THE ADHESIVE DISC OF TRICHODINELLA EPIZOOTICA — ULTRASTRUCTURE AND INJURY TO THE HOST TISSUE

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Abstract. The fine structure of the adhesive disc of Trichodinella epizootica (Raabe), a typical representative of eutrochous trichodinids is described along with interpretation of its function. The attachment to the host’s surface is the result of an elaborate coordination of its constituents — denticles, radial pins, spikes of the border membrane and aboral ciliary wreaths. First, the disc is held to the surface by the action of the ciliary beat, then its space is sealed off by the border membrane cutting its sharp edge into the tissue and then the disc is vaulted to form a cup-like sucker. The injury to the host cell may be done by the edge of the border membrane and by pulling the cells into the vaulted disc. The total damage to the fish depends on the intensity of invasion; if conditions are favourable for the fish, the trichodinids behave as symphoronts. On fish with resistance lowered by other factors they behave like parasites.

Trichodinids are perhaps the most frequent protozoans invading the surface of fishes. Massive occurrence of species of the genera Trichodina Ehrbg., Trichodinella Šrámek-Hušek and Triparticella Lom is frequently accompanied by a serious disease, trichodiniasis. The symptoms are a hyperproduction of mucus, white patches or whitish film over the whole body consisting of disintegrating epithelial cells and mucus. In especially severe cases the skin may peel off, the fins fray, and the fish may die. In the gill tissue, heavy invasion with trichodinids is manifested by mucus hypersecretion, disintegration of epithelium and haemorrhages. The disease occurs in aquarium fish (e.g., Hofer 1904, Huber 1926, Täglich 1952), in fish hatcheries or in free-living game fish (e.g., Schäperclaus 1926, Mueller 1937, Richardson 1937, Bogdanova 1963, Sassman 1966, Lewis 1969, Ivanova 1969) and has been recorded also in marine fish (Pádnoš and Nigrinelli 1942, Niak, Kohnehshahi and Azari 1971) and recently also in marine fish farms (Anonymous 1971, Pearse 1972). Most of the authors, however, did not identify the exact species responsible for the trouble; Hoffman and Lom (1967) proved that, under certain conditions, the individual species may differ in their capability of invading the fishes.

Much more common than massive, disease-causing invasions, are moderate or weak invasions, either persisting throughout the year round or fluctuating in dependence on environmental factors. As corroborated by numerous observations, trichodinids are essentially ectocommensals which, under normal conditions, do not necessarily cause damage to their host, because they feed on water-dispersed particles, bacteria or algae. As a rule, the host epithelium is damaged by a massive invasion in a host whose resistance has been lowered by some adverse conditions (Schäperclaus 1954, Haider
1964, Lom 1965); in this case the ciliates may feed on particles of disintegrating cells. Under such circumstances, trichodinids can be considered as opportune parasites (= "Schwächeparasiten", Schaper 1954).

To reach a complete understanding of the relation of trichodinids to their hosts means also to learn exactly how these ciliates damage their host's surface, being on some occasions able to penetrate even below the epithelium (Frank 1962). The only part of their cell which is in permanent contact with the host and can therefore exert a pathogenic action, is the adhesive disc; to find out the exact mechanism of its function would answer the above mentioned question.

A simple observation of live ciliates reveals how firmly they adhere to the substrate, withstanding fairly strong water currents and at the same time being able to move around or simply to rotate at one spot. The damage to the host was first thought to be due to an abrasive action of skeletal denticles which were supposed to protrude from the rotating adhesive disc. Later, two assumptions prevailed; according to the first (Pénard 1922, MacLennan 1939, Davis 1947) the firm hold of the substrate and simultaneously, the possibility of locomotion is due to the movement of the ciliary wreath, pushing the ciliate to the substrate; on disengaging itself, the protozoon can make use of the movement of the border membrane. However, more widely accepted became the idea of sucker-like action of the adhesive disc, while the border membrane seals the space of the disc (Zick 1928, Precht 1935, Richards 1949, Haider 1964). This sucker works by means of a system of supporting skeletal elements and contractile myofibrils; if suction is loose, the ciliate can move. The suggestion that the contents of the host cells are emptied by direct suction of the disc (Steinman 1924, Raabe 1950) has not found acceptance.

The following electron optical study was undertaken in order to elucidate the structure of the adhesive disc and thus to explain its function. We have chosen the gill-invading species *Trichodinella epizootica* (Raabe) for several reasons. The shape and function of its disc is representative of the whole group; a possible damage to the host cells is better detectable on the gill epithelium than on that of the skin, and, finally, there is also a record (Ivanova 1969) of its pathogenic effect on the host — attenuation of the gill epithelial layer and deformation and degeneration of epithelial cells. The only three papers available on ultrastructure of urcoarids concern but endoparasitic species of other genera — *Trichodinopsis paradoxa* and *Trichodina urinicolus* (Fauré-Fremiet, Rouiller and Gauchery 1956 a, b and Favard, Carasso and Fauré-Fremiet 1963).

**MATERIAL AND METHODS**

For transmission electron microscopy, gill filaments of European perch (*Perca fluviatilis*) heavily invaded with *T. epizootica* were cut off from living fish and fixed immediately in Palade's veronal buffered osmic fixative. Blocks were embedded in araldit (Fluka); sections were double stained with uranyl acetate and lead citrate and examined with Tesla 413 B and Hitachi 11 B electron microscopes. For scanning electron microscopy the ciliates were fixed in Pardue's fixative and prepared according to the technique outlined by Marszalek and Small 1968.

**RESULTS**

The body of *T. epizootica* is disc-shaped; its side walls are rounded to vaulted; the upper surface bears the peristomial adoral zone and hence is called the oral side. The bottom—aboral—face adheres to the substrate. This determines the body orientation
of this group—rather unusual among ciliates—along the oral-aboral axis instead of the ventrodorsal orientation. In fact, the aboral face can be homologized (Fauré-Fremiet, Favard and Carasso 1962) to the dorsal side of other ciliates.

The most salient features of the adhesive disc of *T. epizoootica* are known from light microscopy observations of live, unstained ciliates, as well as of those impregnated by silver methods. The concave surface of the disc is reinforced by arranged skeletal elements—denticles and radial pins. They are a protein in nature, as shown by Fauré-Fremiet and Thaureaux (1944) for *Trichodina tenvidens*. The periphery of the disc is formed by the border membrane, i.e., a pellicular fold reinforced by fine skeletal spikes. In *T. epizoootica* there are just two aboral ciliary wreaths around the body above the adhesive disc. The girdle of marginal cilia (aboral ciliary wreath No. I. in *Trichodina*) is missing. Right below the vaulted side wall of the body (there is no velum developed unlike *Trichodina*) there is the strong locomotory wreath of several rows of cilia (wreath No. II). Separated from it by a well-developed pellicular septum and inserted just above the border membrane, there is wreath No. III, a single row of cilia.

The following description of the ultrastructure will be centered exclusively on the organelles of the adhesive apparatus of *T. epizoootica*, which has not been described in detail as yet. Information concerning the general body organization of this genus at light microscope level may be found elsewhere (Lom 1963, 1964).

Description of the fine structure of other cell components (buccal apparatus, nuclei, cytoplasm) will be presented later.

a) Pellicle and supporting structures

The pellicle covers continuously the whole body, inclusive the surface of adhesive disc; on the latter there are large, very flat pellicular alveoli with irregular borders (Fig. 1, Plate V-1, Plate VI-1). The alveoli are covered by the outer cell membrane as in other ciliates. Thus the surface of the adhesive disc has a smooth lining of the pellicle with only insignificant elevations showing the outlines of the underlying skeletal denticles. Along the centrifugal ends of denticular blades, however, even the outer cell membrane is deeply invaginated (Plate V-1, Plate VI-1). Nevertheless, this invagination, in form of a very narrow slit only, does not interrupt the smooth surface of the adhesive disc. The image of the smooth lining of the disc is clearly seen also in the scanning electron microscope (Plate II-2).

The pellicular cover of the border membrane (Plate VI-1) is somewhat modified; flat pellicular alveoli occur only on the aboral face of the border membrane, while on its oral face all three pellicular membranes stick closely together. The ectoplasmic septum separating both aboral ciliary wreaths is also covered by pellicular alveoli, however fine and irregularly shaped they may be. The oral face of this septum, just beneath the pellicle, runs a flat ribbon of about 11 microtubules, similar to the septum of *Trichodina urinicolae* (Favard, Carasso and Fauré-Fremiet 1963). Evidently, the ribbon has a reinforcing function.

In the central area of the adhesive disc—with in the denticular ring—there are numerous barren kinetosomes oriented perpendicularly—or almost so—to the surface of the disc. In addition to that there are numerous pellicular pores.

The supporting structure of the adhesive disc consists of three types of skeletal formations—denticles, radial pins, and spikes of the border membrane—arranged in regular interconnected rings. The strongest of them are the denticles, interlocked at their conical central parts (Fig. 1, Plate I-2, Plate III-3, Plate V-1, Plate VI-3) and laterally extending into characteristic projections (Plate III-1). In contrast to the genera *Trichodina* or *Tripartiella*, the centrietal projection is but insignificantly developed,
while the centrifugal one forms a wide blade supporting the wall of the adhesive disc by its surface (Plate I-2, Plate V-1 and 3). High magnification discloses a periodicity of light and dark stripes, at intervals of about 120 Å, in the blades.

Above the ring of denticles, i.e., orally to them, there is the sheet-like circle of radial pins; there are 6 pins to each denticle, the total number ranging from 120—170. The more or less oval cross section of the more distal part of the radial pins measures about 0.14 by 0.4 µ, with the narrow side facing the surface of the adhesive disc (Plate III-2). The centripetal ends of the pins, tapered considerably, extend to the central conical parts of denticles, above which they are curved in an arch (Fig. 1, Plate V-1). The middle part of the radial pins widens in an interesting way: their aboral, narrow “upper” face extends to one side as an undulated sheet covering the period of two pins at one

Fig. 1. A simplified radial section through the periphery of the adhesive disc in *T. epizootica*, revealing mutual arrangement of its constituents. Barren kinetosomes of wreath No. 1 are not pictured, as well as the central part of the disc.

Fig. 2. Radial pins viewed from the oral face (top) and their transverse sections at levels indicated by dashed lines (bottom). Flat ends of radial pins are embraced by the split bases of the spikes of the border membrane; the kinetosomes associated with radial pins are drawn without their cilia.
side (Plate V-1 and 2, Plate VI-1 and 6). Undulated sheets of two adjoining radial pins fit one into another with their ridges. Near the centrifugal end of each radial pin, closely attached to its oral face, there is a kinetosome, bearing cilia of the IIIrd aboral ciliary wreath. The end of the pin is flattened in a direction parallel to the surface of the disc.

The radial pins are connected with other structures. They are joined mutually by radially orientated bundles of myofibrils (Plate III-4, Plate V-1) and also to the denticle blades. The oral face of centripetal ends of radial pins abuts on an optically empty cisterna bounded by a simple membrane. A transverse section through the pins (Plate V-3) reveals a rather complicated pattern of the whole system. Here the radial pins have an 8-shaped profile; the walls of the "empty" cisternae adhere to their oral face. Between the radial pins run thin osmiophil fibers within long, narrow and seemingly empty spaces close to the aboral limit of the "empty" cisternae. Empty spaces (Fig. 2) are also in the hollows of the 8-shaped profiles of the radial pins.

The middle part of the pins reveals a periodicity at intervals of about 95 Å.

The flat ends of the radial pins are joined to forked bases of the spikes of the border membrane (Fig. 1; Plate VI-1). Therefore, the spikes can move in oral-aboral direction, but not sideways (Plate VI-1, 2 and 3). The spikes, similar to a bird's claw, are about 0.23 µ long but only 820 Å wide, so that the flattened end of the radial pin can accommodate at least three spikes.

b) Aboral ciliary wreaths

Inserted between ciliated kinetosomes of the simple ciliary wreath No III. we find single barren kinetosomes (Plate III-2 and 4); their proximal ends are equipped with long fibers mentioned before to run between the radial pins. Very often (Fig. 3) these

![Diagram](https://via.placeholder.com/150)

**Fig. 3.** A diagrammatic representation of kinetosomes of the three aboral ciliary rows (I, II, III.). The dashed line indicates that all three rows can be considered a diversified polykinity consisting of oblique rows, each 8 kinetosomes long.

barren kinetosomes alternate regularly with ciliated kinetosomes. However, no other fibrillar structures could be detected to join kinetosomes of this ciliary girdle.

Ciliary wreath No. II plays the main role in the locomotion of the ciliate. It is composed of short, very obliquely arranged rows of six kinetosomes each, forming a continuous belt around the body. These short rows are slanted to the left when viewing the ciliate from the outside and from its aboral end. The proximal end of the kinetosomes is connected with two types of fibrillar structures. First, below the base of each kinetosome, i.e., below two points at its circumference which lie on a line linking the six kinetosomes in each row—there are two nodules of osmiophilic substance. These
nODULES give rise to strands of microfibrils (Plate IV-2) extending to the nodules at neighbouring kinetosomes and, thus, the six kinetosomes are connected in a row. Second, these nodules are connected also, beneath the centre of the kinetosomal cylinder, with the origin of long, strong fibers — ciliary rootlets of Favard, Carasso and Faurre-Fremiet (1963). These ciliary rootlets leave the kinetosomes at an oblique angle and centripetally along the oral face of the radial pins (Fig. 1), at which their tapering proximal ends seem to join the oral edges of the pins between the individual "empty" cisternae. The ciliary rootlets have a periodicity of about 130—140 Å.

Orally to wreath No. II, and without being separated by a distinct pellicular fold, there is a circle of barren kinetosomes (Plate IV-1 and 2), corresponding to ciliary wreath of marginal cilia of the genus Trichodina. However, there are no cilia in this wreath in T. epizootica; yet a fibrillar structure is associated with these kinetosomes, an osmiophil spur extending sidewise from it (Plate IV-2).

In spaces between the skeletal formations and kinetosomes there are numerous ribosomes and a small number of mitochondria. No link — fibrillar or other — could be detected to exist between the structures of the adhesive disc and the adoral zone of cilia, unlike in some other urceolariid genera (e.g., Urceolaria — Peshkovskaya 1926).

**DISCUSSION**

a) **FUNCTION OF THE ADHESIVE DISC**

An observation of a living *Trichodinella* on the gill surface indicates the fundamental properties of its adhesive disc — resiliency, firmness and contractility. In a ciliate gliding over the surface the disc is just slightly concave, being spread flat, and reveals a great plasticity as its border follows exactly the uneven profile of the substrate. On the contrary, in a firmly attached ciliate the disc is strongly vaulted to form a cup embracing epithelial cells of the gills. In our material fixed for electron microscopy, we could find all such variations in shape of the disc (Plate I-1, Plate II-2, Plate VI-1 to 3); the differences in the mutual configuration of all constituents of the disc permitted conclusions concerning their role in disc function during attachment.

The ring of massive skeletal denticles is the main supporting structure of the disc; joint-like junction of denticles permits also their tilting at different degrees of disc vaulting. The ring-like layer of radial pins above the denticles provides the walls of the disc with both resiliency and firmness. Due to the radial arrangement of the pins, the border of the disc can fit exactly into all unevennesses of the substrate even during the gliding of the ciliate over the substrate. Thus the ciliate can firmly adhere to the substrate at any time leaving no leak between the border of the disc and the epithelium. The overlapping, undulated flat extensions of radial pins greatly assist the firm interconnection of the pins.

The denticles and pins are connected with massive strands of microfibrils. Favard, Carasso and Faurre-Fremiet (1963) expressed their doubts on the myofibrillar nature of similar strands in *Trichodina urinicolae* because of the lack of perimyal vesicles known to exist in myonemes of peritrichs. However, the contractile function of these fibrils can hardly be doubted in view of the often forceful contraction of the disc bending sometimes even the elastic blades of the denticles for which no other element could be made responsible.

Contraction of myofibrils brings together the radial pins; it is more pronounced at the periphery, and the disc becomes vaulted. Myofibrillar connection between the pins
and underlying denticles prevents the disc from being vaulted in the opposite direction.

The border membrane is very important in this process. It can move freely up and down since the reinforcing spikes are movable in this direction around the ends of the radial pins. In a slightly attached ciliate with the disc still rather flat (Fig. 1, Plate IV-1), the spikes extend in the same direction as the radial pins or, when moving over an uneven substrate, they may be diverted upwards (Plate VI-1). In a disc constricted around epithelial cells the spikes and the pins form an obtuse till right angle (Plate VI-3) depending on how much the disc is vaulted, and cut sharply into the epithelial cells of the host.

The knowledge of the disc structure along with observation of living ciliates makes possible a clear explanation of its function. In a ciliate driven by a vigorous ciliary beat and gliding over the surface or rotating on the spot, the flat border membrane and septum between the ciliary wreaths can function as guiding planes for the water current produced by the cilia. A ciliate ready to attach itself stops its movement and its ciliary beat produces a water current pressing it close to the substrate. Then the border membrane bites into the substrate and seals off the space beneath the disc. Simultaneous contraction vaults the centre of the disc and this acts as a sucker — epithelial cells are “sucked” into the cup-shaped disc, being embraced firmly by the border membrane (Plate VI-2). Thus a very firm hold is achieved; a ciliate so attached maintains a mild ciliary beat.

b) RELATION TO THE HOST AND MECHANISM OF THE INJURY OF THE HOST CELL

Transmission micrographs as well as scanning microscopy revealed that the surface of the epithelium cannot be damaged by skeletal denticles, since they lie flat beneath the smooth surface of the disc and do not protrude outwards. However, host cells can be damaged by firmly attached ciliates by the border membrane, which cuts sharply into the gill surface, and may bring about irritation of the cell and, finally, a serious injury of the latter. A similar effect can be ascribed to the “sucking” of epithelial cells into the concavity of the disc. Plate I-1 and Plate II-1 reveal a serious damage in the host cell which can be explained by the action of the ciliate.

The pathogenicity of trichodinids depends on the number of ciliates present on the fish. A healthy fish supports only a minimal number of trichodinids, sparsely distributed over the surface. Firmly attached ciliates are always a minority; most of them glide over the surface, the degree of irritation being quite negligible—the ciliates are true ectocommensals, or, more precisely, symphoronts. When adverse conditions prevail against the fish—there may be many factors impairing the animal’s resistance—the suitability of the surface for trichodinids is essentially raised. Whichever the reason may be, the absence of inhibiting substances or the presence of stimulating ones on the surface of the fish, the trichodinids start to proliferate massively on the surface of the fish. A concomitant or earlier invasion by other parasites (e.g., Argulus—Sassman 1966, or monogenea—Noble 1963) may also have a favourable effect on the growth of these ciliates.

A mass of trichodinids causes inevitably severe irritation, which may result in an injury and disintegration of cells; the ciliates start to feed on cell debris and on the increased number of bacteria.

Under those circumstances, trichodinids may become real ectoparasites—they do not only damage their host, but feed on him, which is an essential criterium of parasitism. We witness here that the change in the degree of infestation alters the character of the invading protozoan, a symphoront becoming an ectoparasite.
Our experiment with the aquarium fish, *Puntius conchonius*, may serve as a good example of the importance of the host’s condition upon the invasiveness and pathogenicity of the parasite. We have kept a numerous population in a crowded tank with insufficient food. The fishes, concomitantly invaded by *Oodinium pillularis*, were covered by a continuous thick layer of trichodinids. After being kept for about 2 months in these conditions, they became emaciated, and were covered by a whitish layer of mucus, disintegrated epithelium and protozoa; they started to die. One half of the fish was then transferred into another tank, where they were kept under model conditions. Within a short time, the invasion disappeared; six weeks after the transfer the fish were again in good state and without an detectable invasion.

c) MORPHOGENESIS

Barren kinetosomes between distal ends of radial pins were found also in *Trichodina urinicola* and *Trichodinopsis paradoxa* (Favard, Carasso and Fauré-Fremiet 1963) and seems to be a common feature of urceolariids, playing a role in the morphogenesis of the new adhesive disc after fission. The “haploid” number of radial pins in adhesive discs of the two daughter individuals is completed by the appearance of new ones between the existing pins. The former originate as a thin fiber extending from the barren kinetosomes mentioned above, which gradually thickens. Thus the skeletal organelles of the adhesive disc are proved to originate as derivate of kinetosomes, similarly to the massive protein cytoskeleton in astomatous ciliates (De Puytorac 1958, 1963). The optical anisotropy observed by Fauré-Fremiet and Thaureaux (1944) is in obvious connection with our findings of periodical structures in the skeletal elements of the disc.

d) HOMOLOGIES OF THE ADHESIVE DISC AND OF THE SCOPULA OF SESSILINE PERITRICHES

Kinetosomes of the three aboral wreaths are all arranged into oblique rows (Fig. 3) so that they all together can be taken for a polykinety similar to the trochal band of sessilines peritrichs, which has been secondarily modified: the first (= barren wreath No. I) and last (= single ciliary girdle No. III) kinetosomes in each of the oblique rows are separated from the rest and differ also in their ciliary equipment and function and associated fibers. In ciliary wreath No. II., the kinetosomes are associated with microfibrillar links and ciliary rootlets of periodic structure similar to those in the trochal band of *Opisthobranchia* (Bradbury 1965). The stout supporting fibers accompanying kinetics of the trochal band of *Opisthobranchia* may have a similar function, even if they are hardly homologous to the radial pins. However, the homologies in the structure of the trochal band and aboral ciliary wreaths as well as barren kinetosomes occurring in both the scopula and adhesive disc, offer additional evidence in favour of the supposed origin of the suborder Mobilina from telotroch-like stages of the suborder Sessilina (Raabe 1952).

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Explanation of abbreviations used in figures and plates: A — pellicular alveolus; B — spikes of the border membrane; BM — border membrane; C — clear space above the radial pins; D — denticles; K — kinetosome; M — myofibrillar strands; P — peristomial ciliary spiral; R — radial pins; S — septum between ciliary wreaths; SF — striated ciliary rootlet.
УЛЬТРАСТРУКТУРА ПРИКРЕПИТЕЛЬНОГО ДИСКА У TRICHO-
NELLA EPIZOOTICA И НАНОСИМЫЙ ХОЗЯЙН ПОД КАВЕРНУ 

П. Лом

Резюме. Дано описание тонкой структуры прикрепительного диска у Trichodinella epizootica (Raabe), типичного представителя ойгонихихих триходинелл и изложена его функция. Прикрепление к поверхности тела хозяина является результатом сложной координации всех составных частей: зубчиков, радиальных колечек, шипов мембраны и абдоминальных ресничных клеток. На первых дисков прикрепляются к поверхности ударами ресничек, затем его пространство отсасывается мембраной, врезающей свой острые края в ткань, причем диск вздувается и образует присоску в виде чашечки. Хозяйская ткань повреждается острыми краями мембраны и тем, что клетки вытнуты в выделяемый диск. Общий вид наносимый рыбой зависит от интенсивности поражения, но в целом условия благоприятны для рыб, триходинеллы ведут себя как симбионты. На рыбах с пониженной устойчивостью последствия других факторов они ведут себя как паразиты.

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Fig. 1. A radial section through an attached Trichodinella epizootica. The rim of the border membrane cuts deep into the epithelial cells of the host which are pulled in to fill the space of the adhesive disc. $\times 4,000$; the scale indicates 5 $\mu$.

Fig. 2. A tangential section through the ciliate attached to a secondary gill filament whose part is pulled into a considerably vaulted adhesive disc $\times 6,000$; the scale indicates 5 $\mu$. 
Fig. 1. A section through another ciliate attached to the gill filament; note the cross-section of a horse-shoe shaped macronucleus; to the left is the peristomial ciliary spiral; there is also a cross-section through the infundibulum with its ciliary row. × 4,000; scale equals 5 μ.

Fig. 2. A scanning electron micrograph revealing the real shape of the adhesive disc, its smooth pellicular lining and sharp edge of the border membrane. × 4,000.
Fig. 1. Adhesive disc of *T. epizootica* impregnated with Klein's dry silver method. × 3,000.

Fig. 2. The periphery of the adhesive disc cut tangentially at the level of kinetosomes of wreath No. 111, which are associated with the end parts of radial pins. Between the pins are barren kinetosomes. × 24,000; scale equals 0.8 μ.

Fig. 3. A section parallel with the surface of the adhesive disc. Interlocked central parts of denticles are surrounded by the proximal end of the radial pins (R); note the barren kinetosome in the centre of the disc. × 23,000, scale equals 0.5 μ.

Fig. 4. Longitudinal section of radial pins with associated kinetosomes; one of the barren kinetosomes is also visible. Note the myofibrillar strands connecting the pins, and also numerous ribosomes × 36,000; scale equals 0.5 μ.
Fig. 1. Section through the periphery of the disc showing border membrane pressed into the surface of the host cell, cross section through radial pins with associated kinetosomes, barren kinetosomes, as well as kinetosomes of the two other ciliary wreaths. × 30,000; scale equals 1 μ.

Fig. 2. Transverse section through kinetosomes of the three aboral rings (I, II, III) with associated fibrillar structures. × 50,000; scale equals 0.5 μ.
Fig. 1. Section through interlocked denticles and associated structures. \( \times 31,000 \); scale equals 1 \( \mu \).

Fig. 2. Radial pins with undulated, overlapping extensions; to the left and right, ciliary rootlets of ther polykinety (II) kinetosomes. \( \times 22,000 \); scale equals 1 \( \mu \).

Fig. 3. Transverse section through the denticle blades and radial pins with adhering clear cisterna, \( \times 34,000 \); scale equals 1 \( \mu \).

Fig. 4. Detail of the area pictured in Fig. 2, showing the periodicity of radial pins. \( \times 114,000 \); scale equals 0.1 \( \mu \).
Figs. 1 to 3. Periphery of the adhesive disc: spikes of the border membrane set at various angles to the radial pins, so that, accordingly, the border membrane is more or less pressed into the epithelial cell. × 13,000; × 12,000; × 8,000; the scales equal 1 μ.

Fig. 4. Flat endings of pins with adjoining spikes; above, the ciliary rootlets. × 17,000; the scale equals 1 μ.

Fig. 5. Undulated extension of the radial pin overlapping another pin; to the right, the end of undulated extensions of a foregoing pin. × 52,000.