. For the identification of a sporozoon a vegetative stage is rarely sufficient; the form and number of the spores produced during the propagative period of reproduction are characteristic.

In the sub-class Telosporidia one may distinguish two orders on the basis of the habit of the parasites and the mode of fertilization which prevails. Thus in the Coccidiomorpha the vegetative stage is permanently intracellular, while the sexual generation may be so only transiently. The fertilization is anisogamous, *i.e.*, the fusion of differently formed gametes. In the Gregarinida on the other hand, the vegetative stage is intracellular only at the start, as the adult organism is extracellular and the sexual generation also. The fertilization is isogamous, *i.e.*, the fusion of equal and similar gametes. Under the order of the Coccidiomorpha are included forms which until recently have been treated as much more distinct. But more careful study, particularly of the life history, has shown an increasing degree of likeness until they are now included in the same order, and mutually opposed to the Gregarinida in the specific cell parasitism, and in a similar alternation of generations and of hosts in addition to the features pointed out in the outline of the system given above. The features which serve to distinguish the two sub-orders of the Coccidiomorpha are these: The Coccidia produce sporozoites encased in sporocysts, with the exception of *Legerella*, the copula is non-motile and remains in the cell. In the Hæmosporidia the sporozoites are always free, the copula is an active ookinet, and migrates to a new location before undergoing further development.

The adult Coccidia occur as parasites in epithelial cells, particularly of the alimentary canal and its adnexa, though the excretory organs, the male sexual organs, and most recently the spleen are also reported as affected. While the protoplasm of the host cell is ordinarily the seat of the parasite, there are not wanting such as occur in the nucleus itself. Only rarely is more than a single parasite found in an epithelial cell.

In form the Coccidia are uniform and constant, being spherical, oval, or elliptical, and without organs of locomotion of any sort or organs of attachment. Their size is regularly insignificant. A noteworthy characteristic is the absence of differentiation into ectoplasm and endoplasm. The plasma of the cell is finely granular, alveolar, and without reserve bodies or food vacuoles. The nucleus is large, vesicular, and characterized by a single prominent central nucleolus. No contractile vacuole is present, and no further structural differentiations can be noted. The cell and nucleus increase gradually in size at the expense of the host cell, which ultimately in most cases degenerates to a mere empty membrane encircling the coccidium.

The nucleus of the now full-grown parasite undergoes multiple division, the protoplasm arranges itself in individual masses about the many daughter nuclei, and there results a stage in which a rosette of young forms (Fig. 5176) encircles a central portion of protoplasm, known as the reliquary body or residual mass. This is without nuclear matter and destined to play no further part. It is left behind, and perishes when the young forms wander out to infect new epithelial cells of the same host, and repeat the process just sketched. This is evidently the multiplicative reproduction already referred to. It serves to effect the auto-infection of the host, and is generally known as the period of asexual reproduction or schizogony. The cell parasites which undergo these changes are schizonts, while the young forms are denominated merozoites. The merozoites are capable of active movements by contraction and twistings, or with a gliding movement, in which a trail of mucus is left behind. The growth of merozoites to schizonts in the epithelial cells, the production of new merozoites, and the infection of new cells proceed often with considerable rapidity, but only within certain limits, for a new type of reproduction intervenes.

In this which regularly begins under the pressure of excessive infection of the host, the merozoites develop not to schizonts, but to forms of two sorts, which at first sight are very similar to schizonts, and but little different from each other. The one form is opaque with a richly granular plasma; the other has a clear but dense plasma. The opaque form is the female gamete, or macrogamete, and attains maturity by the rejection of a portion of its nuclear substance. The clear cell, known as a microgametocyte, undergoes multiple nuclear division. The many nuclei produced then migrate to the surface, each collects a small part of the plasma about itself, and projects as an elongated spindle-shaped structure, the microgamete or male cell, which becomes free, forms two flagella, and enters upon active locomotion. The major portion of the microgametocyte is abandoned, and subserves no further function.

Fig. 5176.—*Eimeria Stiedæ*. Adult Schizont Completely Divided into Merozoites. Cyst formed of degenerated host cell is not represented. Magnified. (After Simond.)

The microgametes swarm about the macrogametes, and as soon as one has succeeded in entering, the macrogamete forms at once a firm membrane, which forbids entrance to other microgametes. The two nuclei unite and the act of fertilization is completed. The product is known as an oocyst, copula, or sporont, and forms the starting-point of a new period in the life cycle, which is that previously designated as the propagative reproduction. It is also known as the sexual spore-forming period, or sporogony, and in most coccidia takes place outside of the host, after the oocyst has been evacuated in fæces or urine. The steps in the process of sporogony may be outlined next in general terms (Fig. 5177).

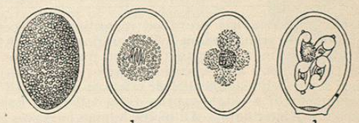


Fig. 5177.—*Eimeria hominis*, Sporogony. *a*, *b*, Oocyst; *c*, sporoblasts with residual mass; *d*, sporocysts with contained sporozoites. Magnified. (From Braun after Riek.)

The nucleus of the oocyst (*a*) divides twice, and about the four daughter nuclei the protoplasm separates into four parts known as sporoblasts (*b*), and sometimes also