

ResearchOnline@JCU

This file is part of the following reference:

Smith, Richard Stewart (1985) *Photoreceptors of serpulid polychaetes*. PhD thesis, James Cook University.

Access to this file is available from:

<http://eprints.jcu.edu.au/24188/>

If you believe that this work constitutes a copyright infringement, please contact ResearchOnline@jcu.edu.au and quote <http://eprints.jcu.edu.au/24188/>

VOLUME TWO

List of Figures

Figure	Title	Page
Chapter 2		
1	Location maps of major collection sites.	425
2	Members of the <i>Spirobranchus giganteus</i> complex: Live appearance (colour plate).	426
3	Opercula of the <i>Spirobranchus giganteus</i> complex.	427
4	Bayonet collar setae of the <i>Spirobranchus giganteus</i> complex.	428
5	Thoracic and abdominal setae and uncini of the <i>Spirobranchus giganteus</i> complex.	429
6	Opercula of the <i>Spirobranchus tetraceros</i> complex and <i>Spirobranchus sinensis</i> .	430
7	Bayonet collar setae of the <i>Spirobranchus tetraceros</i> complex and <i>Spirobranchus sinensis</i> .	431
8	Setal details of the <i>Spirobranchus tetraceros</i> complex and <i>Spirobranchus sinensis</i> .	432
9	Live appearance of some studied serpulids (colour plate).	433
10	Setal characteristics and opercula of <i>Galeolaria caespitosa</i> and <i>Serpula jukesti</i> .	434
11	Setal characteristics of <i>Protula tubularia</i> and <i>Protula anomala</i> .	435
12	Setal characteristics of <i>Protula bispiralis</i> and <i>Salmacina</i> sp.	436
13	<i>Salmacina</i> sp.	437
Chapter Three		
14	Embryology.	438
15	Early differentiation.	439
16	Two eyed trochophore.	440
17	Larval muscle system (schematic).	441
18	Distribution of larvae in relation to light.	442
19	Nectochaete and metamorphosing larva.	443
20	Searching phase larva and settled larva.	444
21	Settlement.	445
22	Scanning electron micrographs of juvenile tubes.	446
23	Detail of pinnule tip.	447
24	Juvenile <i>Spirobranchus giganteus</i> sp.A (Orpheus Island).	448
25	Opercular differentiation.	449
26	Juvenile <i>Spirobranchus giganteus</i> sp.A (Lateral view).	450
Chapter Four		
27	Sensory cilia tufts (scanning electron micrographs).	451
28	Sensory cilia tufts (transmission electron micrographs).	452
29	Diagram of the trochophore ocellus of <i>Spirobranchus giganteus</i> sp.A.	453

30	The trochophore ocellus of <i>S. giganteus</i> sp.A (T.E.M.).	454
31	The trochophore ocellus of <i>S. giganteus</i> sp.A (T.E.M.).	455
32	The trochophore ocellus and juvenile ocellus of <i>S. giganteus</i> sp.A (T.E.M.).	456
33	Diagram of the brain of <i>S. giganteus</i> sp.A.	457
34	Diagram of the brain of <i>S. giganteus</i> sp.A.	458
35	Diagram of the brain of <i>S. giganteus</i> sp.A.	459
36	Diagram of an adult cerebral ocellus of <i>S. giganteus</i> sp.A.	460
37	The cerebral ocellus of <i>S. giganteus</i> sp.A (T.E.M.).	461
38	The cerebral ocellus of <i>S. giganteus</i> sp.A (T.E.M.).	462
39	The cerebral ocellus of <i>S. giganteus</i> sp.A (T.E.M.).	463
40	The cerebral ocellus of <i>S. giganteus</i> sp.A (T.E.M.) - mitochondria/rootlet associations.	464
41	The cerebral ocellus of <i>S. giganteus</i> sp.A (T.E.M.) - mitochondria/rootlet associations.	465
42	The cerebral ocellus of <i>S. giganteus</i> sp.A (T.E.M.) - mitochondria/rootlet association.	466
43	Diagrammatic representation of a mitochondria - rootlet association.	467
44	Live appearance of <i>Spirobranchus</i> eyes (colour plate).	468
45	The compound branchial eye of <i>Spirobranchus</i> (optical and S.E.M.).	469
46	Diagram of a single photoreceptor unit from the compound eye of <i>Spirobranchus</i> .	470
47	The compound eye of <i>Spirobranchus</i> (T.E.M.): Distal sensory cell.	471
48	The compound eye of <i>Spirobranchus</i> (T.E.M.): Distal sensory cell.	472
49	The compound eye of <i>Spirobranchus</i> (T.E.M.): Distal sensory cell.	473
50	The compound eye of <i>Spirobranchus</i> (T.E.M.): Rhabdom.	474
51	The compound eye of <i>Spirobranchus</i> (T.E.M.): Rhabdom.	475
52	The compound eye of <i>Spirobranchus</i> (T.E.M.): Rhabdom.	476
53	The compound eye of <i>Spirobranchus</i> (T.E.M.): Rhabdom.	477
54	The compound eye of <i>Spirobranchus</i> (T.E.M.): Accessory organelles of rhabdom.	478
55	The compound eye of <i>Spirobranchus</i> (T.E.M.): Proximal sensory segment and upper soma.	479
56	The compound eye of <i>Spirobranchus</i> (T.E.M.): Lamellar region.	480
57	Diagram of a sensory cilium of the photosensory cell.	481

LEGEND FOR PHOTORECEPTOR LINE DIAGRAMS

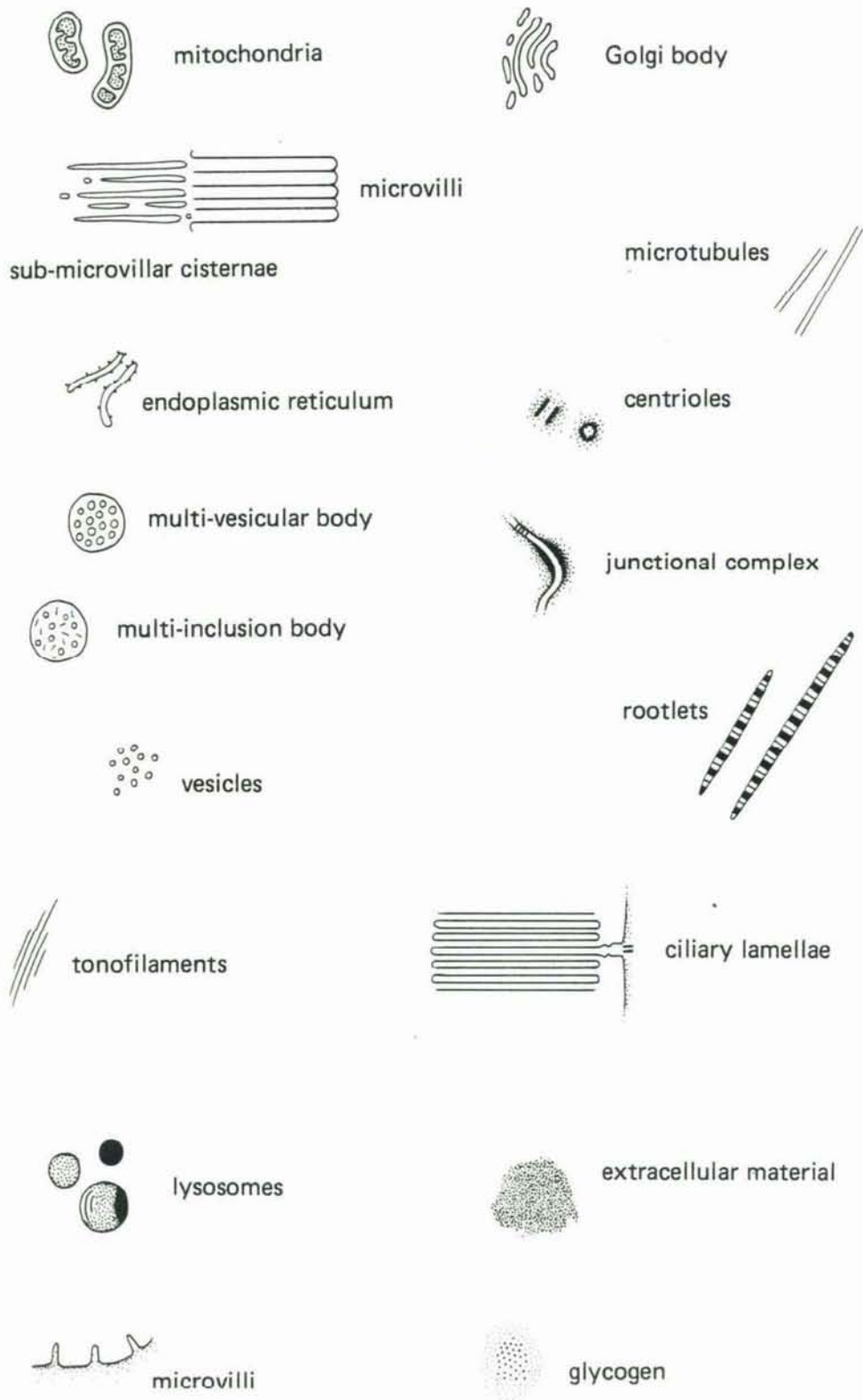


FIGURE 1 : LOCATION MAPS OF MAJOR COLLECTION SITES

- A - The Australian continent showing the location of the three eastern Australian sampling regions (B,C and D).
- B - The coastline at Sydney, New South Wales.
- C - Lizard Island and surrounds; northern section, Great Barrier Reef.
- D - The coastline of the central section of the Great Barrier Reef. The dotted line east of Magnetic Island represents the approximate position of benthic sledge sampling stations.

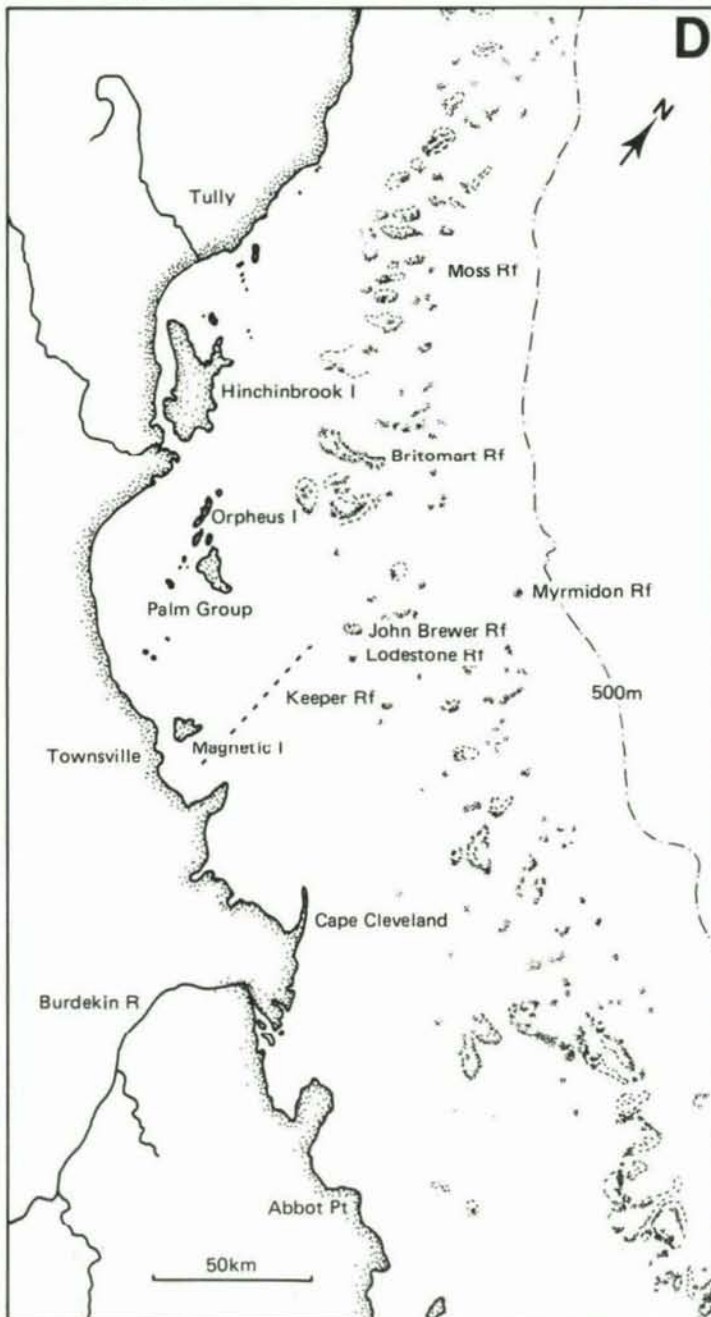
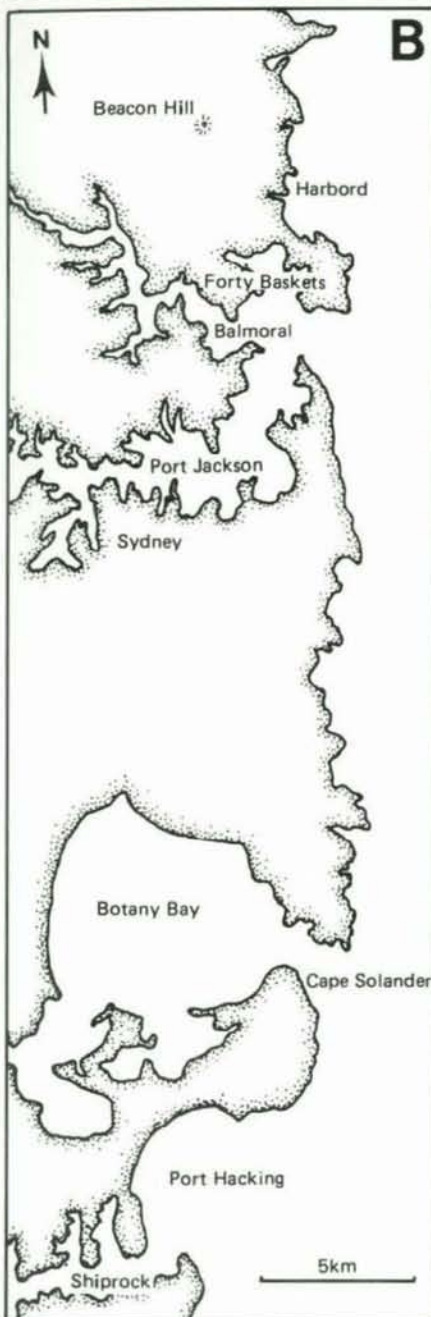
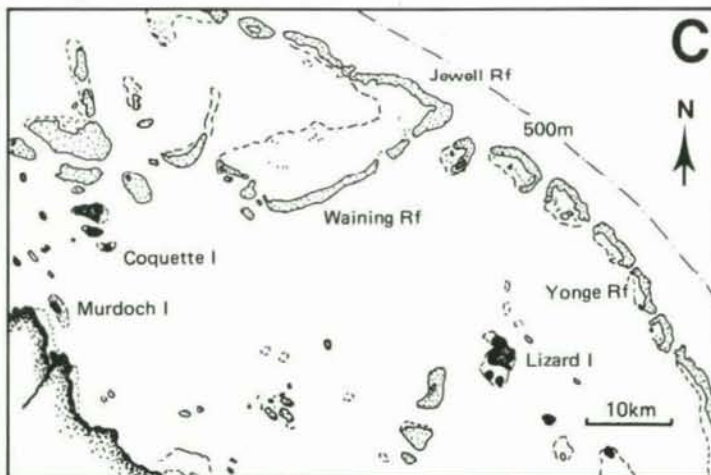
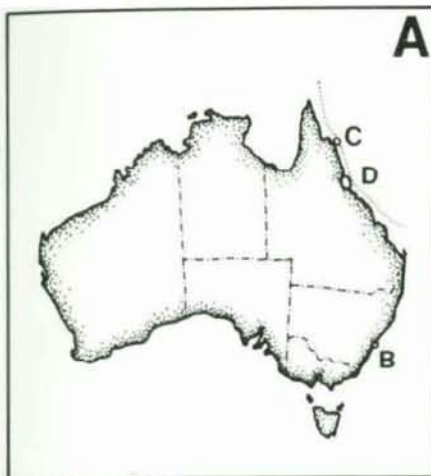


FIGURE 2 : MEMBERS OF THE *SPIROBRANCHUS GIGANTEUS* COMPLEX =
LIVE APPEARANCE (COLOUR PLATE)

- A - *Spirobranchus giganteus* sp.A. Red colourmorph
photographed at Lizard Island. Scale bar = 1cm.
- B - *S. giganteus* sp.B. Navy blue colourmorph photographed
at Lizard Island. Scale bar = 1cm.
- C - *S. giganteus* sp.C. Yellow colourmorph photographed
at Orpheus Island. Scale bar = 0.3cm.
- D - *S. giganteus* sp.D. Photographed in aquarium, Orpheus
Island. Scale bar = 0.3cm.
- E - *S. gardineri*. White colourmorph, photographed at
Lizard Island. Scale bar = 1cm.
- F - *S. gardineri*. Yellow colourmorph, photographed at
Orpheus Island. Scale bar = 1cm.

Note: photographic reproduction does not match exactly
the colour of the live material.

Details of tube and opercular morphology are best displayed
when worms are withdrawn. The red-orange compound
branchial eyes can be seen at the base of the branchial
crown in most of these photographs.

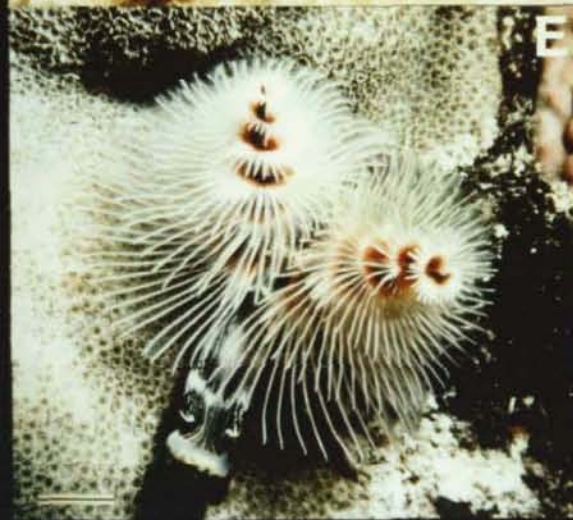
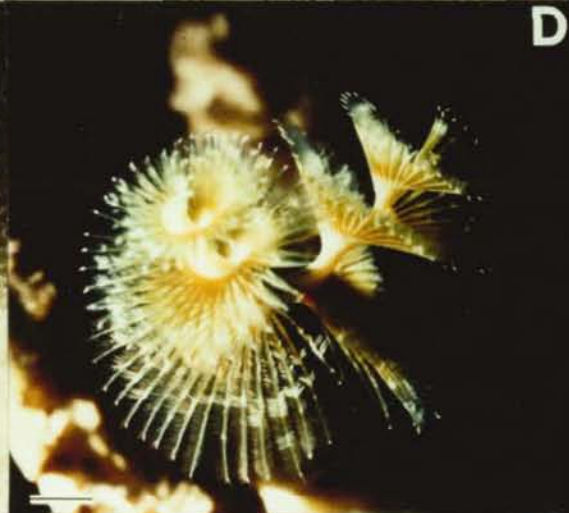
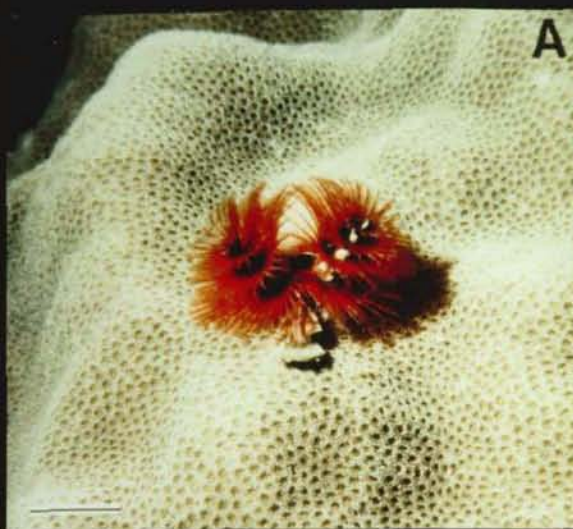


FIGURE 3 : OPERCULA OF THE *SPIROBRANCHUS GIGANTEUS* COMPLEX

A,B - *S. giganteus* sp.A, dorsal views.

C,D - *S. giganteus* sp.B, dorsal views.

E,F - *S. giganteus* sp.C, dorsal views.

G,H - *S. gardineri*, ventral (G) and dorsal (H) views.

I,J - *S. gardineri* type 1, ventral (I) and dorsal (J) views.

K,L - *S. gardineri* type 2, ventral (K) and dorsal (L) views
(different opercula).

All scale bars = 1mm

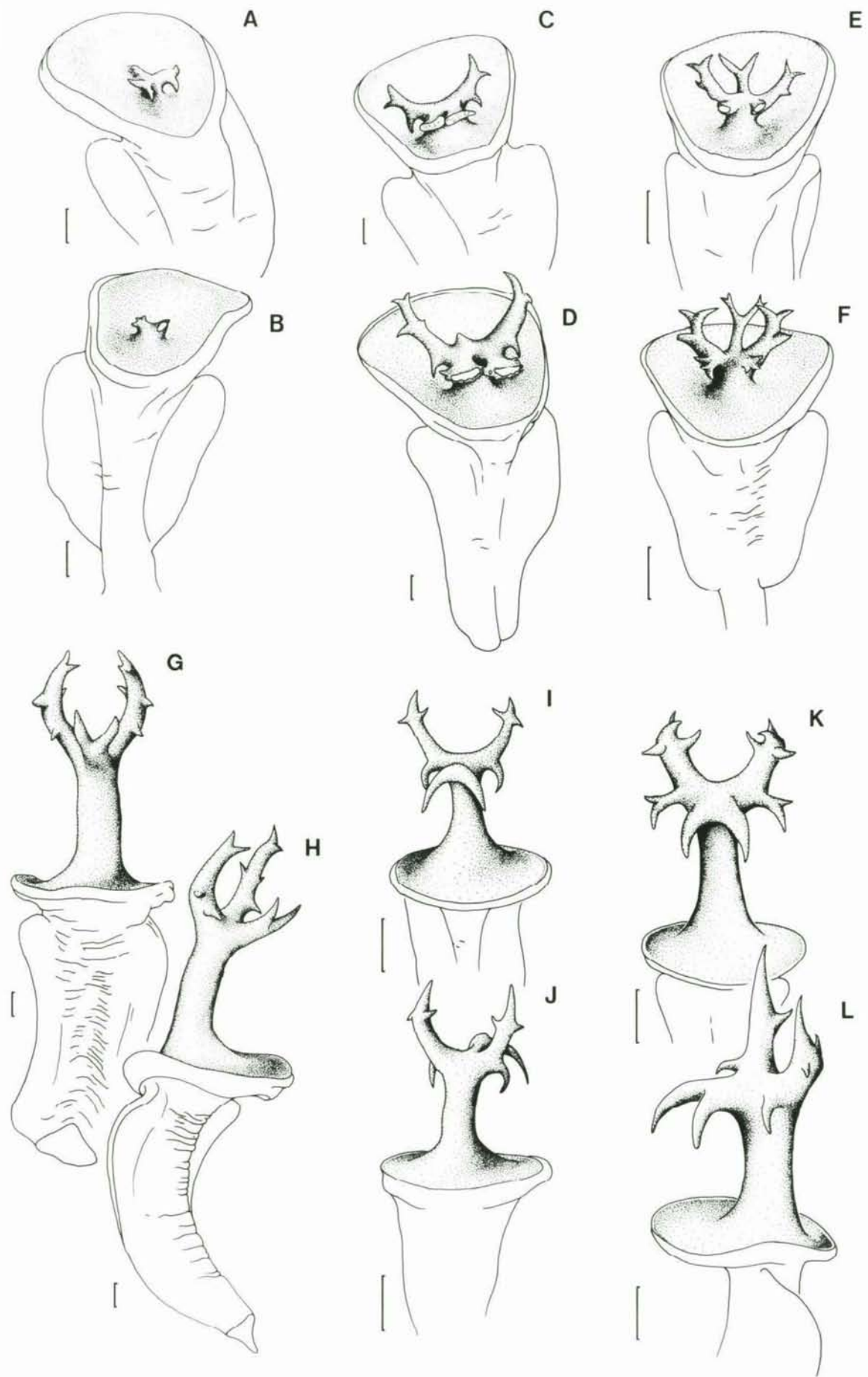


FIGURE 4 : BAYONET COLLAR SETAE OF THE *SPIROBRANCHUS GIGANTEUS* COMPLEX

- A-E - *S. giganteus* sp.A
F-I - *S. giganteus* sp.D
J-N - *S. giganteus* sp.B
O-Q - *S. giganteus* sp.C
R,S - *S. gardineri* type 2
T-W - *S. gardineri*
X,Y - *S. gardineri* type 1

Scale bar = 0.1mm

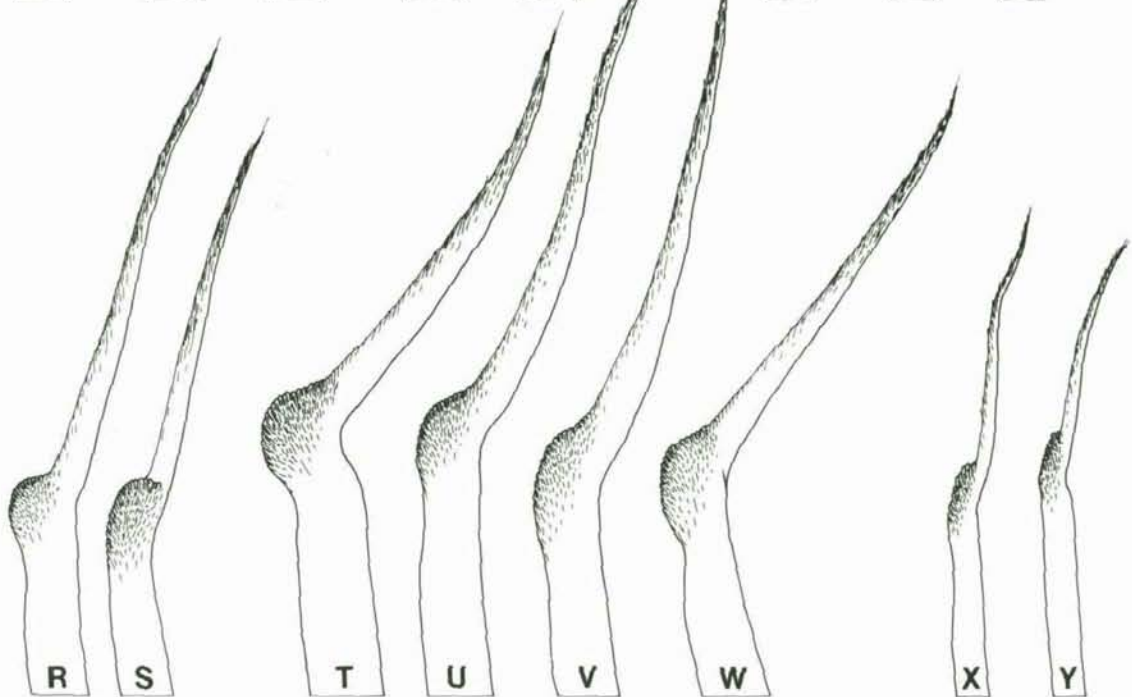
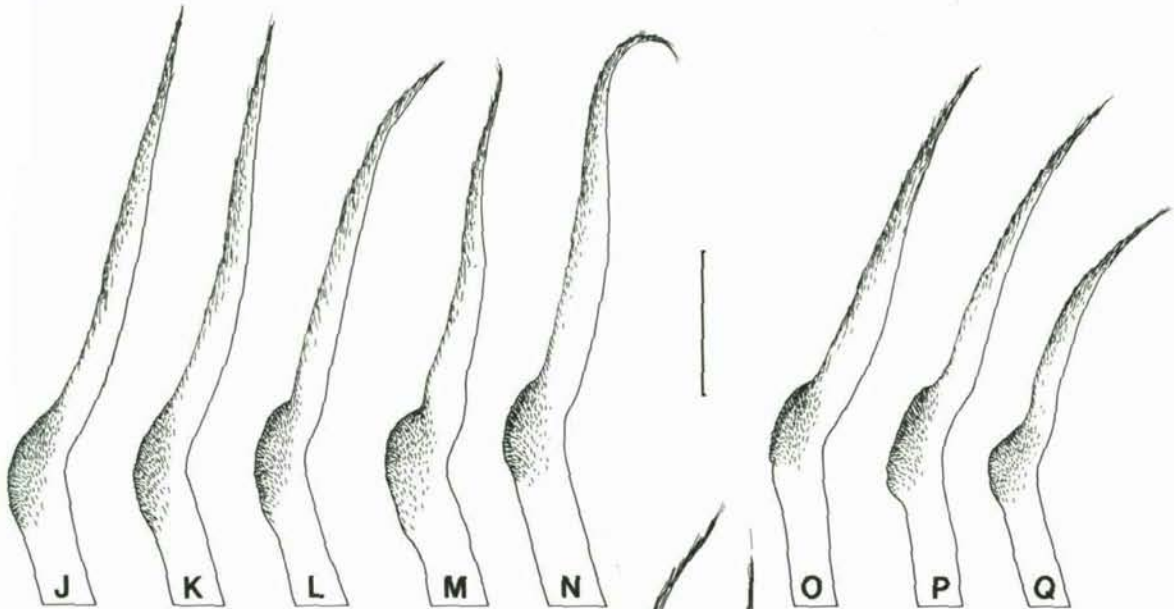
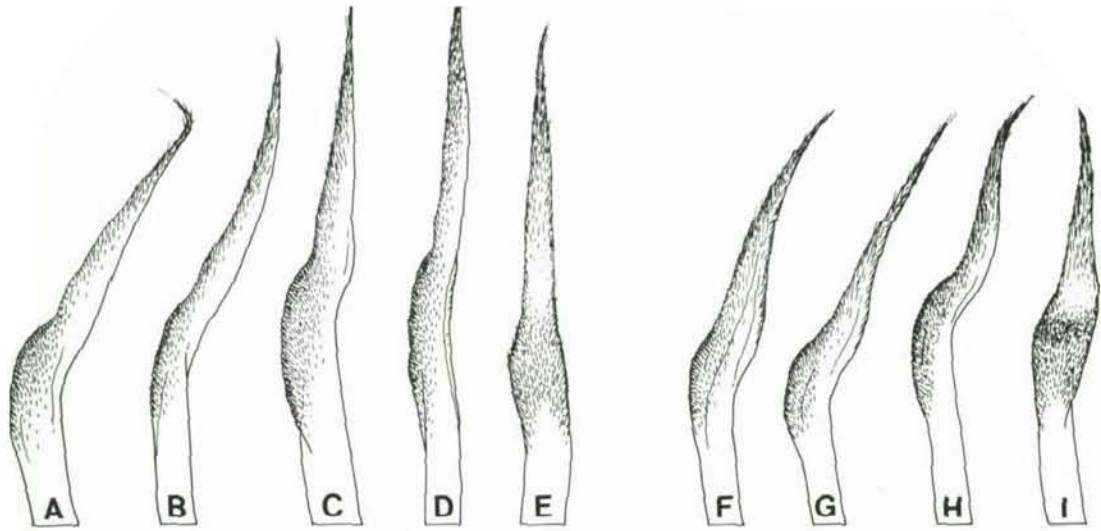


FIGURE 5 : THORACIC AND ABDOMINAL SETAE AND UNCINI OF THE
SPIROBRANCHUS GIGANTEUS COMPLEX

Top row - Thoracic setae. Scale bar = 50µm

Middle row - Thoracic uncini (outer) and abdominal
uncini (inner). Scale bar = 50µm.

Bottom row - Abdominal setae. Scale bar = 50µm.

Vertical rows - *S. giganteus* sp.A : A,F,G,P
S. giganteus sp.B : B,H,I,Q
S. giganteus sp.C : C,J,K,R
S. giganteus sp.D : D,L,M,S
S. gardineri : E,N,O,T

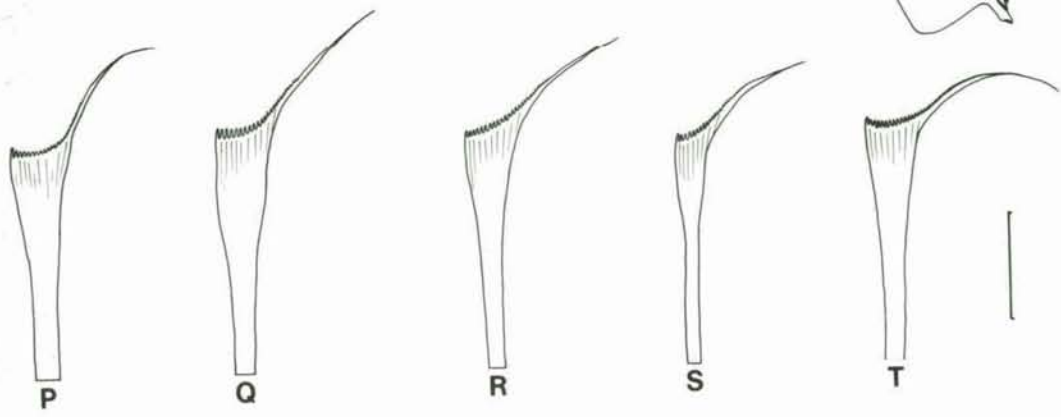
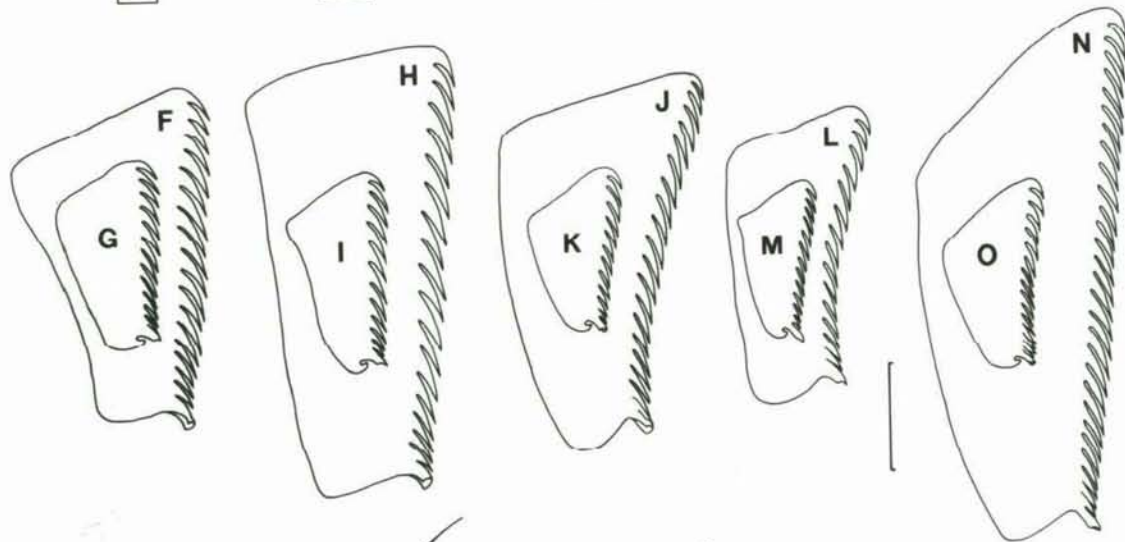
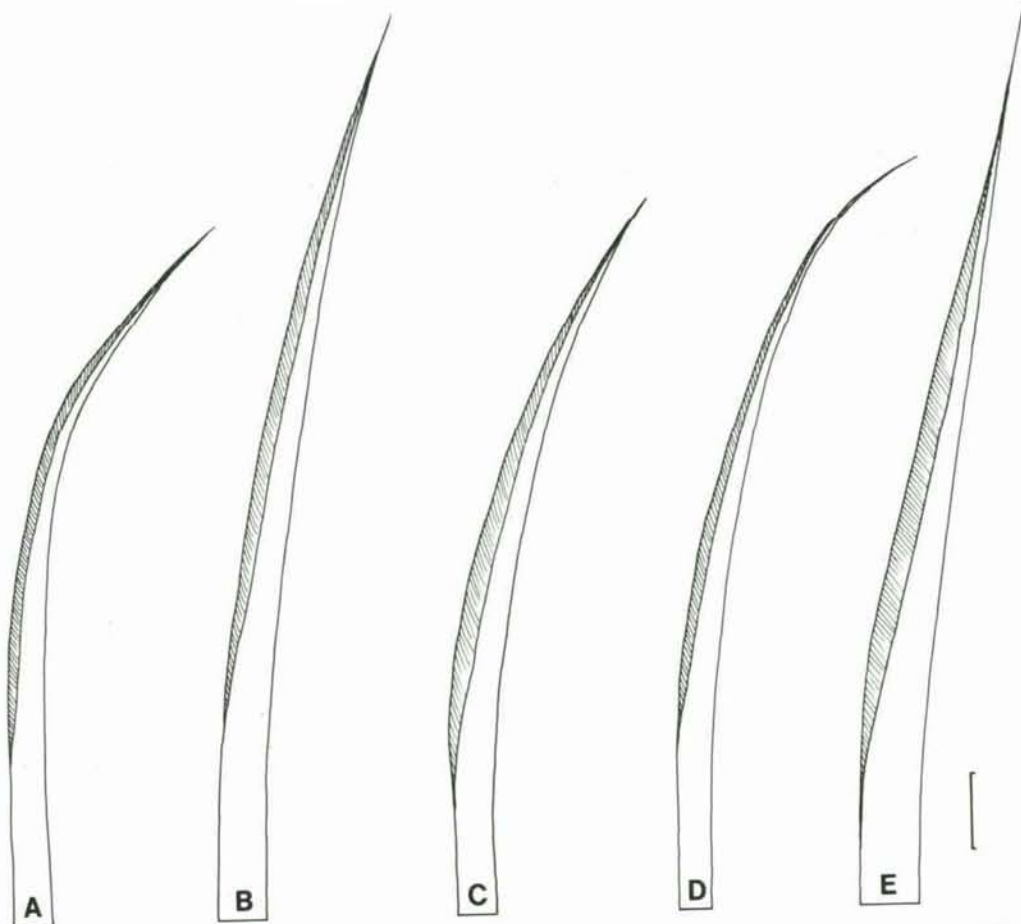


FIGURE 6 : OPERCULA OF THE *SPIROBRANCHUS TETRACEROS* COMPLEX
AND *SPIROBRANCHUS SINENSIS*

A,B - *S. tetraceros* sp.A, dorsal view (A) and view from
above (B) with dorsal uppermost.

C,D - *S. tetraceros* sp.B, dorsal view (C) and view from
above (D) with dorsal uppermost.

E,F - *S. tetraceros* sp.C, dorsal view (E) and ventral
view (F)

G,H - *S. decoratus*, dorsal view (G) and ventral view (H)

I,J - *S. sinensis*, juvenile (I) and adult (J) opercula.
(Both dorsal views).

All scale bars = 1mm

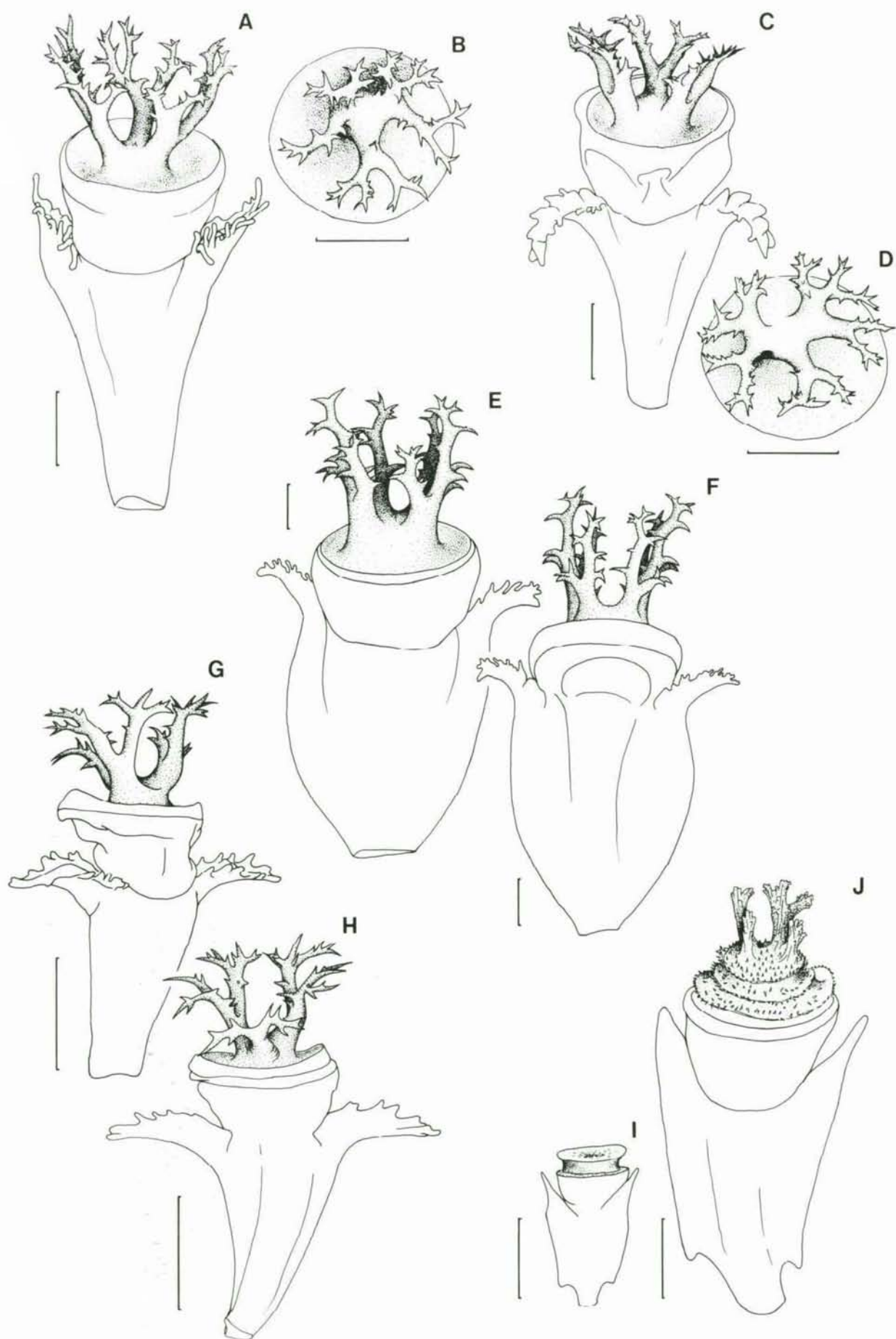


FIGURE 7 : BAYONET COLLAR SETAE OF THE *SPIROBRANCHUS TETRACEROS*
COMPLEX AND *SPIROBRANCHUS SINENSIS*

A-C - *S. tetraceros* sp.A

D-F - *S. tetraceros* sp.B

G-J - *S. tetraceros* sp.C

L,M - *S. decoratus*

N,O - *S. sinensis*

Scale bar = 0.1mm

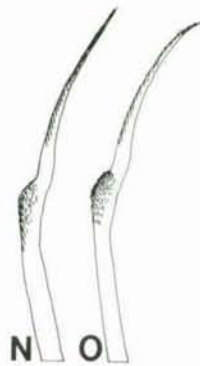
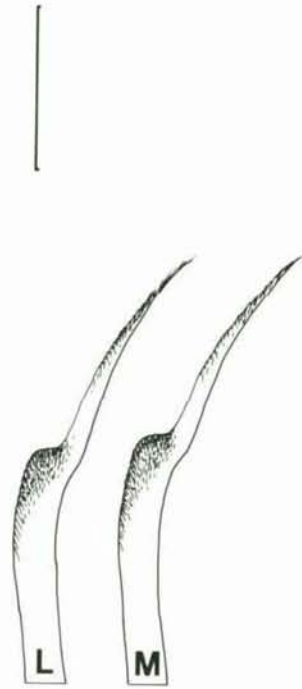
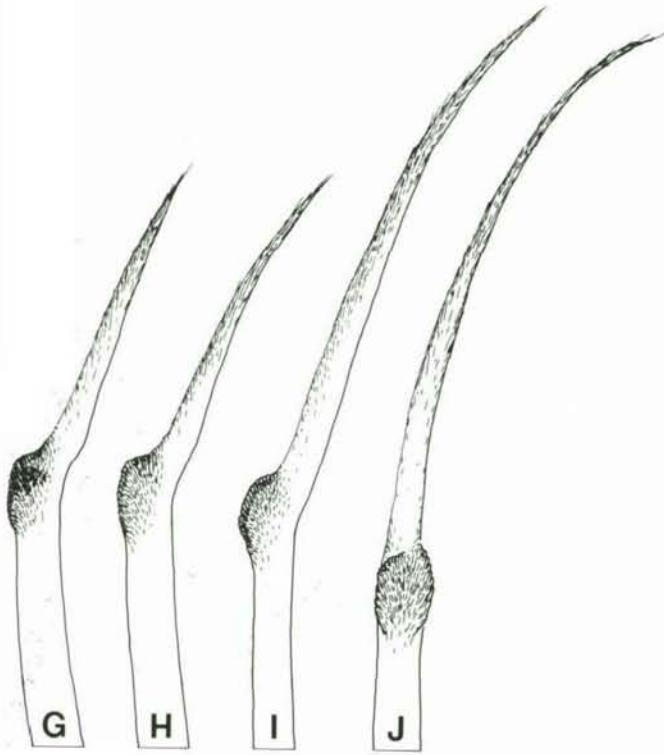
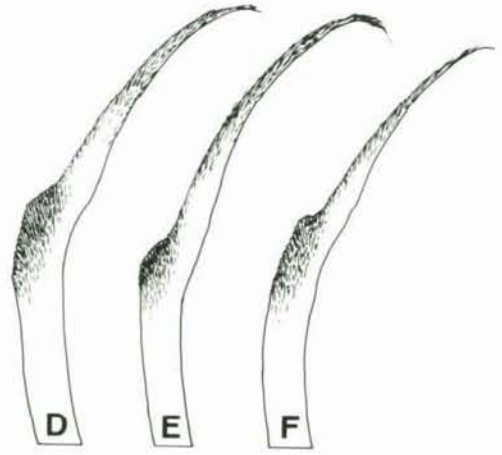
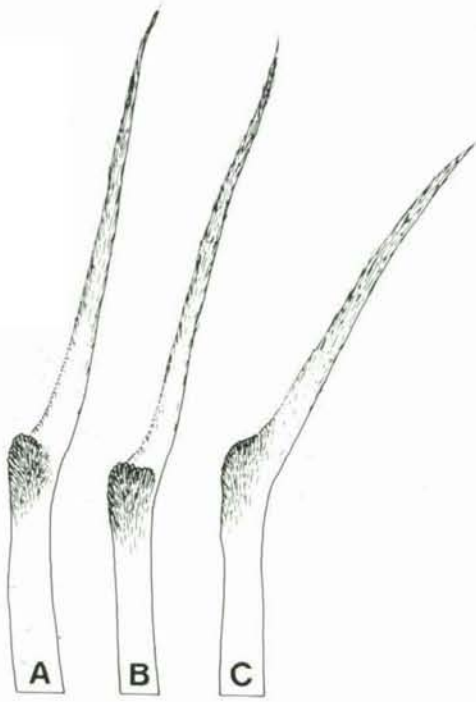


FIGURE 8 : SETAL DETAILS OF THE *SPIROBRANCHUS TETRACEROS* COMPLEX AND *SPIROBRANCHUS SINENSIS*

- Top row - Thoracic setae. Scale bar = 50µm.
- Second row - Thoracic uncini. Scale bar = 50µm.
- Third row - Abdominal uncini. Scale bar = 50µm.
- Fourth row - Distal edge of branchial membrane.
Scale bars = 0.5mm.
- Bottom row - Abdominal setae. Scale bar = 50µm.
- Vertical rows - *S. tetraceros* sp.A : A,F,G,P,U
S. tetraceros sp.B : B,H,I,Q,V
S. tetraceros sp.C : C,J,K,R,W
S. decoratus : D,L,M,S,X
S. sinensis : E,N,O,T,Y
- Inset - The difference in appearance of the anterior uncinal tooth between the *S. giganteus* complex and the *S. tetraceros* complex.
a = *S. tetraceros* complex, vertical view
b = *S. giganteus* complex, vertical view

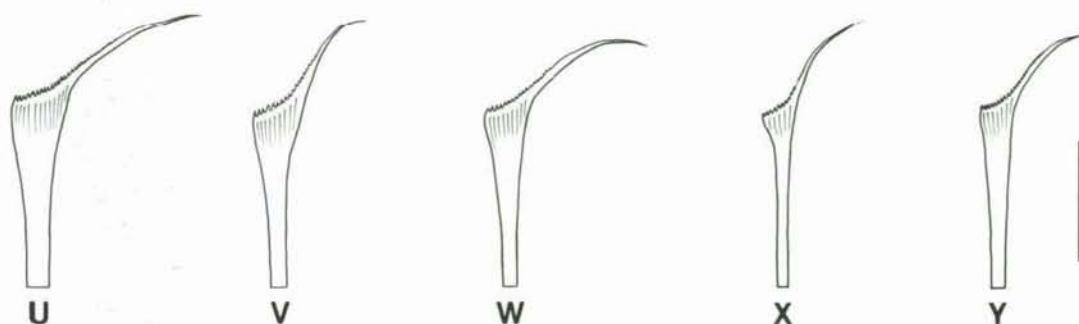
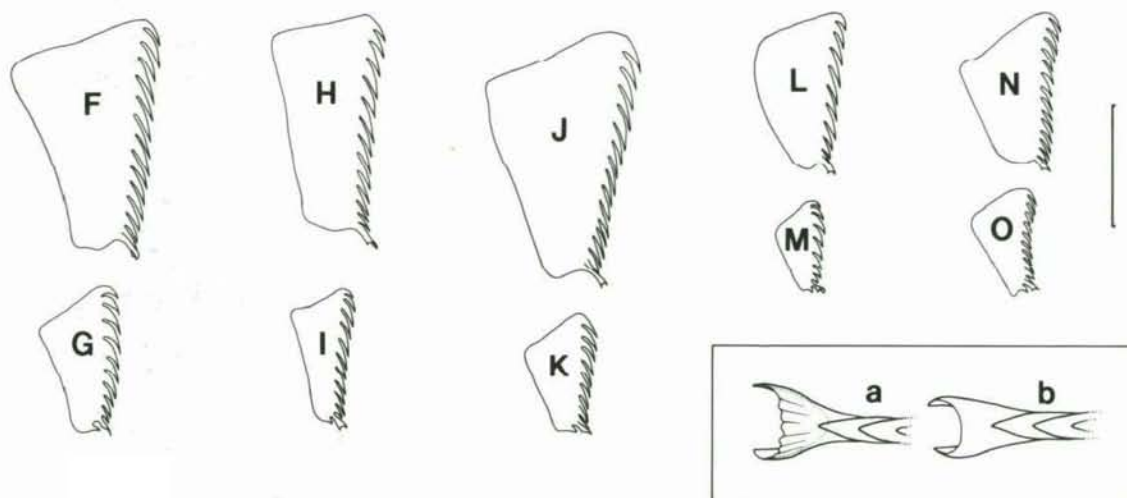
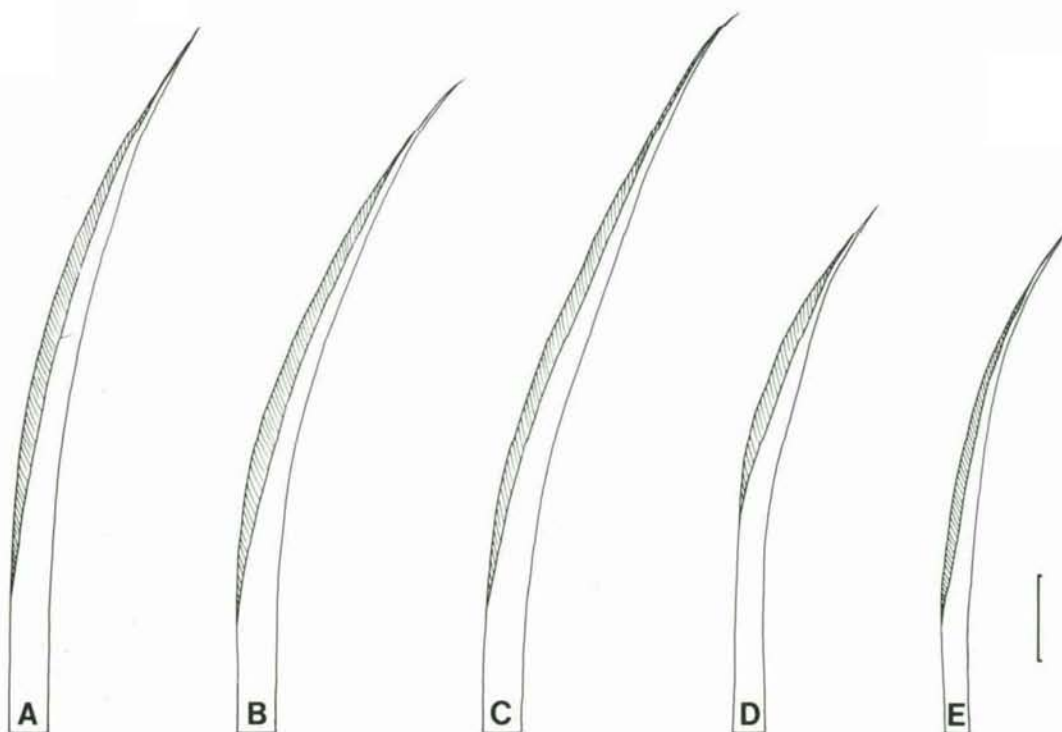


FIGURE 9 : LIVE APPEARANCE OF SOME STUDIED SERPULIDS
(COLOUR PLATE)

- A - *Spirobranchus tetraceros* sp.B. Pink colourmorph
(Orpheus Island). Scale bar = 1mm.
- B - *Galeolaria caespitosa* (Harbord Beach, Sydney).
Scale bar = 0.5mm.
- C - *Serpula jukesii* (Abbot Point).
Scale bar = 1cm.
- D - *Protula tubularia* (Shiprock, Sydney).

Scale bar = 1mm.
- E - *Protula hispiralis* (Lizard Island).
Scale bar = 1cm.
- F - *Salmacina* sp. (off Townsville - photomicrograph of
detubed animals, note the cerebral ocelli which appear
as dark spots in the lower prostomium).
Scale bar = 0.5mm.

Note: this photographic reproduction does not match
exactly the colour of the live material.

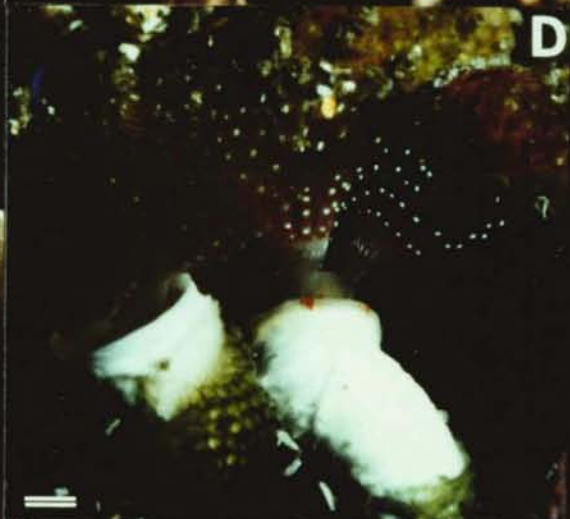
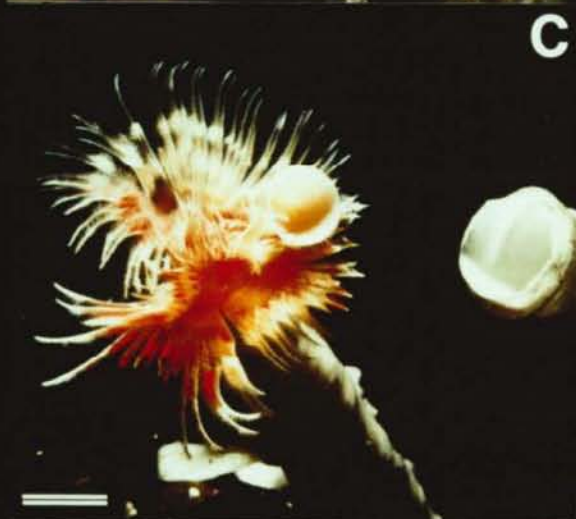


FIGURE 10 : SETAL CHARACTERISTICS AND OPERCULA OF *GALEOLARIA CAESPITOSA* AND *SERPULA JUKESII*

Galeolaria caespitosa A - Operculum, ventral view.

Scale bar = 0.5mm.

B - Limbate collar seta.

Scale bar = 50µm.

C - Limbate thoracic seta.

Scale bar = 50µm.

D - Capillary abdominal seta.

Scale bar = 50µm.

E - Abdominal geniculate seta.

Scale bar = 50µm.

F - Thoracic uncinus.

Scale bar = 50µm.

G - Abdominal uncinus

Scale bar = 50µm.

Serpula jukesii

H - Operculum. Scale bar = 1mm.

I-K - Bayonet collar setae (different specimens). Scale bars = 50µm.

L - Limbate collar seta.

Scale bar = 50µm.

M - Limbate thoracic seta.

Scale bar = 50µm.

N - Abdominal capillary seta.

Scale bar = 50µm.

O - Abdominal trumpet-shaped seta.

Scale bar = 50µm.

P - Thoracic uncini.

Scale bar = 50µm.

Q - Abdominal uncini.

Scale bar = 50µm.

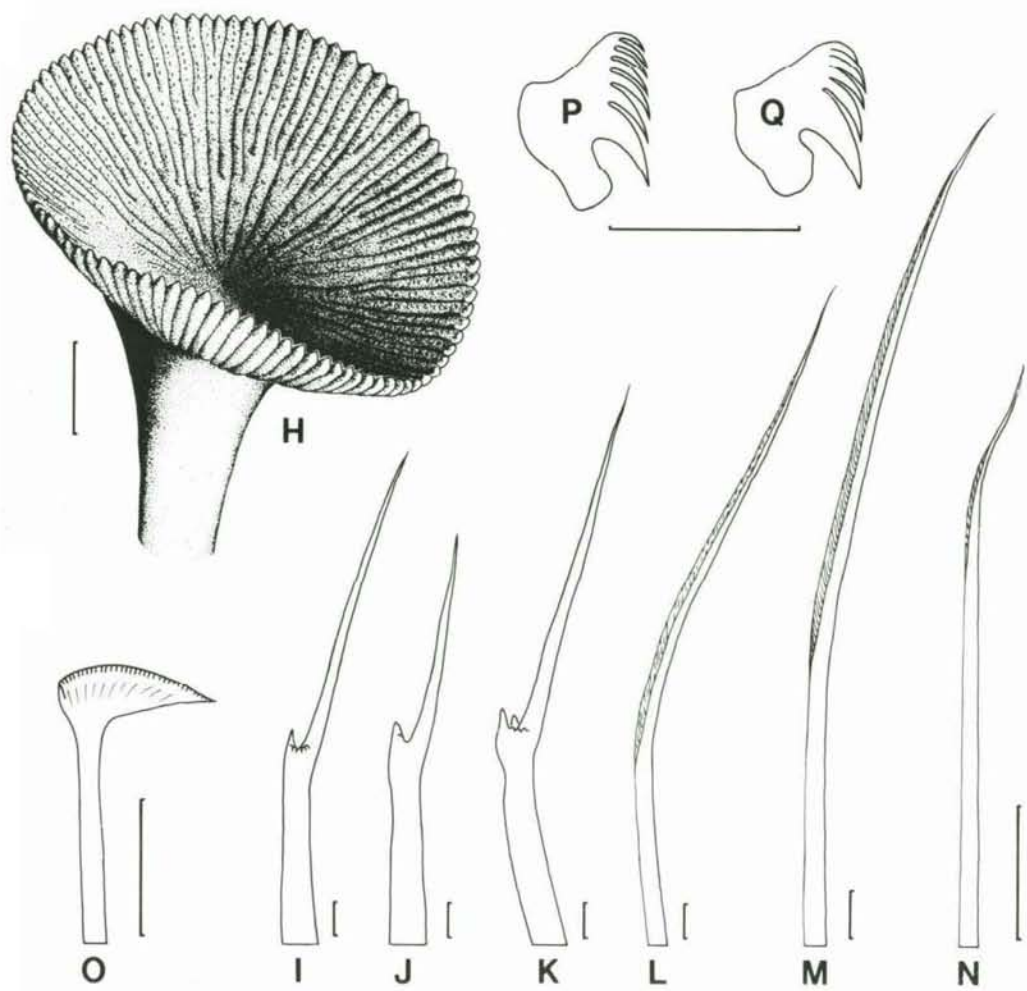
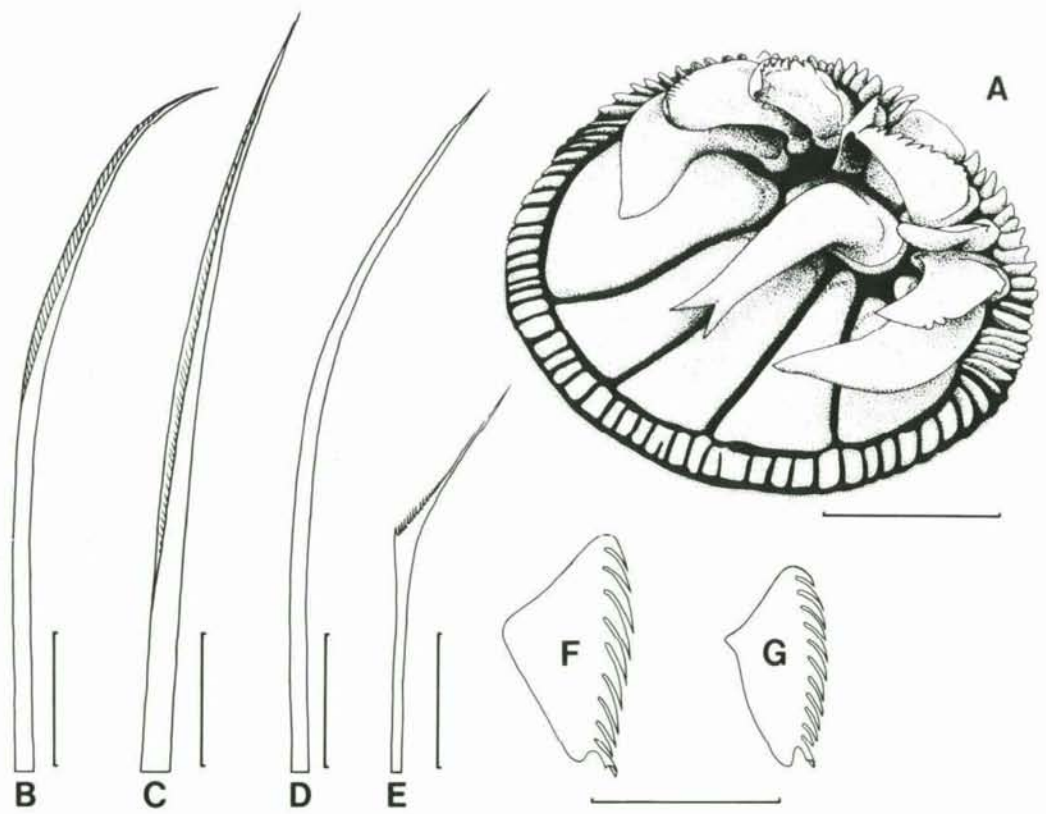


FIGURE 11 : SETAL CHARACTERISTICS OF *PROTULA TUBULARIA* AND
PROTULA ANOMALA

- Protula tubularia*
- A - Collar seta. Scale bar = 50µm.
 - B - Limbate thoracic seta.
Scale bar = 50µm.
 - C - Capillary thoracic seta.
Scale bar = 50µm.
 - D - Thoracic sickle-shaped seta.
Scale bar = 50µm.
 - E - Abdominal capillary seta.
Scale bar = 50µm.
 - F - Abdominal sickle-shaped seta.
Scale bar = 50µm.
 - G - Thoracic uncinus.
Scale bar = 20µm.
 - H - Abdominal uncinus.
Scale bar = 20µm.
- Protula anomala*
- I - Collar seta. Scale bar = 25µm.
 - J - Thoracic limbate seta.
Scale bar = 25µm.
 - K - Thoracic "capillary" seta.
Scale bar = 50µm.
 - L - Thoracic sickle-shaped seta.
Scale bar = 50µm.
 - M - Abdominal capillary seta.
Scale bar = 50µm.
 - N - Abdominal sickle-shaped seta.
Scale bar = 50µm.
 - O - Thoracic uncinus.
Scale bar = 20µm.
 - P - Abdominal uncinus.
Scale bar = 20µm.

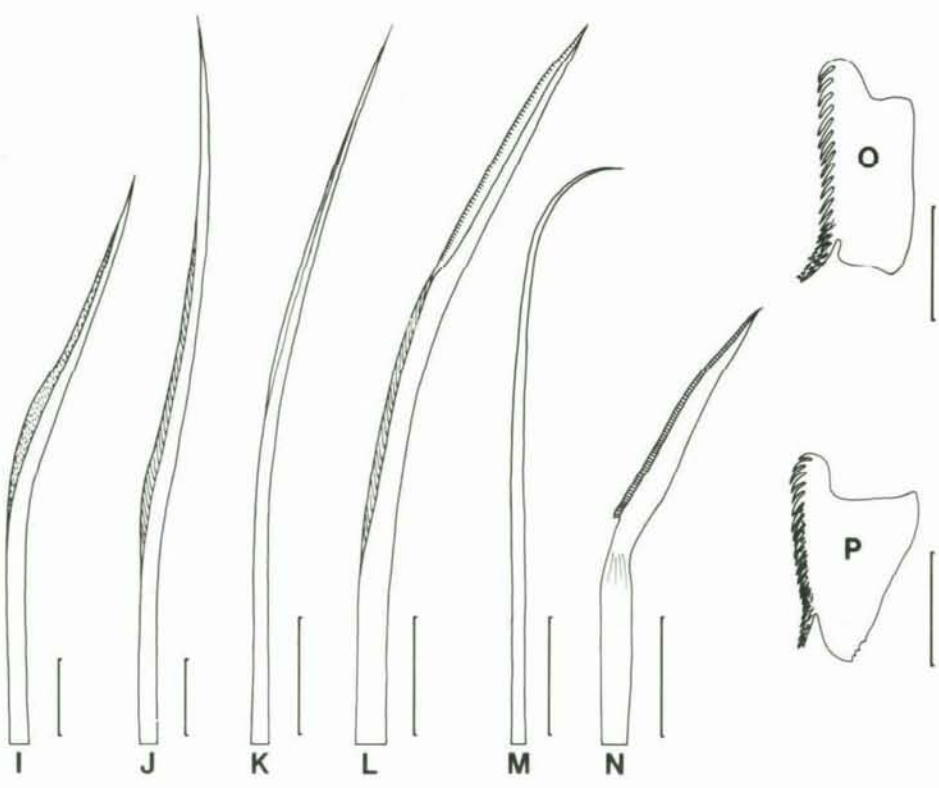
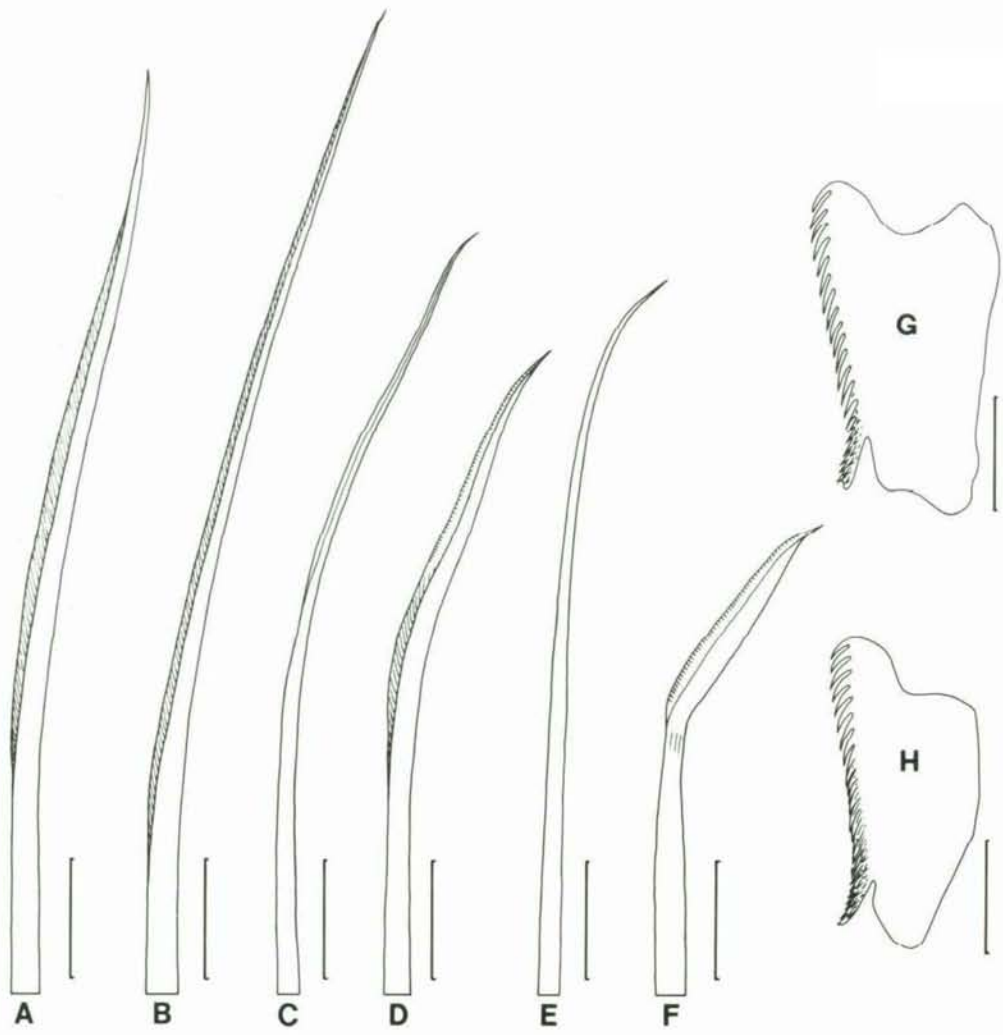


FIGURE 12 : SETAL CHARACTERISTICS OF *PROTULA BISPIRALIS* AND *SALMACINA* SP.

- Protula bispirealis*
- A - Thoracic limbate seta from collar fascicle. Scale bar = 50µm.
 - B - Thoracic limbate seta. Scale bar = 50µm.
 - C - Abdominal capillary seta. Scale bar = 50µm.
 - D - Abdominal sickle-shaped seta. Scale bar = 50µm.
 - E - Abdominal uncinus. Scale bar = 20µm.
- Salmacina* sp.
- F - Collar bayonet seta. Scale bar = 10µm.
 - G - Collar limbate seta. Scale bar = 10µm.
 - H - Thoracic limbate seta. Scale bar = 10µm.
 - I - Thoracic sickle-shaped seta. Scale bar = 10µm.
 - J - Abdominal seta. Scale bar = 10µm.
 - K - Thoracic uncinus. Scale bar = 10µm.
 - L - Abdominal uncinus. Scale bar = 10µm.

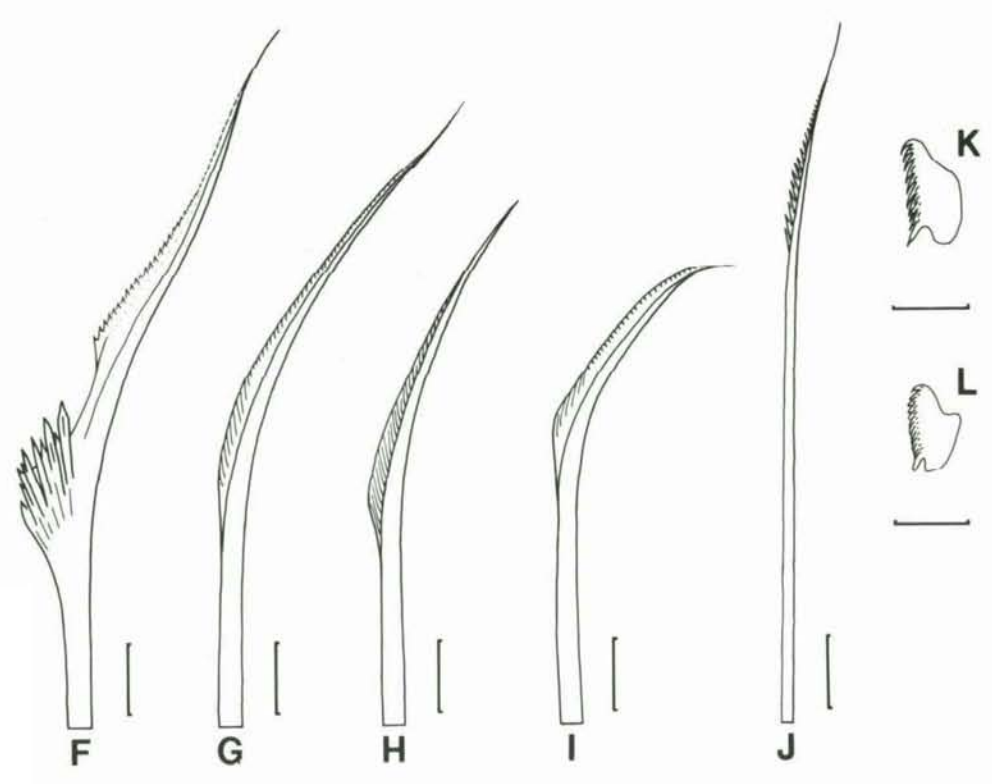
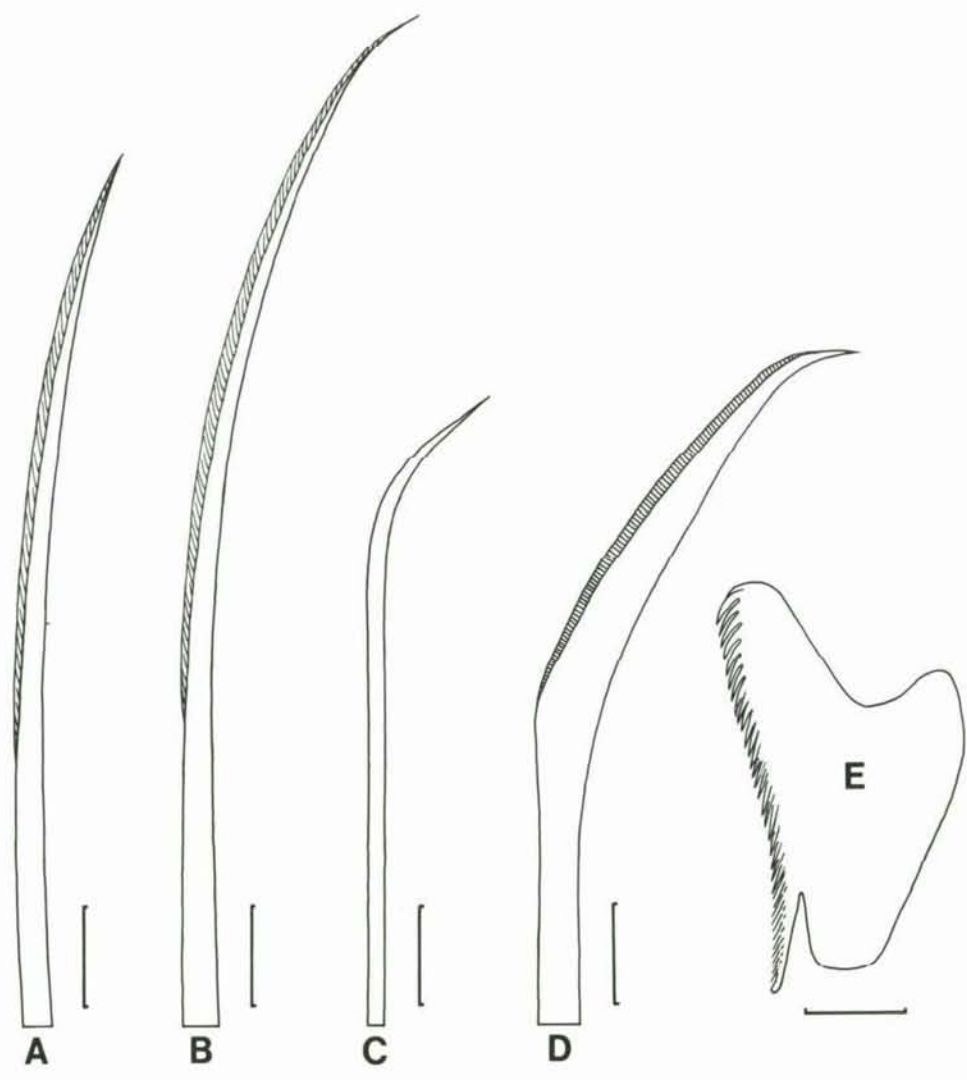


FIGURE 13 : *SALMACINA* SP.

- A - The whole animal undergoing morphophalaxis, dorsal view. Note the presumptive juvenile (pj) developing from the lower abdomen (bc, radioles of branchial crown; th, thorax; ab, abdomen). Scale bar = 0.2mm.
- B - Detail of anterior end, ventral view. Note the pair of cerebral ocellar clusters (ce) embedded within the lower prostomium (lf, lateral collar fold; vf, ventral collar fold). Scale bar = 0.1mm.

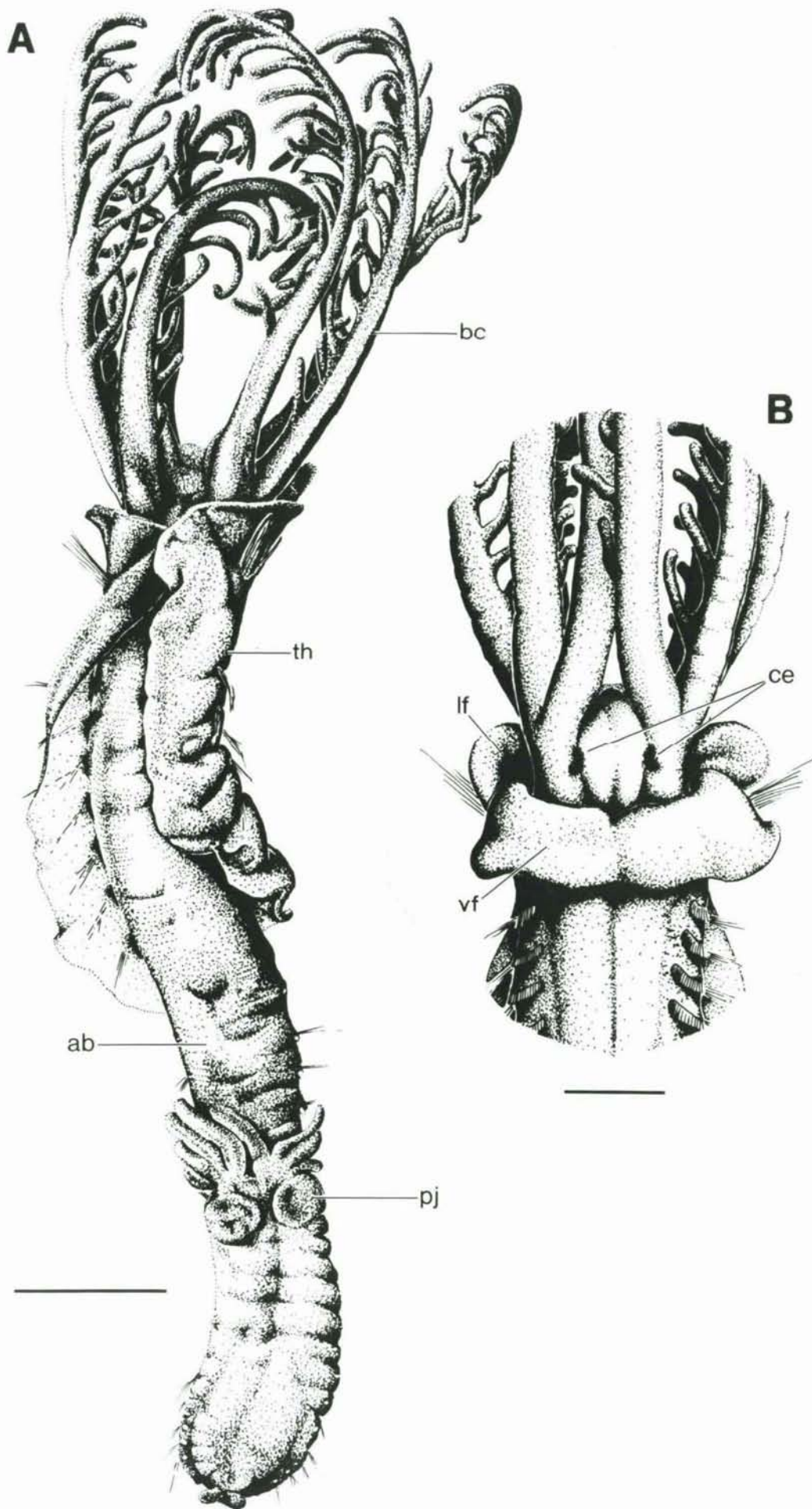


FIGURE 14 : EMBRYOLOGY

- A - Unfertilized egg (ec, eggcoat)
- B - Fertilized egg
- C - First cleavage
- D - Second cleavage (pb, polar bodies)
- E - 64 cell stage (approx.)

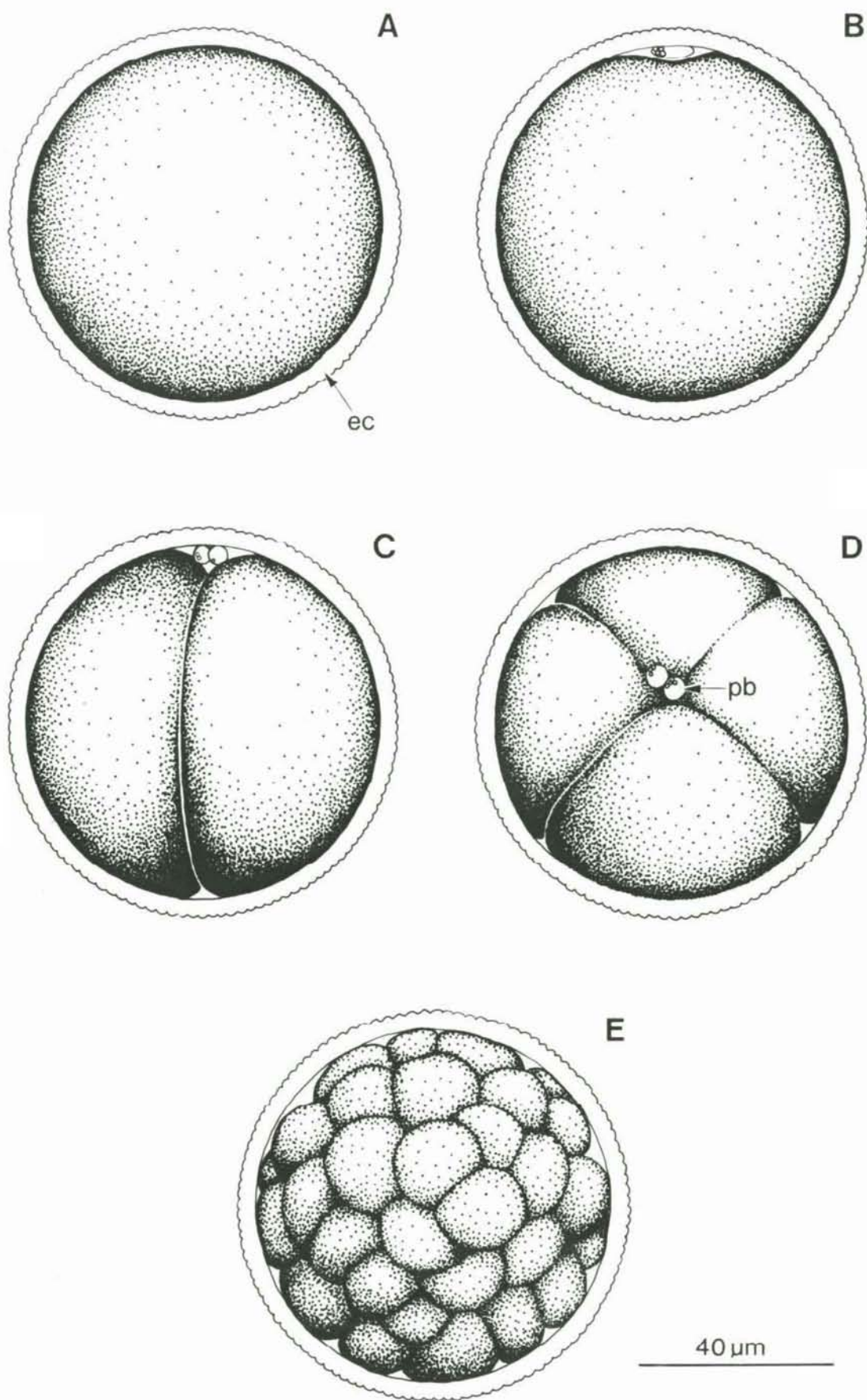


FIGURE 15 : EARLY DIFFERENTIATION

- A - Blastula (c, cilia; ec, eggcoat)
- B - Early trochophore (about 18 hours), lateral view
(at, apical tuft; ao, apical organ; p, pharynx; st, stomach; i, intestine; a, anus; pt, prototroch; ne, neurotroch)
- C - 24 hour trochophore, lateral view (ro, right ocellus; sp, gut sphincter; m, mouth; pt, prototroch; mt, metatroch; fb, ciliary feeding band; av, anal vesicle; pn, protonephridium; vl, ventral longitudinal muscle)

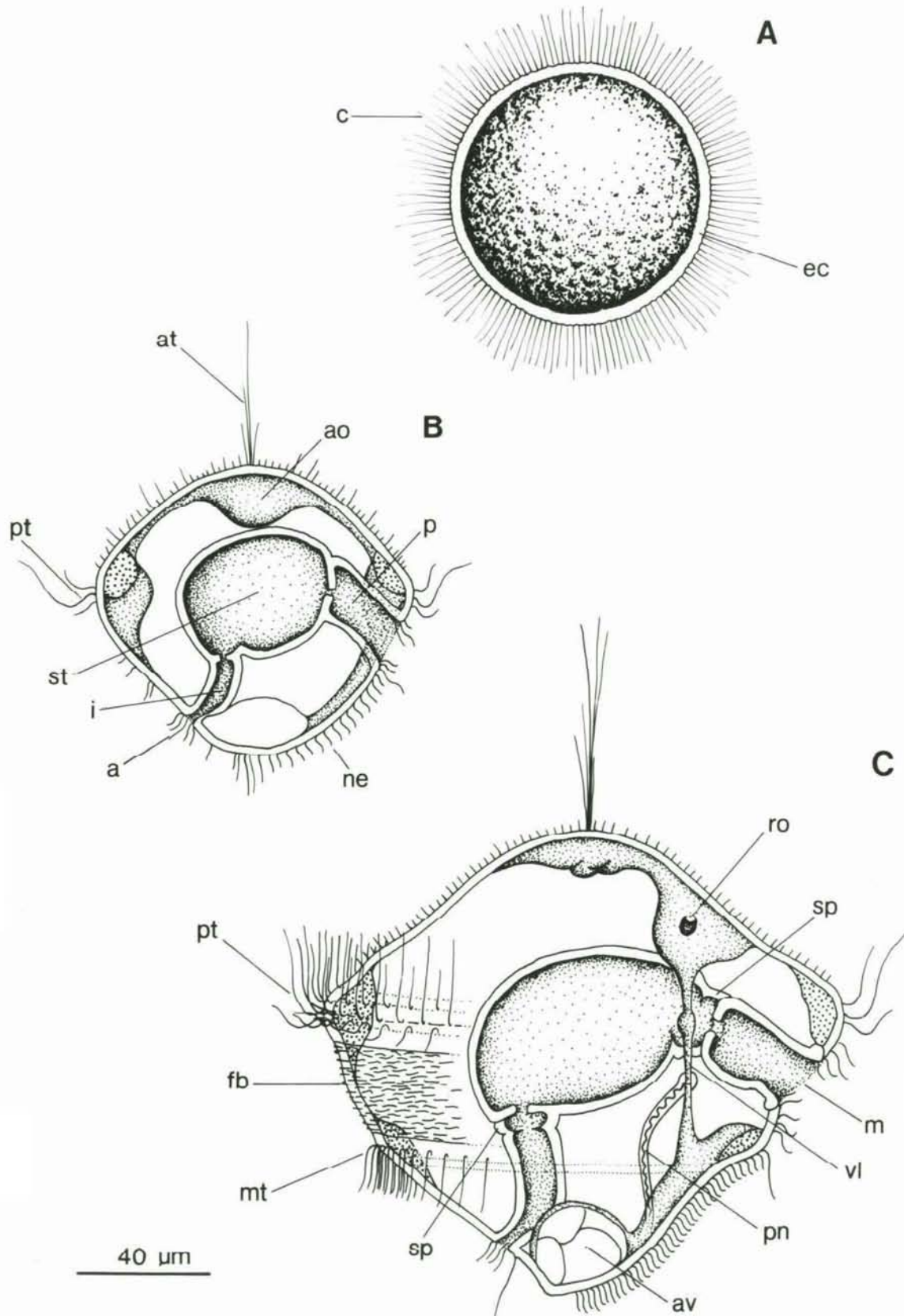


FIGURE 16 : TWO EYED TROCHOPHORE

- A - Metatrochophore, lateral view (ac, anterior circular muscle; vl, ventral longitudinal muscle; dl, dorsal longitudinal muscle; mc, metatroch circular muscle; pa, pharyngeal attachment muscle; me, mesodermal tissue)
- B - Metatrochophore, ventral view (ao, apical organ, ro, right ocellus; lo, left ocellus; ac, anterior circular muscle; dl, dorsal longitudinal muscle; vl, ventral longitudinal muscle; vr, ventral radial muscle; pa, pharyngeal attachment muscle; ne, neutrotrach; me, mesoderm)

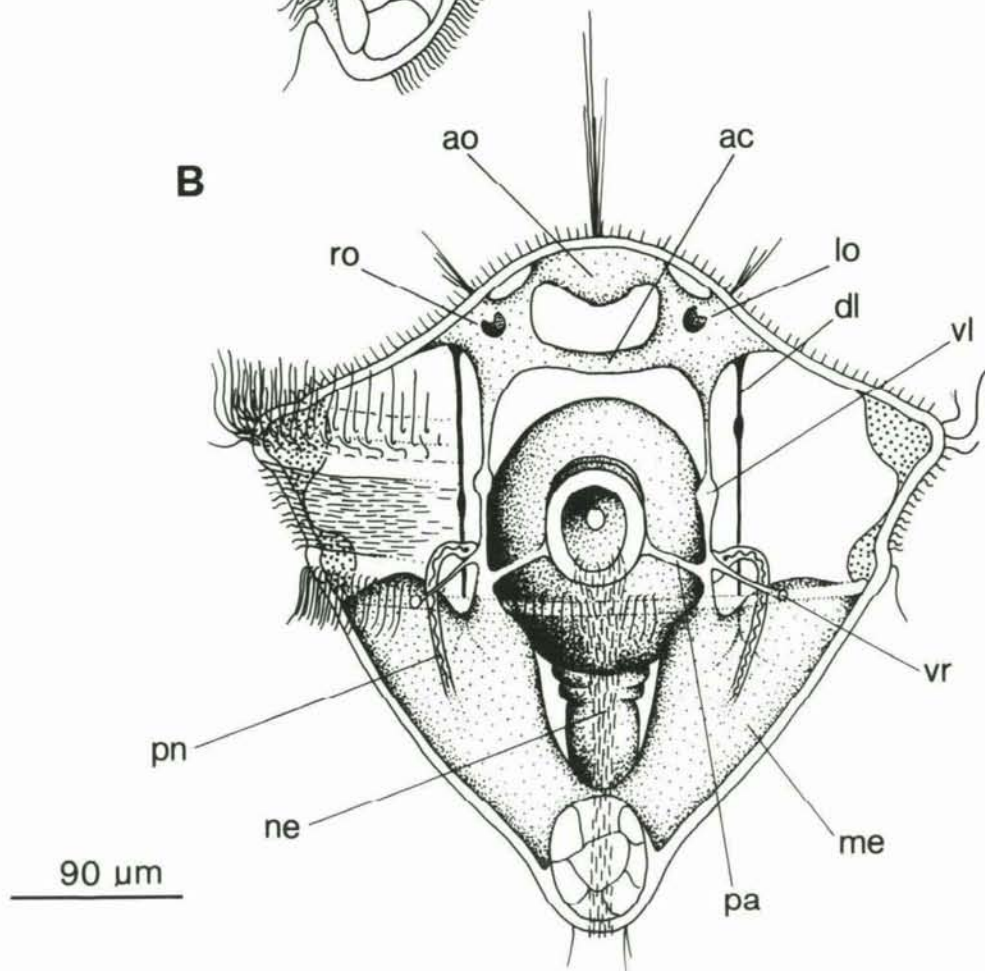
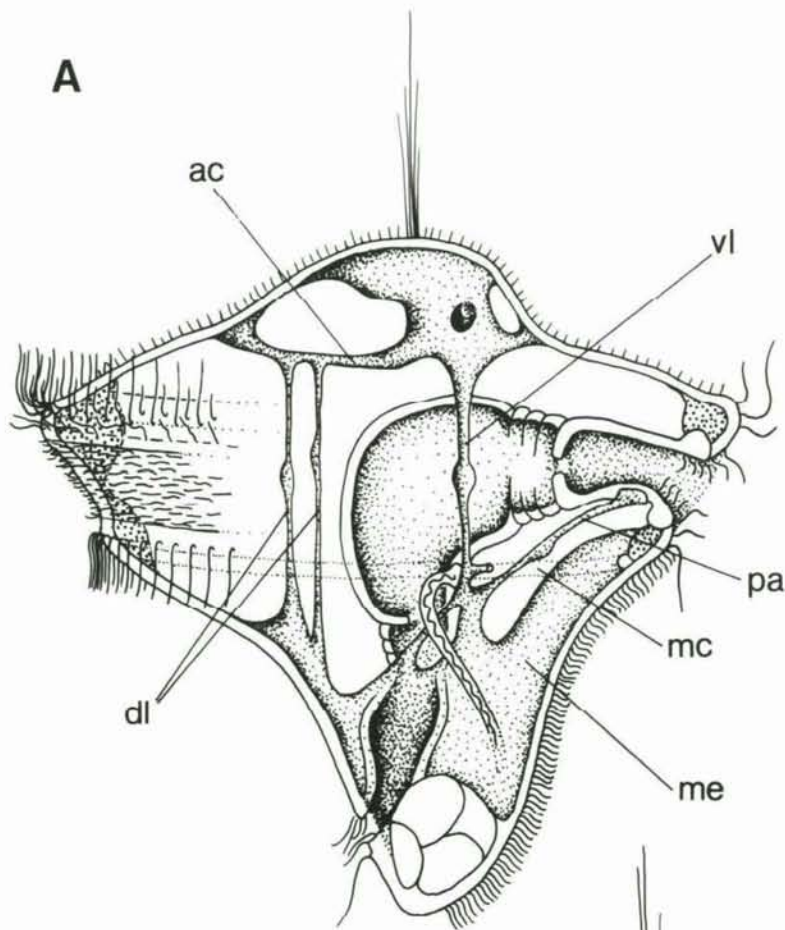


FIGURE 17 : LARVAL MUSCLE SYSTEM (SCHEMATIC)

(ac, anterior circular muscle; dl, dorsal longitudinal muscle; vl, ventral longitudinal muscle; pc, prototroch circular muscle; mt, metatroch circular muscle; pa, pharyngeal attachment muscle; vr, ventral radial muscle)

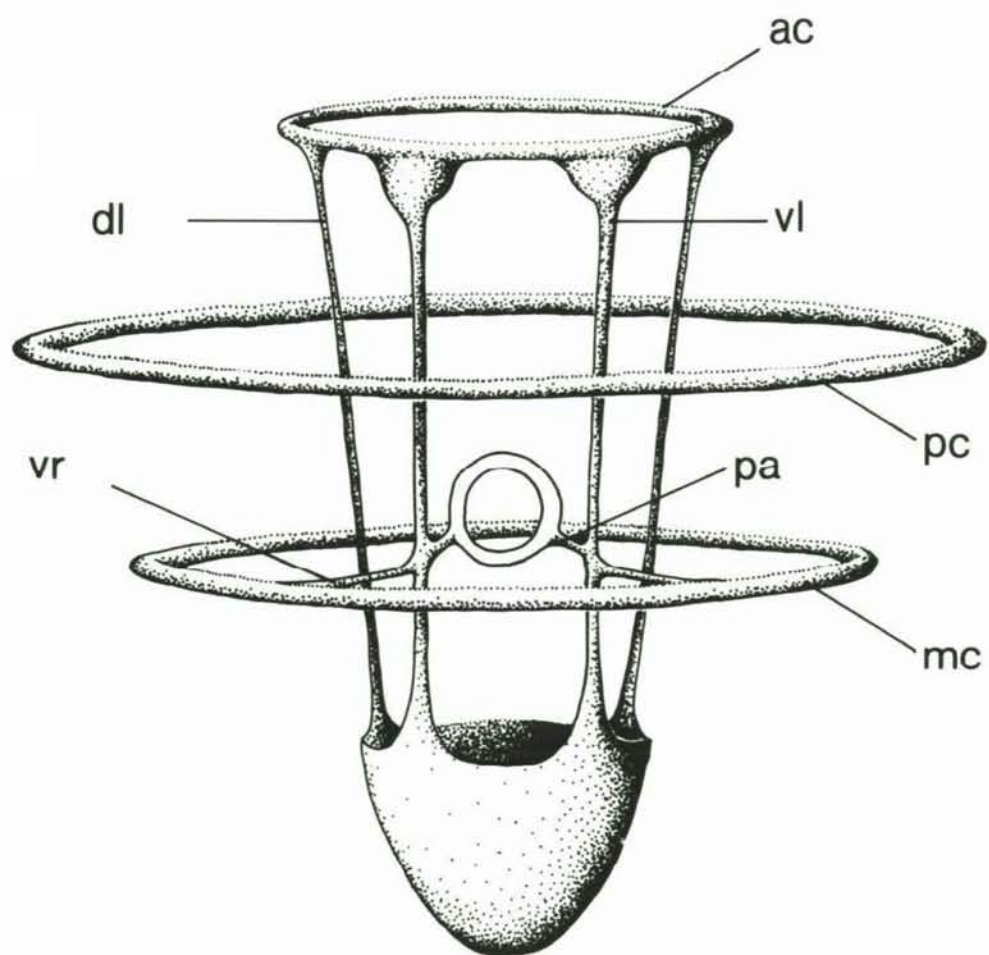


FIGURE 18 : DISTRIBUTION OF LARVAE IN RELATION TO LIGHT

(black circles indicate darkness, open circles represent illumination)

A - 24 hours

B - 48 hours

C - 64 hours onwards

D - Movement of larvae with shift in illumination

E - Distribution of larvae in horizontal chambers

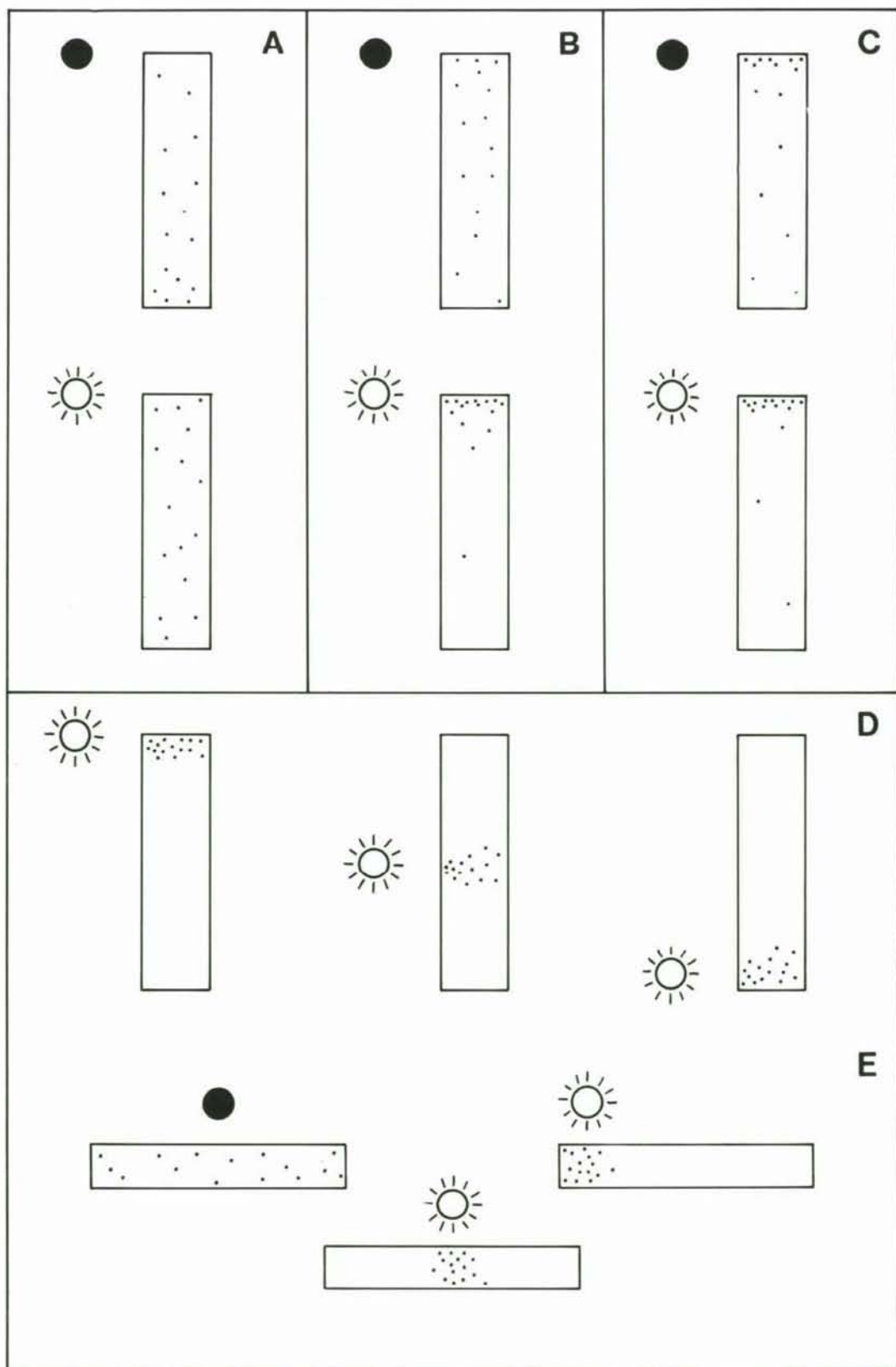
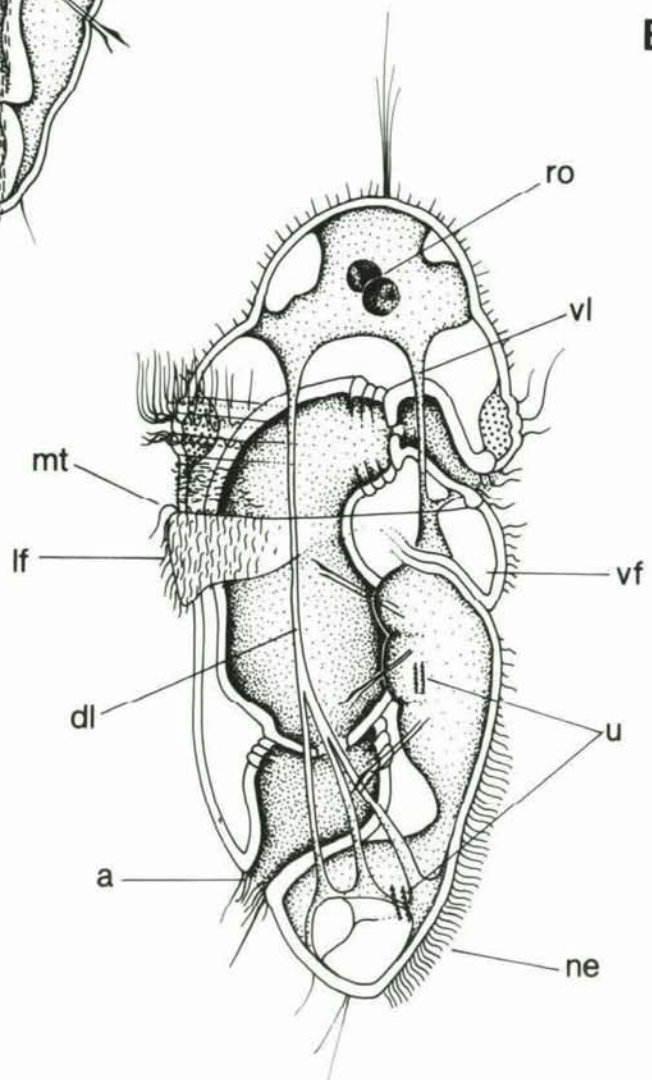
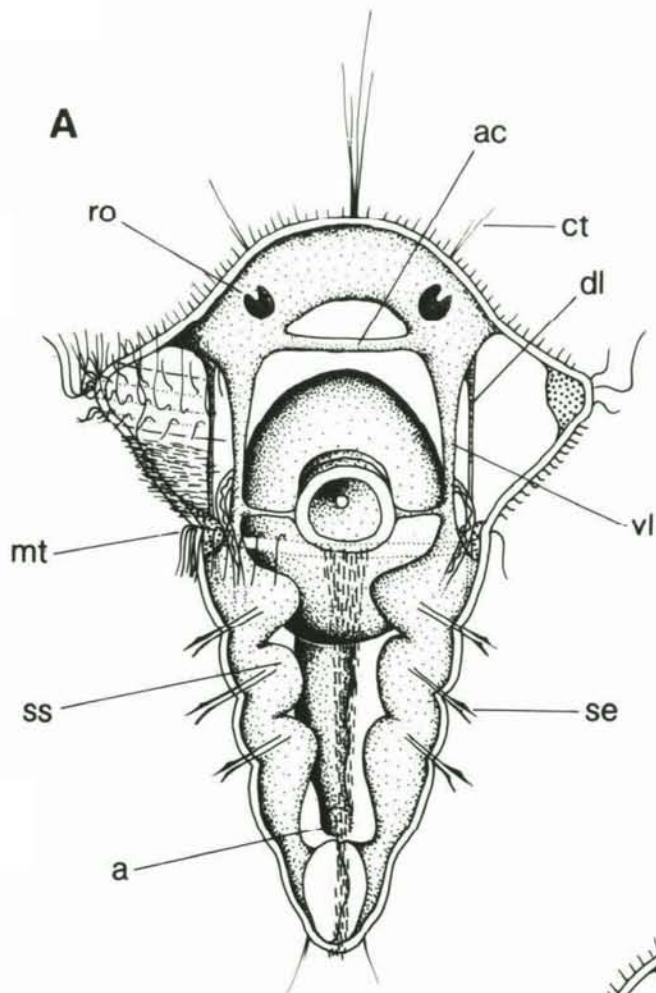


FIGURE 19 : NECTOCHAETE AND METAMORPHOSING LARVA

- A - Nectochaete, ventral view (ct, ciliary tufts; se, setae; ss, setal sacs; ac, anterior circular muscle; ro, right ocellus; dl, dorsal longitudinal muscle; vl, ventral longitudinal muscle; a, anus; mt, metatroch)
- B - Nectochaete commencing metamorphosis, lateral view (vf, ventral collar fold; lf, lateral collar fold; u, uncini; mt, metatroch; ro, right ocellus; vl, ventral longitudinal muscle; dl, dorsal longitudinal muscle; a, anus; ne, neurotroch)



100 μ m

FIGURE 20 : SEARCHING PHASE LARVA AND SETTLED LARVA

- A - Searching phase larva, ventral view (cg, cerebral ganglion; br, branchial rudiments; lf, lateral collar fold; vf, ventral collar fold; u, uncini; pt, prototroch; mt, metatroch; m, mouth; i, intestine; dl, dorsal longitudinal muscle; av, anal vesicle)
- B - Immediate post settled larva removed from tube, ventral view (cs, collar setae; br, branchial rudiments; m, mouth; lf, lateral fold; vf, ventral fold; dl, dorsal longitudinal muscle; vl, ventral longitudinal muscle; u, uncini)
Numerals on branchiae refer to their sequence of development.

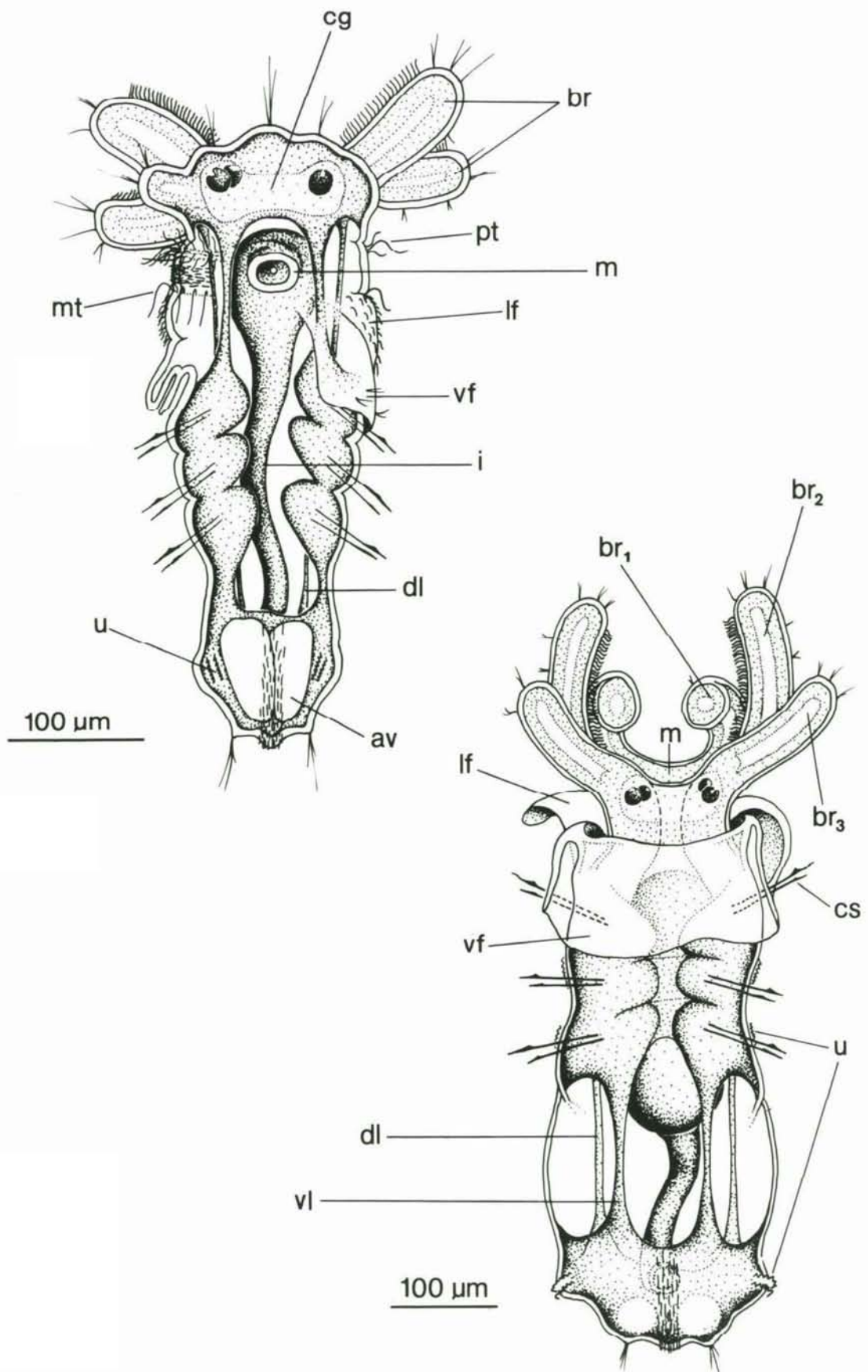


FIGURE 21 : SETTLEMENT

- A - Juvenile settles on non-living area of coral and commences tube construction. Numerals refer to order of branchial development.
- B - Juvenile commences growth across coral tissue (mb, mucus bag; t, tube)
- C - Operculum-like swellings develop on branchiae 3
- D - Coral tissue surrounds juvenile tube and incorporates it into its skeleton (e, edge of live coral; os, operculum-like swellings)
Note: length of tube is truncated in this figure.

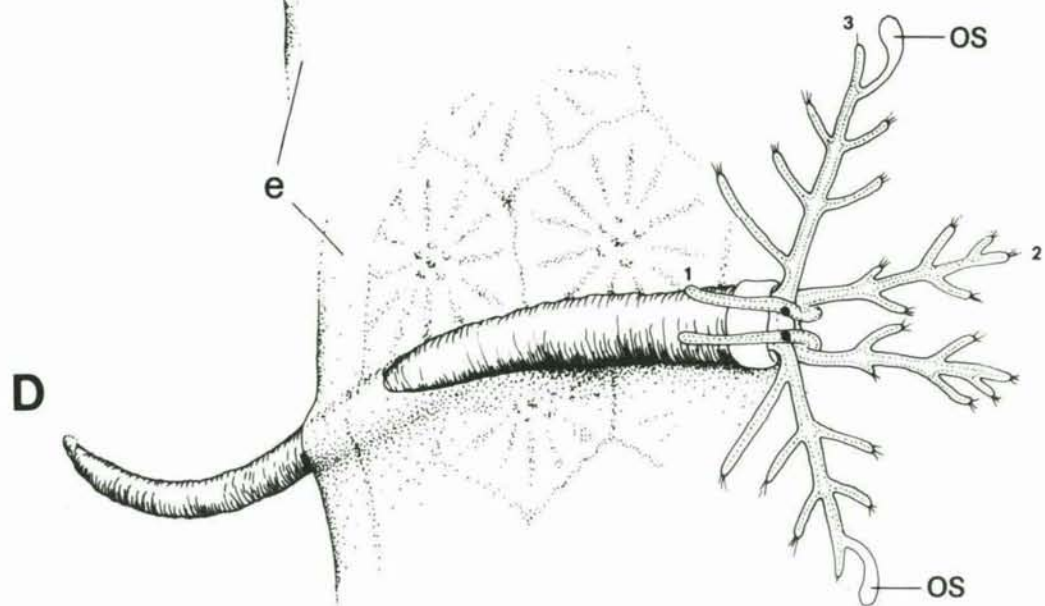
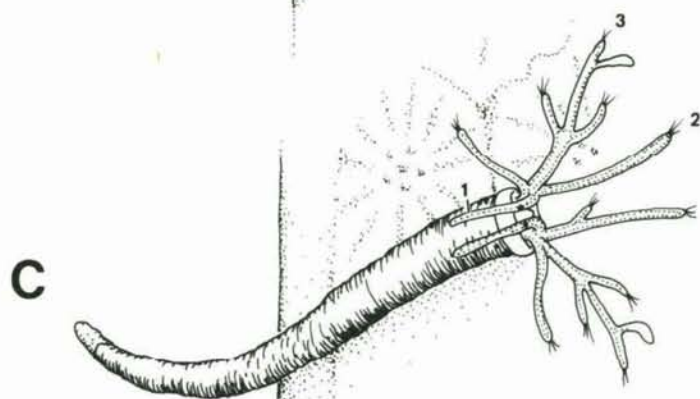
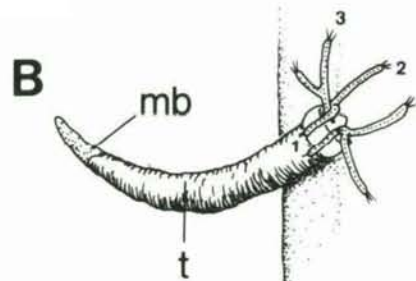
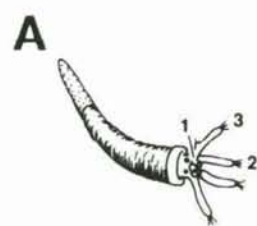


FIGURE 22 : SCANNING ELECTRON MICROGRAPHS OF JUVENILE TUBES

- A - Tube constructed by settled worm less than 2 days old. Note that tube secretion has commenced on ventral surface only and gradually extended to the dorsal aspect. The initial mucus tube has been removed during specimen preparation (ve, ventral; do, dorsal; t, tube). Scale bar = 50µm
- B - Juvenile tubes on *Porites* fragment (co, coral)
Scale bar = 50µm
- C - Detail of exterior of juvenile tube. Note the irregular additions of tube material. (Mo, tube mouth). Scale bar = 5µm
- D - Detail of interior surface of juvenile tube. Note the numerous small cylindrical secretions (sec, secretions). Scale bar = 5µm
- E - Juvenile tube on *Porites* fragment.
Scale bar = 5µm

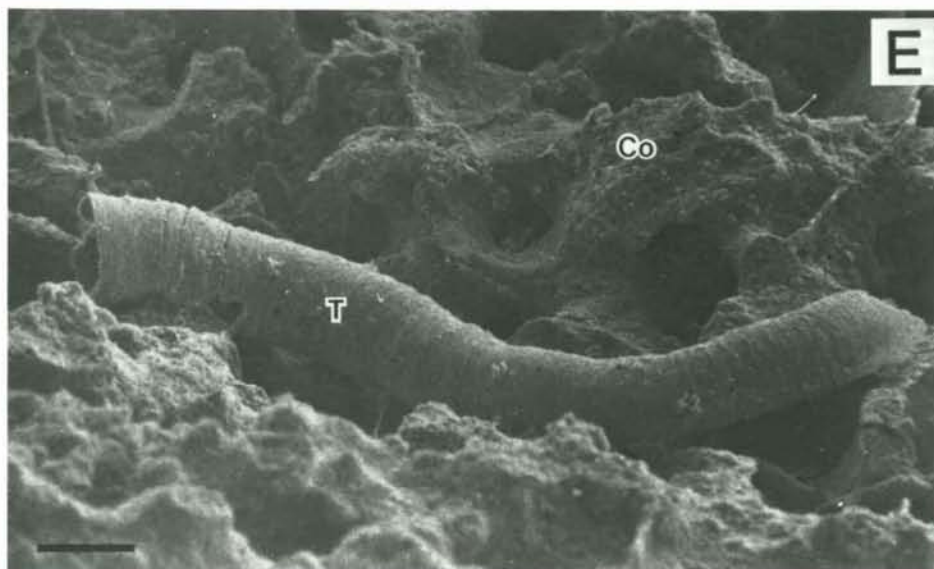
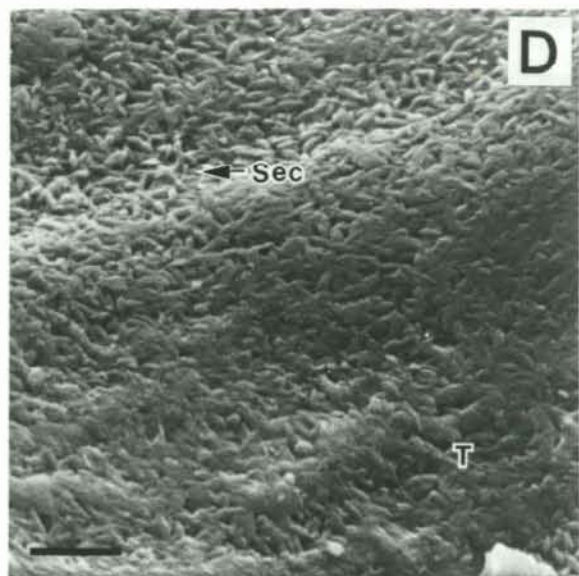
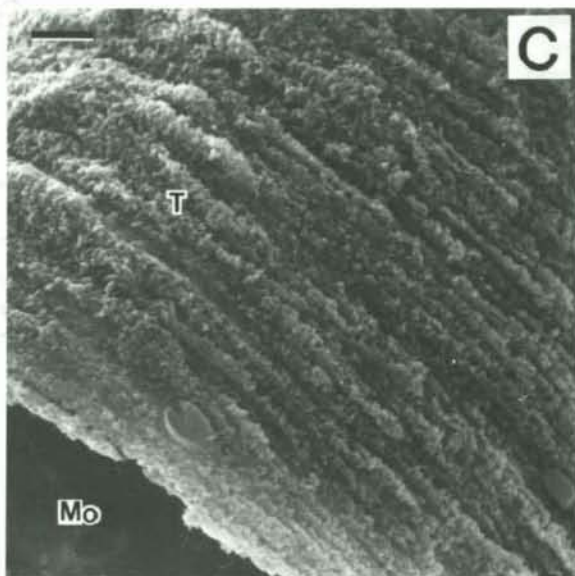
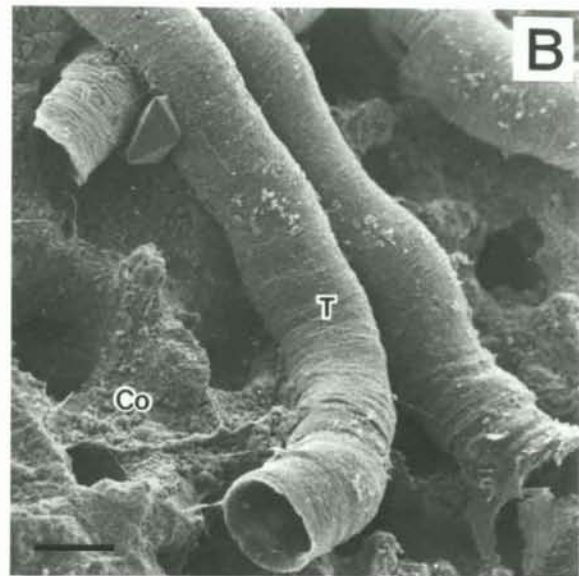
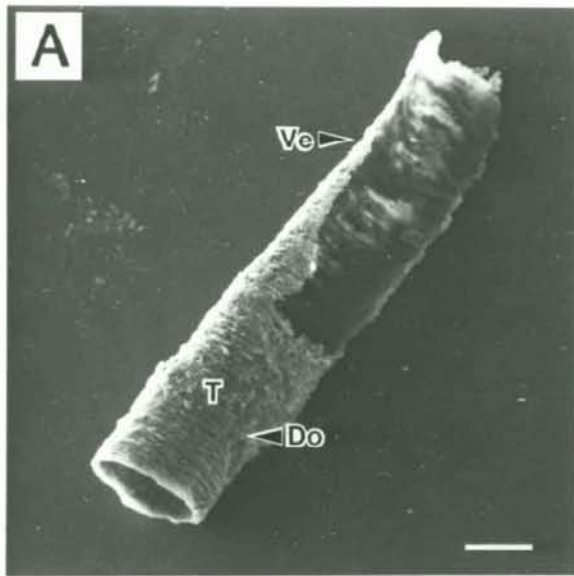


FIGURE 23 : DETAIL OF PINNULE TIP

(sc, stiff sensory cilia tufts; uc, undulating sensory cilia tuft; fc, feeding cilia)

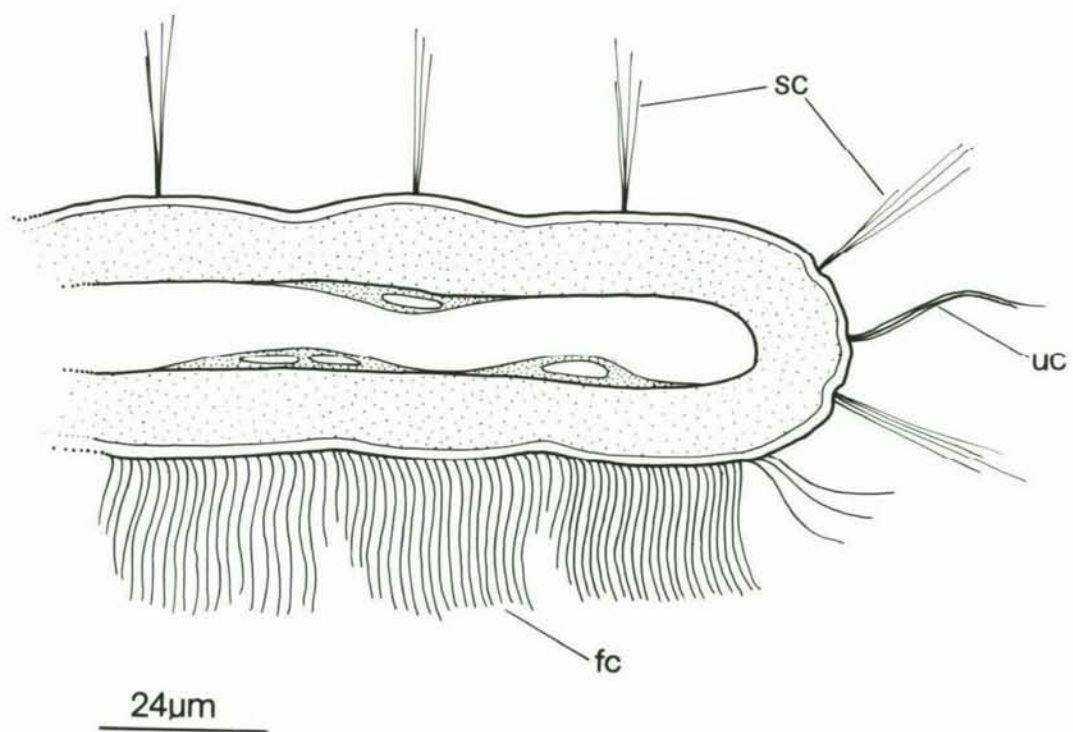


FIGURE 24 : JUVENILE *SPIROBRANCHUS GIGANTEUS* SP.A
(ORPHEUS ISLAND)

(op, operculum; be, branchial eyes; lf, lateral fold;
vf, ventral fold; th, thorax; ab, abdomen)

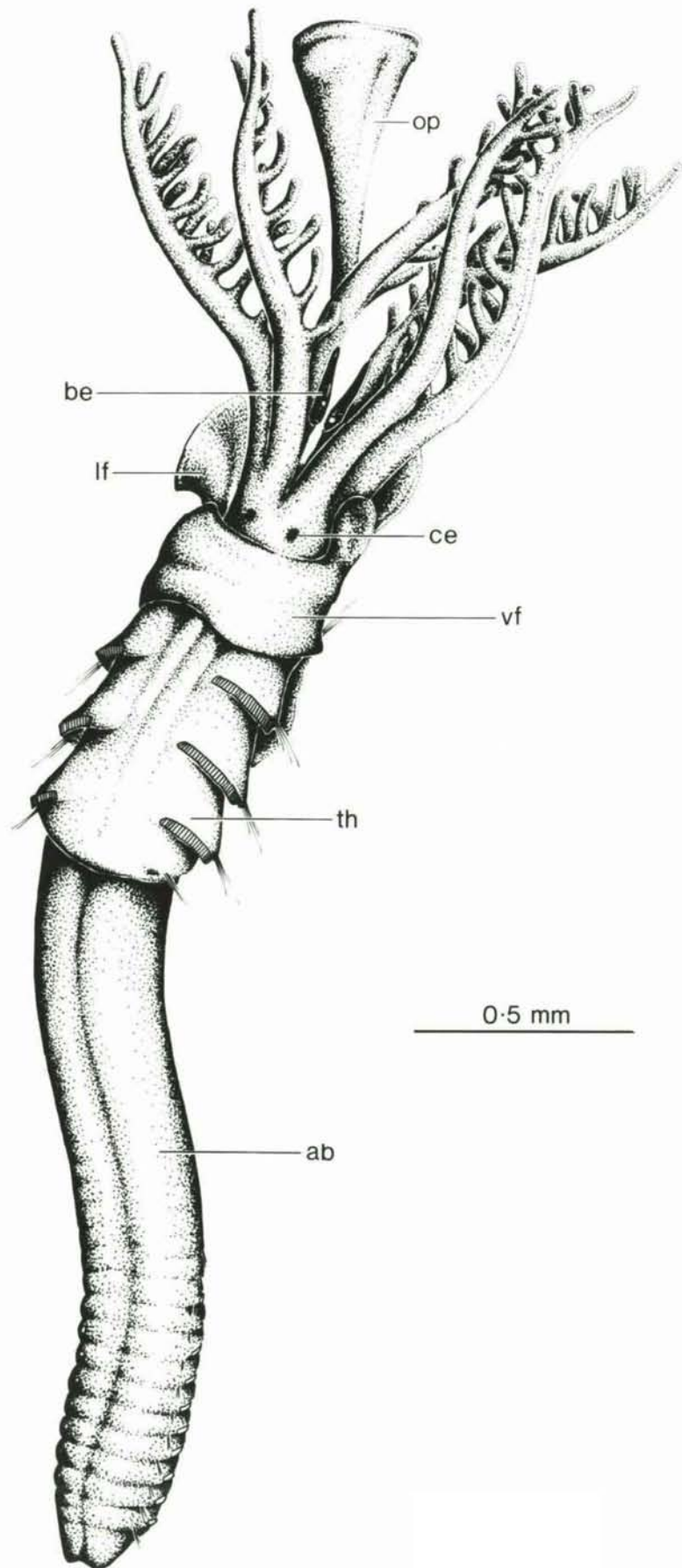


FIGURE 25 : OPERCULAR DIFFERENTIATION

- A - Initial operculum bud
- B - Distal swelling
- C - Distal swelling flattens
- D - Differentiation of the presumptive peduncle from the opercula ampulla
- E-G - Commencement of wing formation and initial calcification of opercular plate (different specimens)
- H,I - Differentiation of opercular spines (same specimens)
- J,K - Obvious wings and spines (different specimens)
- L-N - Well differentiated operculum (ventral, lateral and dorsal views of same specimen). Note the disproportionately large and well developed spines (compare with Figure 3A,B).

This figure is drawn from specimens collected in the field. The exact time scale is not know, however, progress from an opercular bud (A) to a well differentiated operculum (e.g. L-N) probably takes about 2 months. All drawn to same scale. Scale bar = 1mm

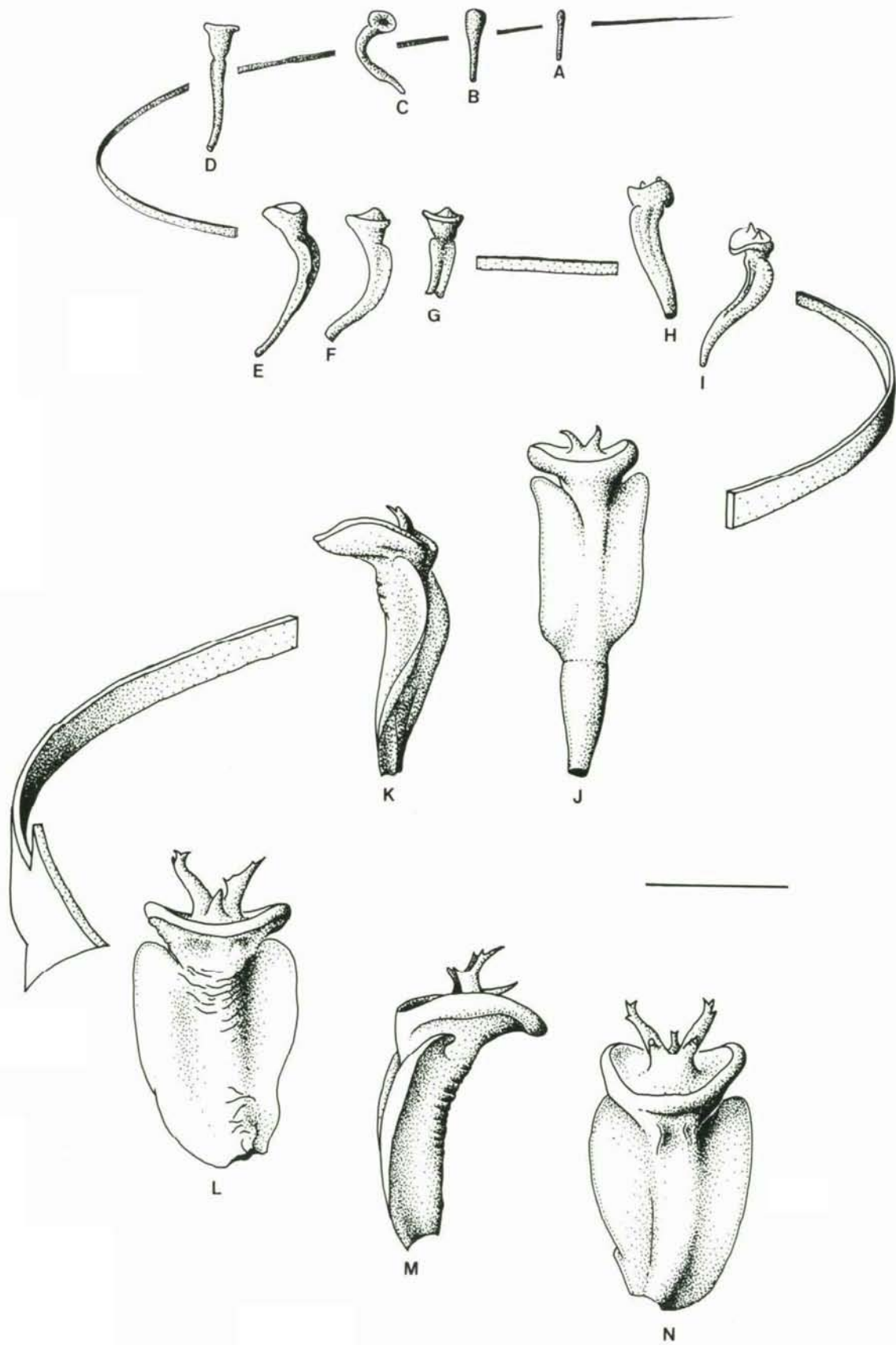


FIGURE 26 : JUVENILE *SPIROBRANCHUS GIGANTEUS* SP.A
(LATERAL VIEW)

This worm, collected at Orpheus Island in late February 1984, is considerably more developed than the one shown in Figure 24 and at this stage displays the characteristic pigmentation of adult worms. For clarity, the obscured lobe of the branchial crown is omitted from this diagram (op, operculum; pd, peduncle; bm, branchial membrane; vf, ventral collar fold; lp, collar lappet; lf, lateral collar fold; vs, ventral shield; ts, thoracic notosetae; to, thoracic torus bearing uncini; tm, thoracic membrane fold; ab, abdomen).

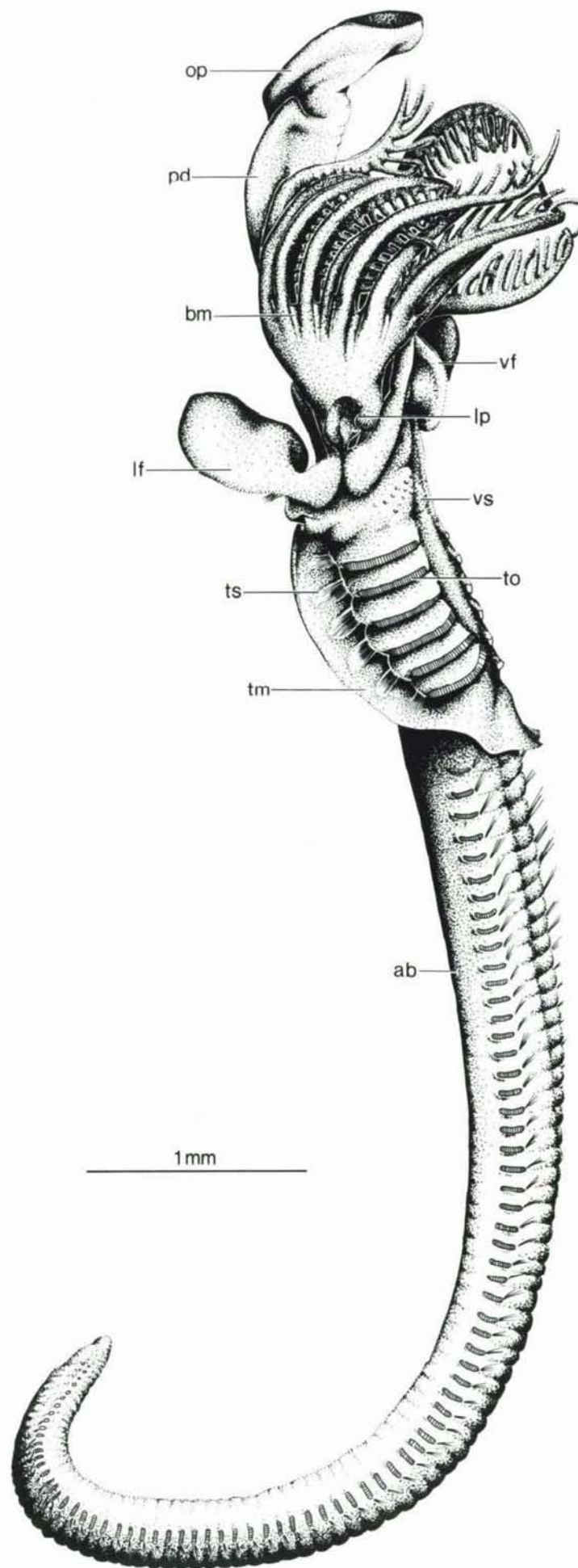


FIGURE 27 : SENSORY CILIA TUFTS (SCANNING ELECTRON MICROGRAPHS)

- A - *Spirobranchus giganteus* sp.A. Detail of a single sensory cilium tuft protruding from the aboral pinnule surface. (Ci, cilium; P, pinnule). The flaccid appearance is a result of preservation techniques. Scale bar = 1µm.
- B - *S. giganteus* sp.A. Lateral view of pinnule. Note the pores of the mucus cells (Mcp) associated with the feeding cilia (Fc). (Sct, sensory cilium tuft). Scale bar = 10µm.
- C - *Galeolaria caespitosa*. Distal ends of pinnules. Note the stiff sensory cilium tufts projecting apically. Scale bar = 10µm.
- D - *G. caespitosa*. Detail of distal end of pinnule. The sensory cilium tuft arrowed is presumed to be the one capable of slow undulation. Scale bar = 10µm.
- E - *Spirobranchus tetraceros* sp.B. View of pinnules showing the regular spacing of sensory cilium tufts (arrowed). Scale bar = 10µm.
- F - *S. giganteus* sp.A. Lateral view of pinnules. Scale bar = 10µm.

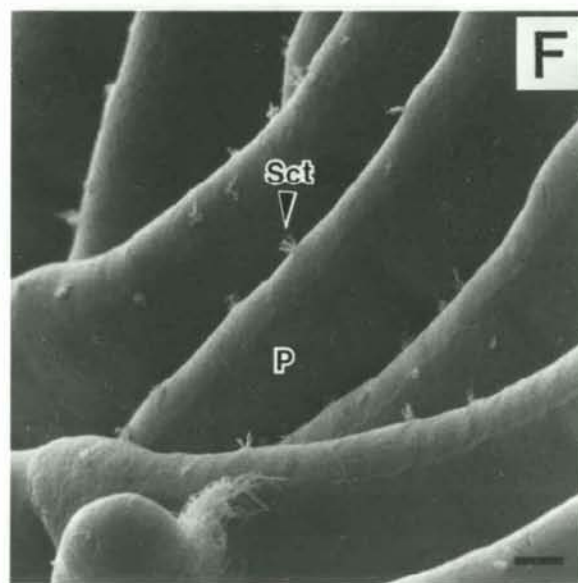
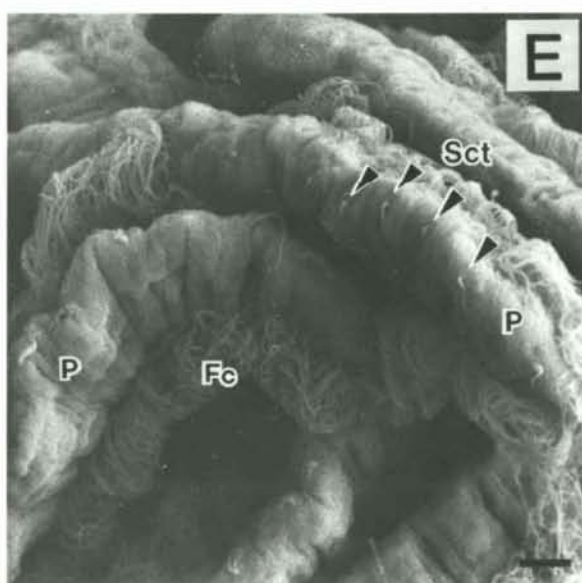
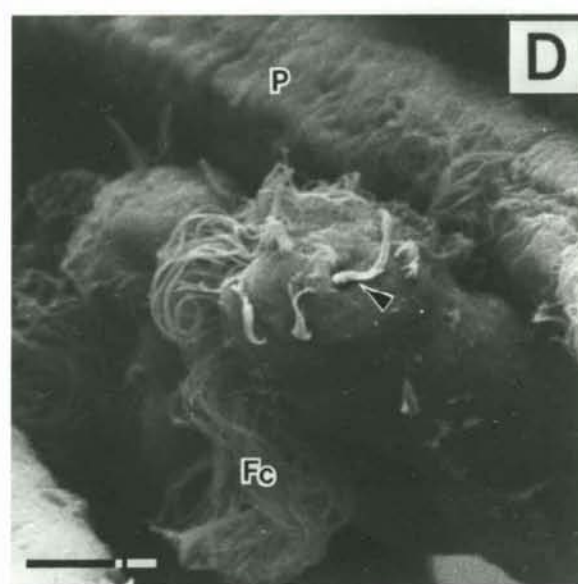
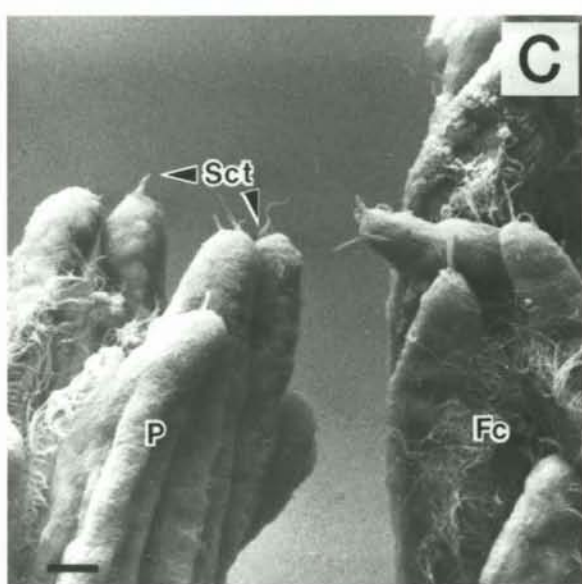
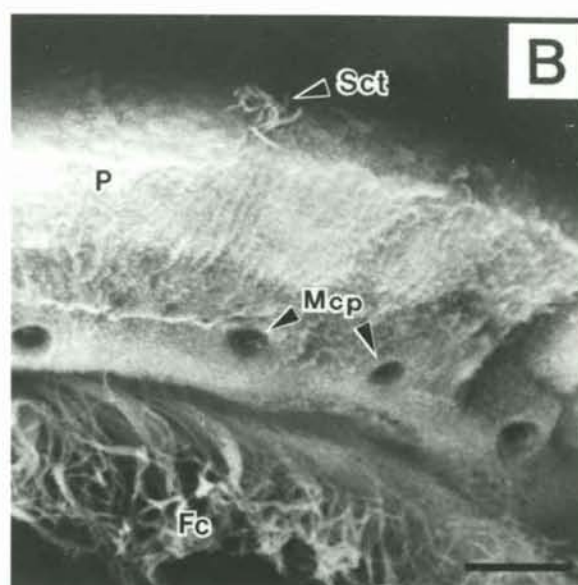
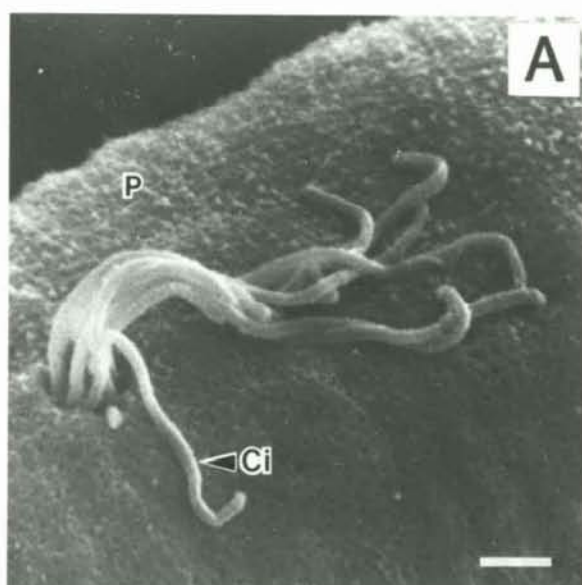


FIGURE 28 : SENSORY CILIA TUFTS (TRANSMISSION ELECTRON MICROGRAPHS)

- A - *Protula tubularia*. Note constriction at the cell apex. This is encircled by a complex junction consisting of an adhering zonule (ZA) and septate desmosome (Mvb, multi-vesicular body; Ci, cilium; G, Golgi body; Nu, nucleus). Scale bar = 1 μ m.
- B - *Protula tubularia*. Several cilia can be seen leaving the cuticle through a common pore in this micrograph. Note the root structures (R) extending from the basal apparatus. (Epi, epicuticle). Scale bar = 1 μ m.
- C - *Protula tubularia*. General view of sensory cilia tuft cell. (Ct, cuticle). Scale bar = 1 μ m.
- D - *Spirobranchus tetraceros* sp.A. The sensory cell (SC) is conspicuous lying amongst the pigmented cells (PC) of the eye region in this micrograph. Note the slight apical depression of the sensory cell and the border of microvilli (Mv) surrounding the more central cilia. (M, mitochondria). Scale bar = 1 μ m.

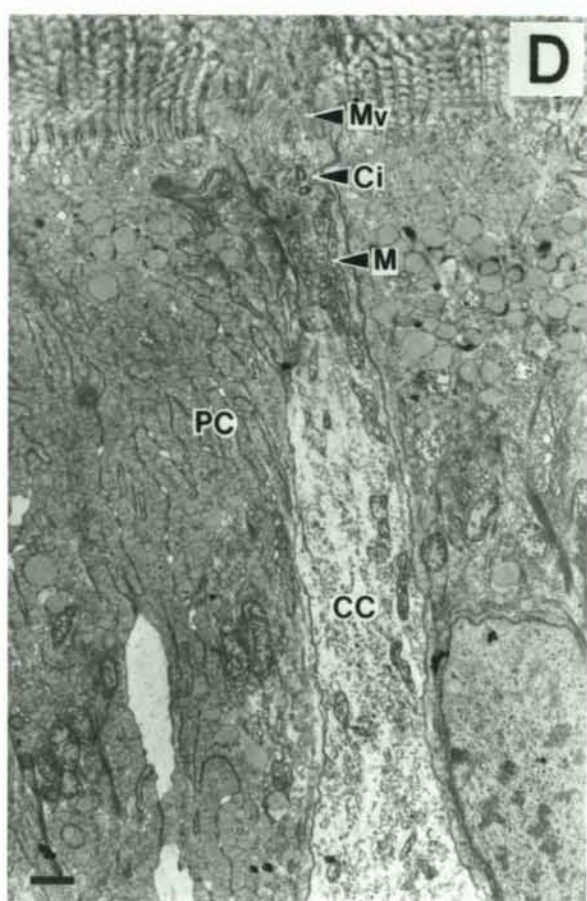
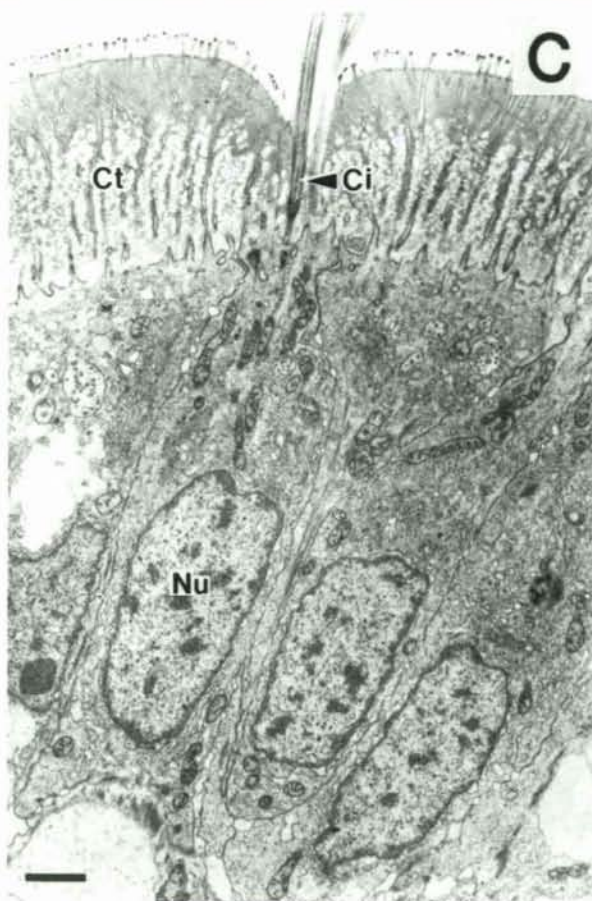
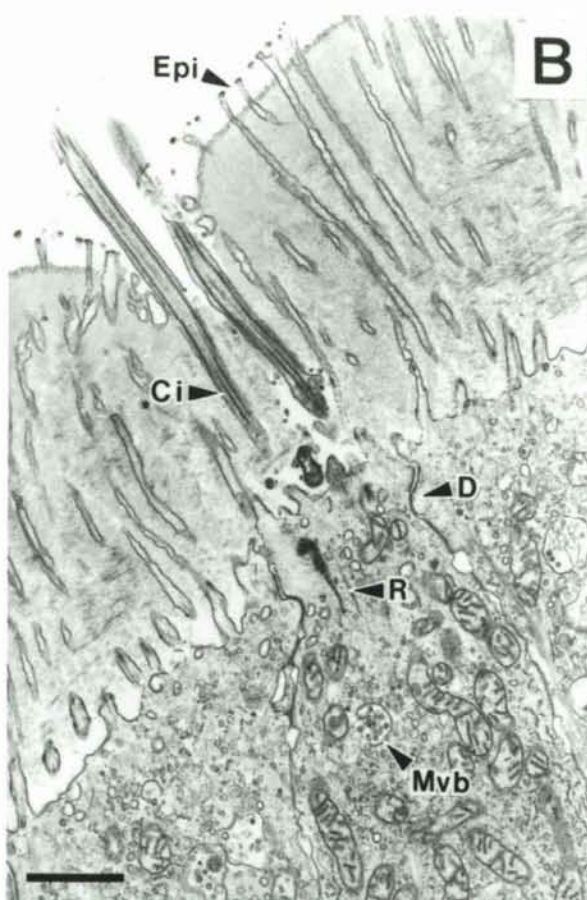
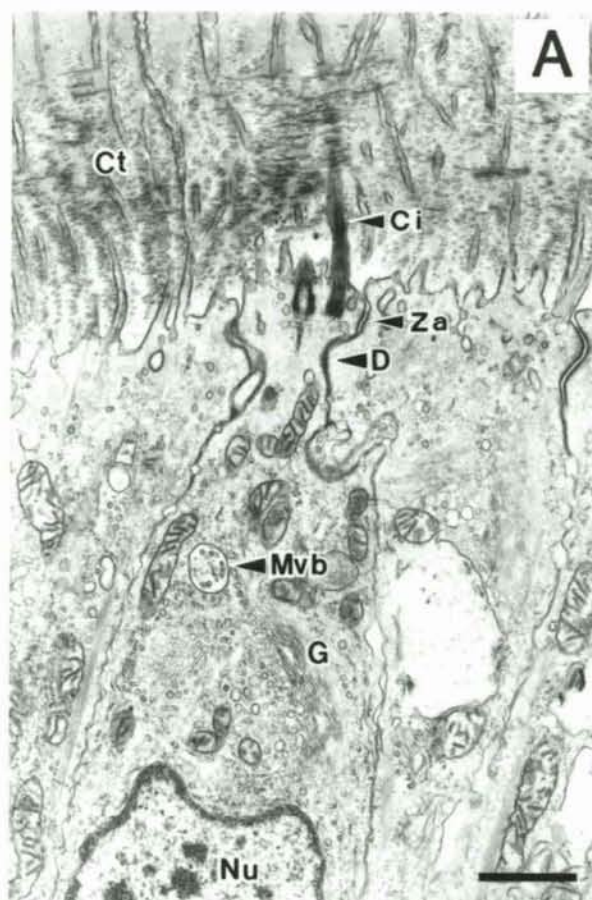


FIGURE 29 : DIAGRAM OF THE TROCHOPHORE OCELLUS OF *SPIROBRANCHUS GIGANTEUS* SP.A.

Idealized longitudinal section
(refer to Legend for organelle identification).

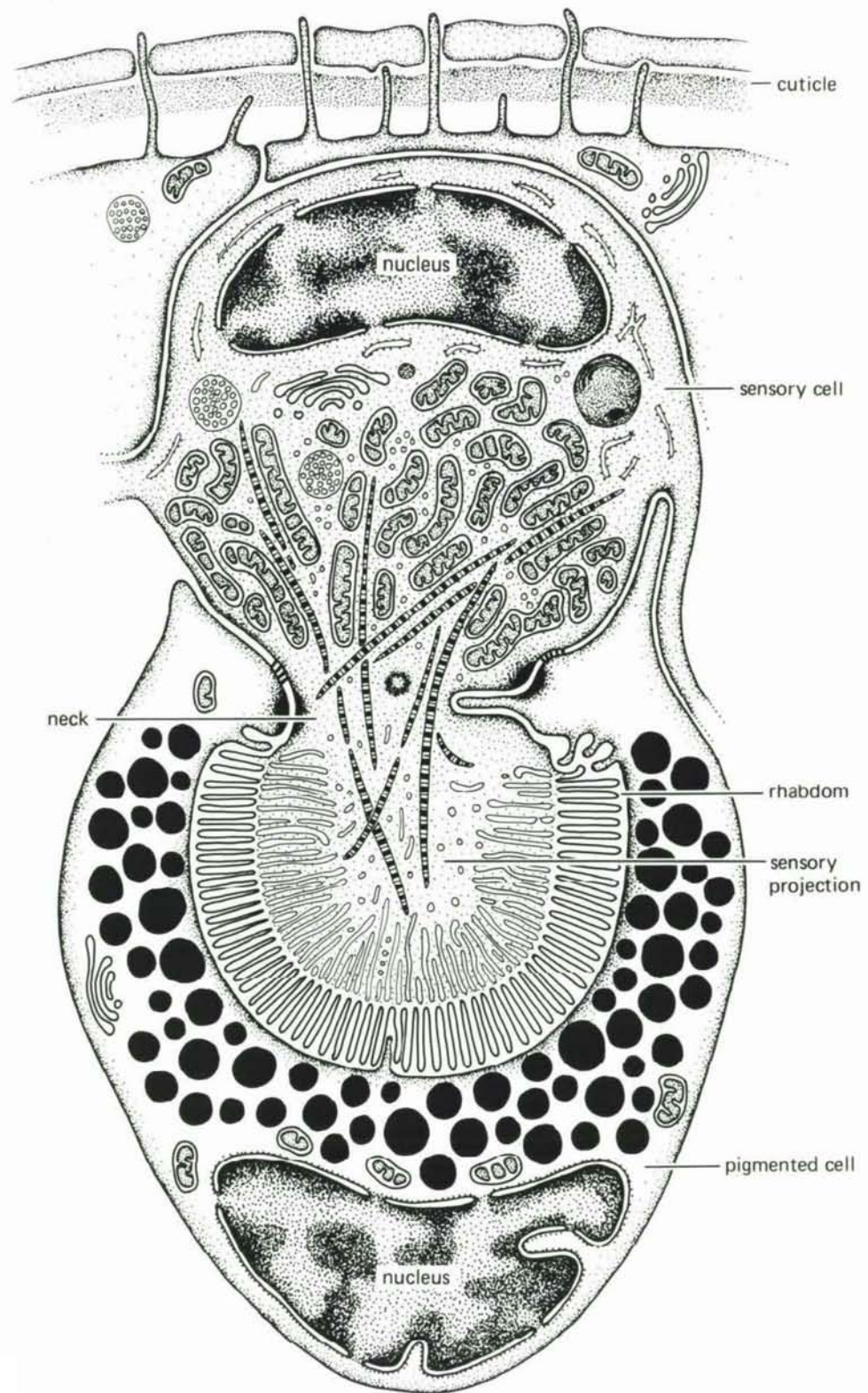


FIGURE 30 : THE TROCHOPHORE OCELLUS OF *S. GIGANTEUS* SP.A (T.E.M.)

The map below illustrates the principal components seen in this longitudinal section.

34600 X

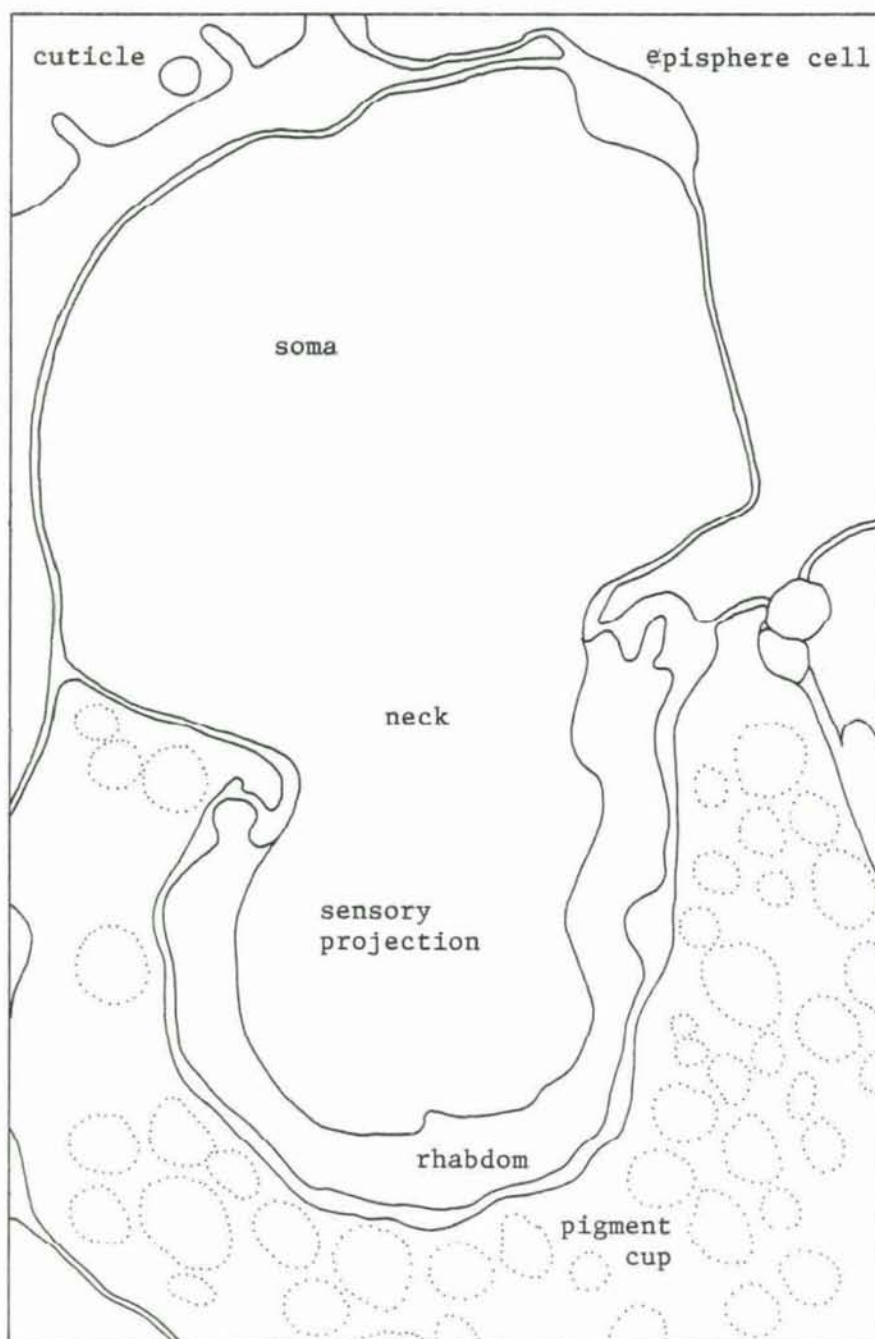




FIGURE 31 : THE TROCHOPHORE OCELLUS OF *S. GIGANTEUS* SP.A (T.E.M.)

- A - Two adjacent ocelli of a metatrochophore in oblique section. The microvilli of the rhabdoms are visible, as are the interdigitations (I) of the sensory (SC) and pigmented cells at the neck of the sensory projection. (PCN, pigmented cell nucleus). Scale bar = 1 μ m.
- B - Longitudinal section through the ocellus showing the sensory projection. (PC, pigment cup of pigmented cell). Scale bar = 1 μ m.
- C - A similar section to B but showing a central centriole (C) and a number of root-like structures (R). (M, mitochondria; Za, adhering zonule). Scale bar = 1 μ m.
- D - Transverse section through the rhabdom showing the radial arrangement of the microvilli (Mv). The sensory projection is packed with submicrovillar cisternae (Smc). Scale bar = 1 μ m.

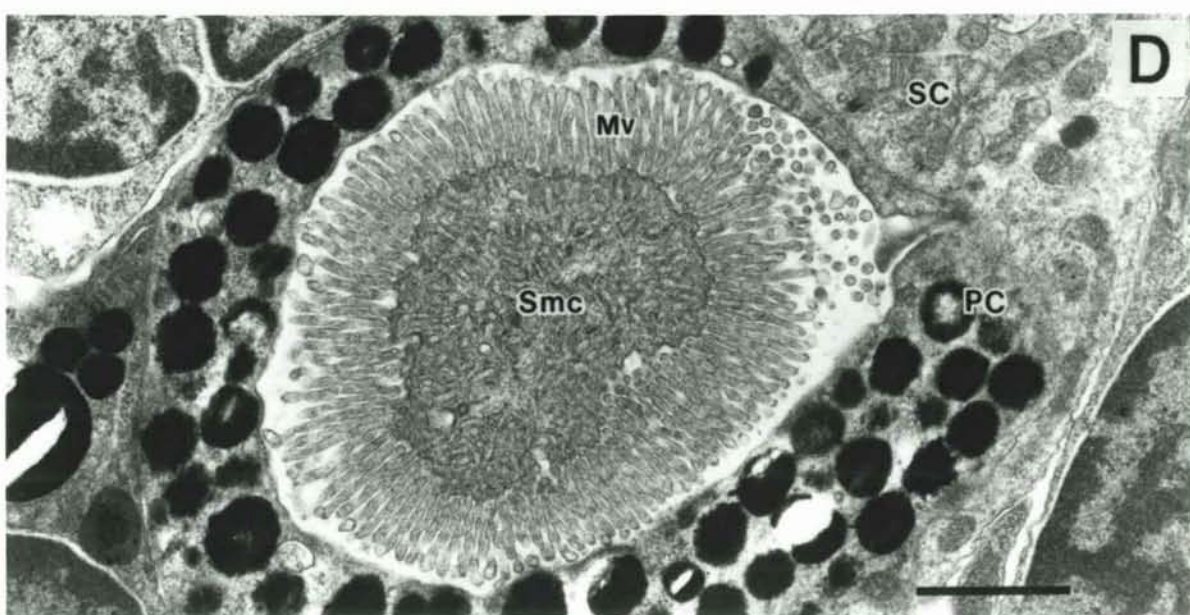
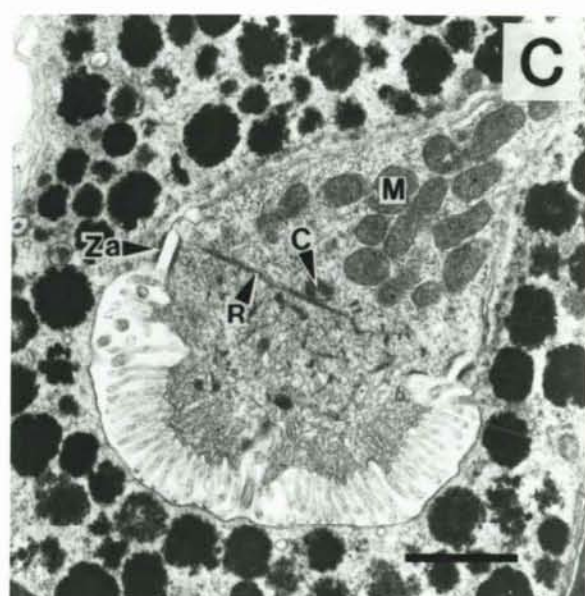
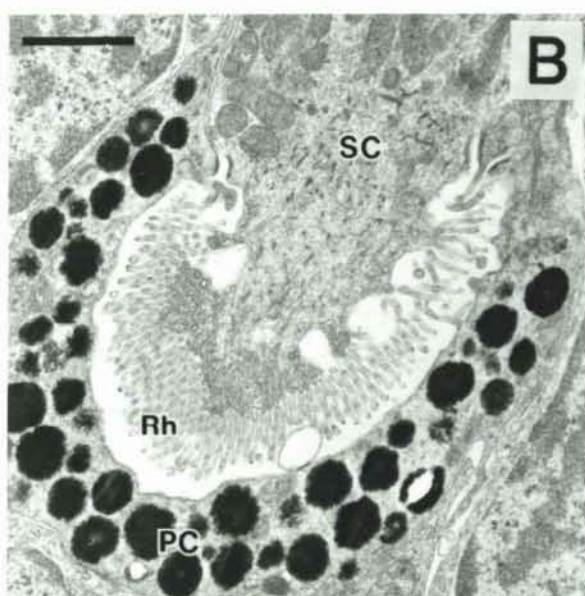
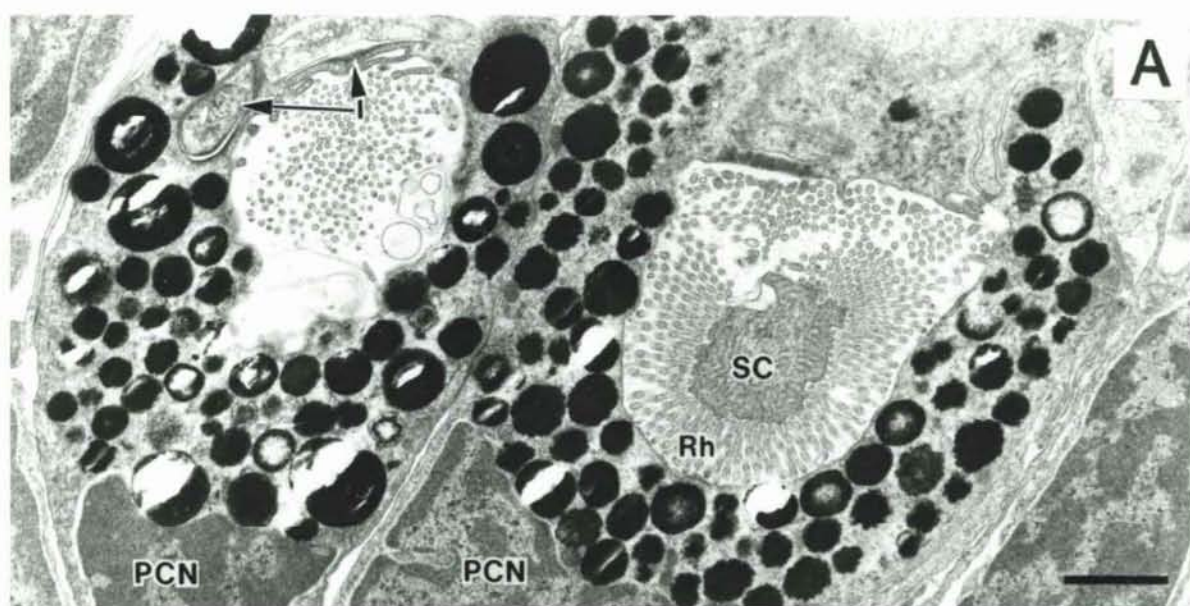


FIGURE 32 : THE TROCHOPHORE OCELLUS AND JUVENILE OCELLUS OF
S. GIGANTEUS SP.A.

- A - General longitudinal section showing the location of the ocellus below the cuticle (Ct). The sensory cell (SC) contains many mitochondria (M). The gaps between adjacent cells are an artifact of fixation (Ly, lysosome). Scale bar = 1 μ m.
- B - Detail of neck region (Za, adhering zonule; C, centriole). Scale bar = 0.5 μ m.
- C - Mitochondria-rootlet association (M,R). (Er, tubules of endoplasmic reticulum; Nu, sensory cell nucleus). Scale bar = 0.25 μ m.
- D - Ocellus of a newly settled juvenile. (PC, pigmented cell; Ax, axon leading from sensory cell; Nb, adjacent nerve bundle). The preservation of the rhabdom is poor. Scale bar = 1 μ m.

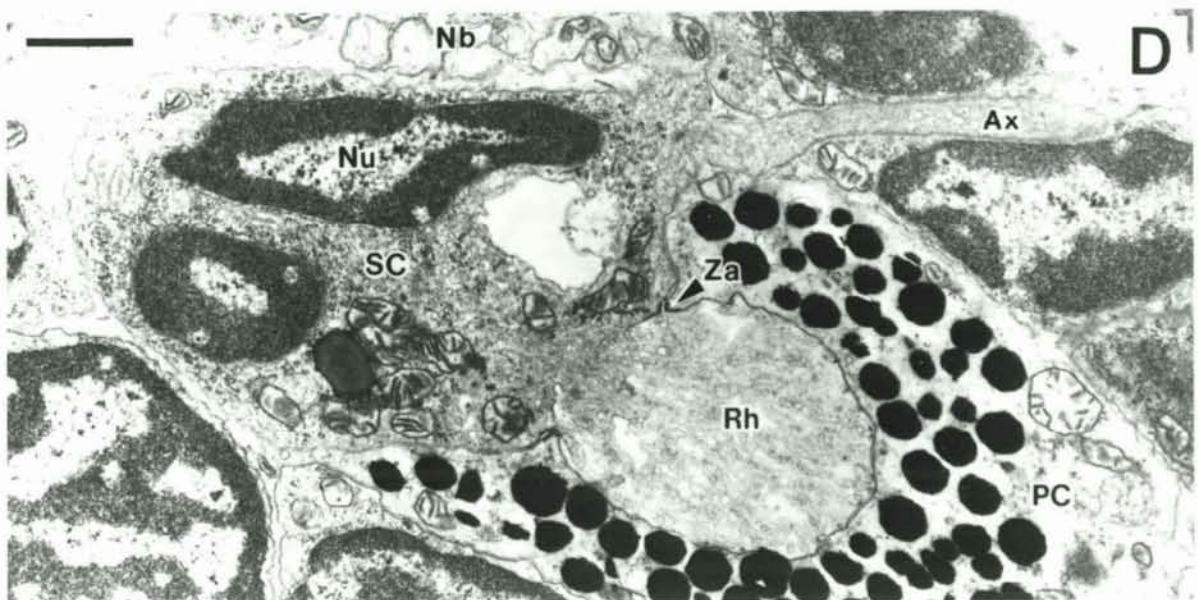
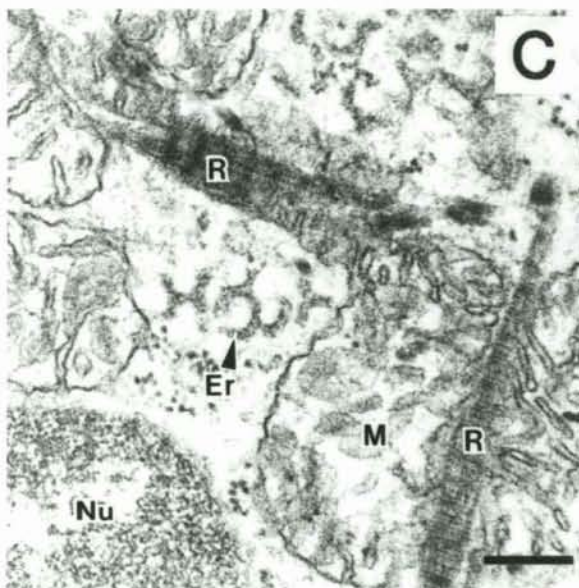
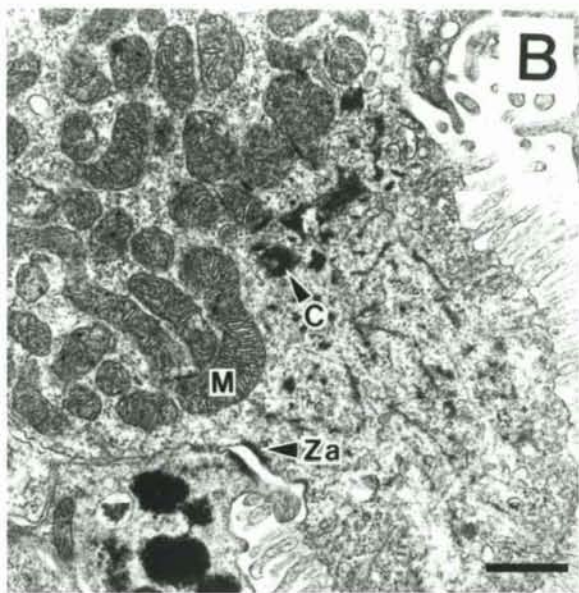
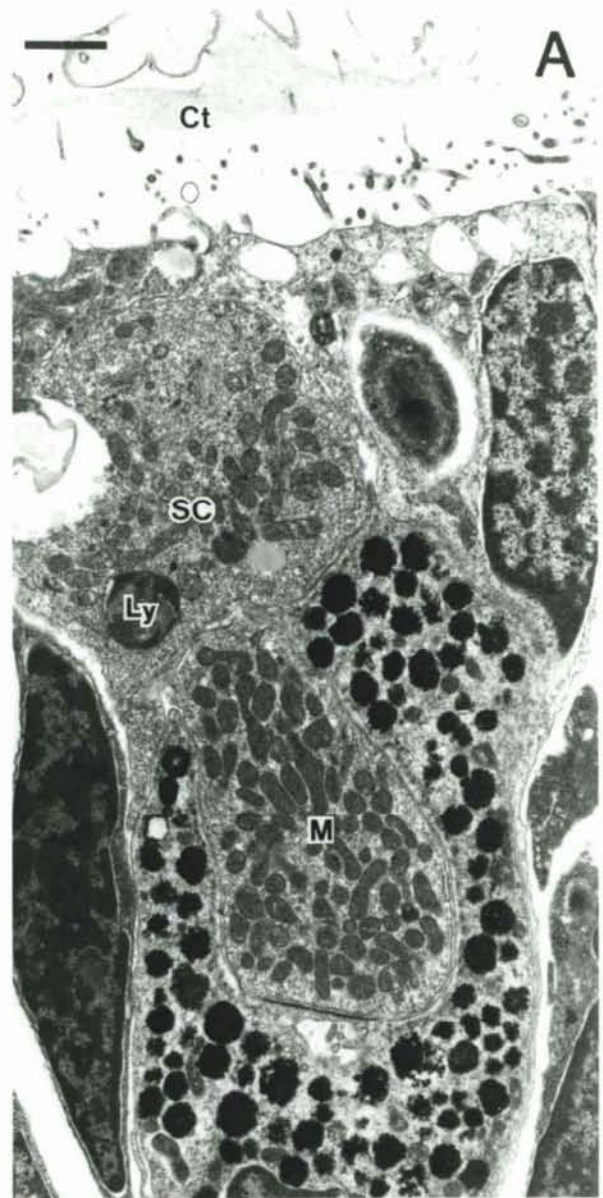


FIGURE 33 : DIAGRAM OF THE BRAIN OF *S. GIGANTEUS* SP.A

Ventral view of brain reconstructed from serial sections.
(ON, nerve to operculum; OpN, nerve to compound branchial
eye; IBN, internal branchial nerves; IBNT, internal
branchial nerve trunk; BG, branchial ganglion; EBN, external
branchial nerves; EBNT, external branchial nerve trunk;
CG, cerebral ganglion; OL, optic lobes; CC, circum-
oesophageal connectives; SG, sub-oesophageal ganglion;
SC, sub-oesophageal commissure; VNC, ventral nerve cord;
MN, median nerve; smaller nerves numbered 1-10).

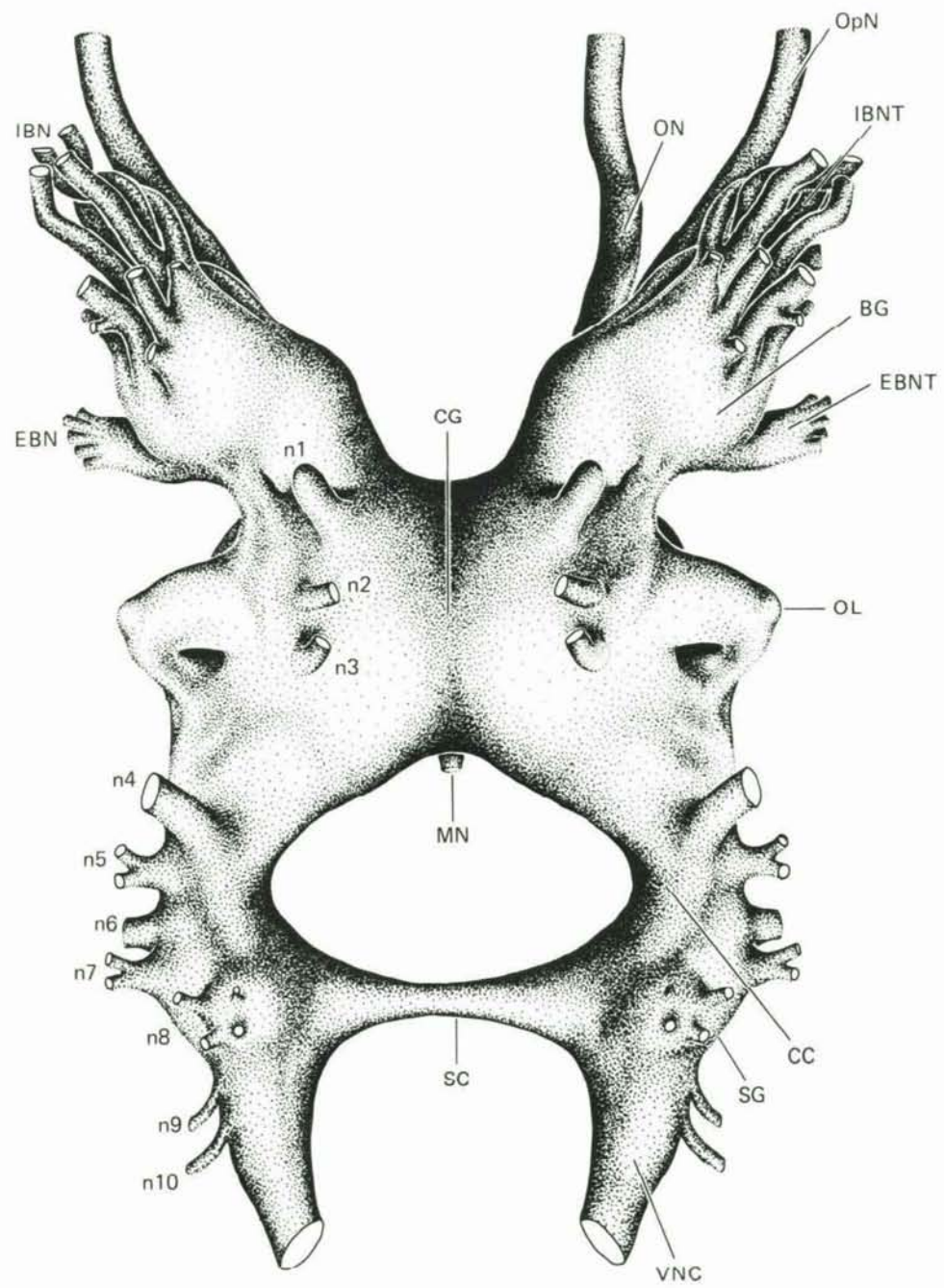


FIGURE 34 : DIAGRAM OF THE BRAIN OF *S. GIGANTEUS* SP.A

Dorsal view of brain reconstructed from serial sections. (ON, opercular nerve; OpN, optic nerves; IBNT, internal branchial nerve trunk; IBN, internal branchial nerves; EBNT, external branchial nerve trunk; EBN, external branchial nerves; CG, cerebral ganglion; MN, median nerve to blood vessel; DA, dorsal arch; OL, optic lobe; CC, circum-oesophageal connective; SG, sub-oesophageal ganglion; SC, sub-oesophageal commissure; VNC, ventral nerve cord; smaller nerves numbered 1-10).

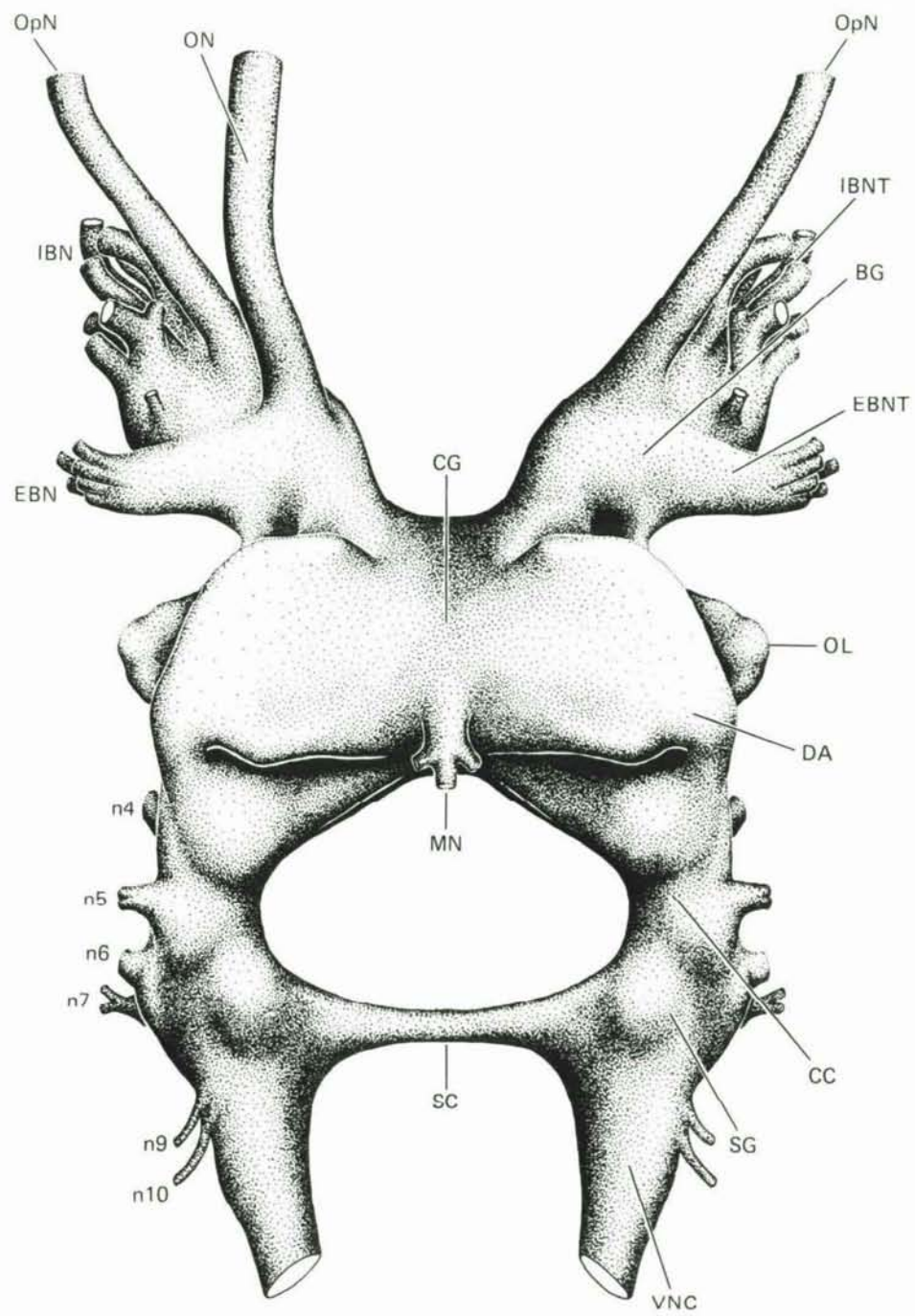


FIGURE 35 : DIAGRAM OF THE BRAIN OF *S.GIGANTEUS* SP.A

Lateral view of left side of brain reconstructed from serial sections. (OpN, optic nerve; ON, opercular nerve, IBNT, internal branchial nerve trunk; EBNT, external branchial nerve trunk; BG, branchial ganglion; CG, cerebral ganglion; DA, dorsal arch; CC, circum-oesophageal connective; SG, sug-oesophageal ganglion; VNC, ventral nerve cord; smaller nerves numbered 1-10).

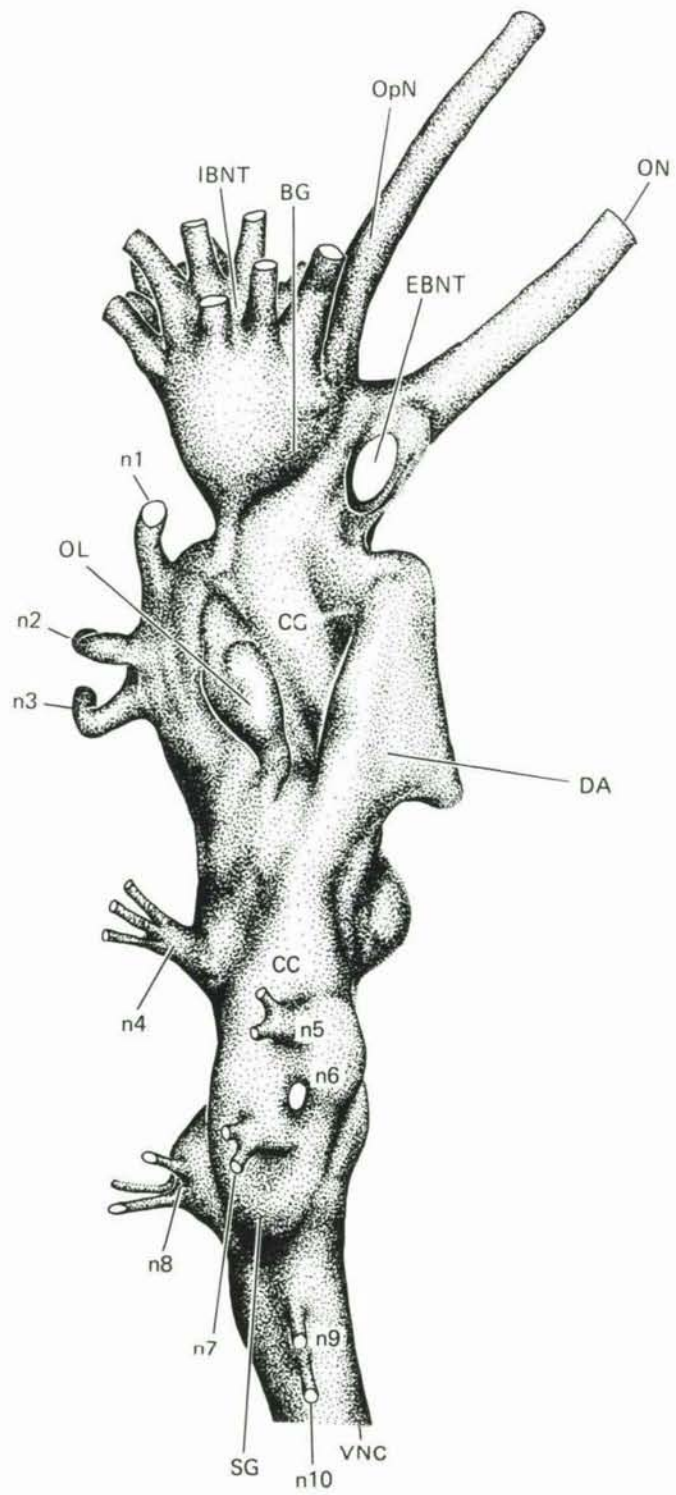


FIGURE 36 : DIAGRAM OF AN ADULT CEREBRAL OCELLUS OF *S. GIGANTEUS*
SP.A

Idealized longitudinal section
(refer to Legend for organelle identification)

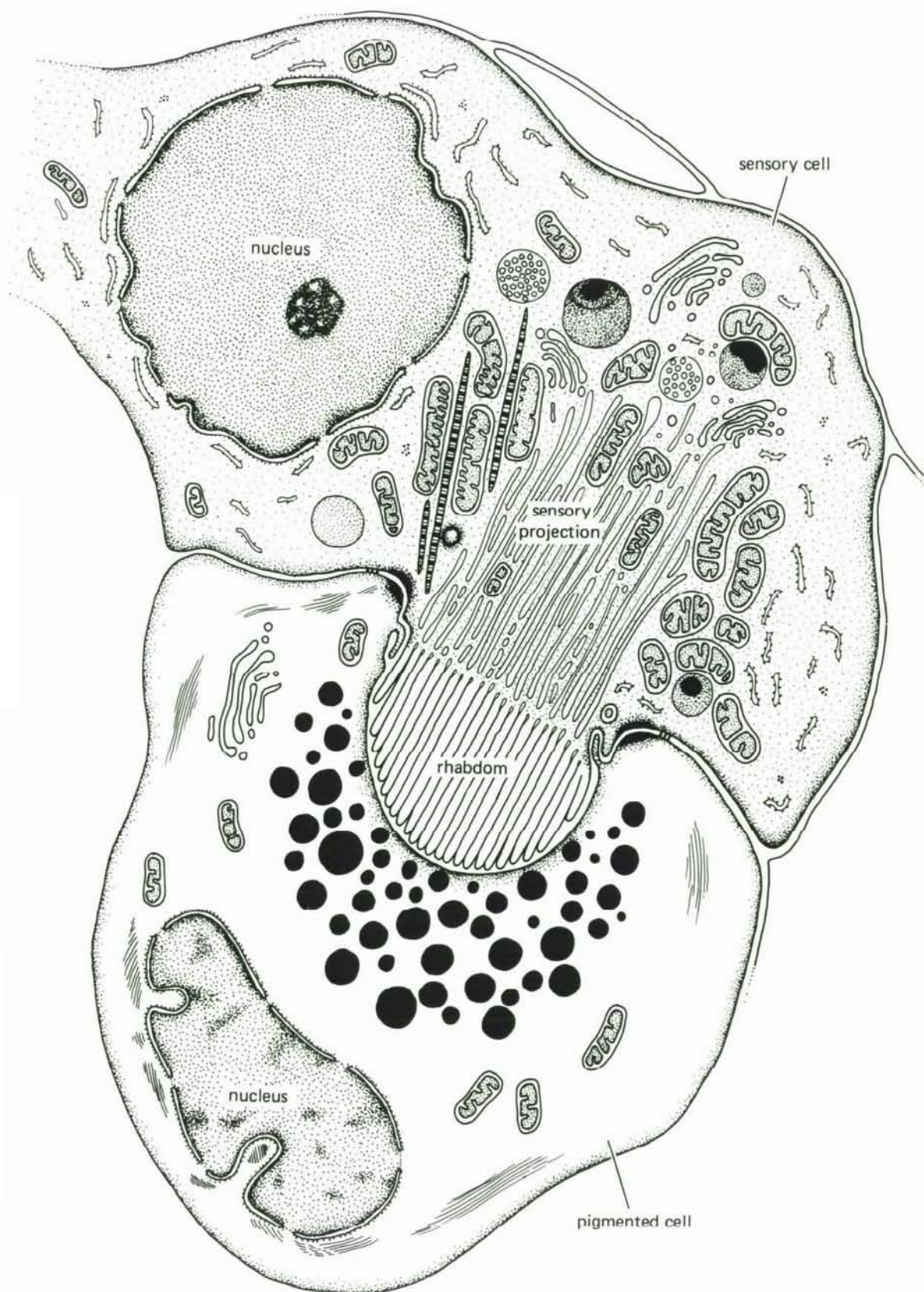
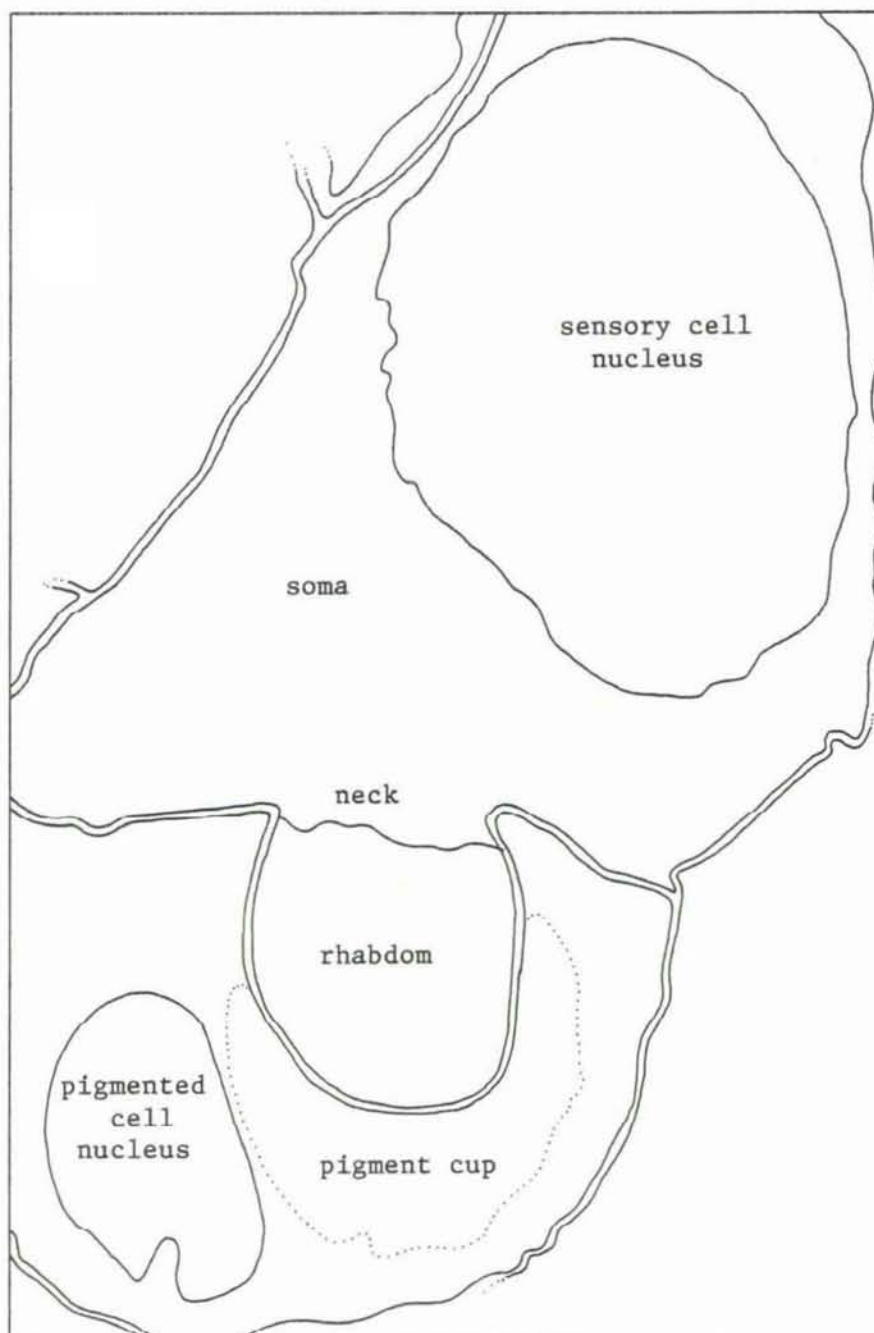


FIGURE 37 : THE CEREBRAL OCELLUS OF *S. GIGANTEUS* SP.A (T.E.M.)

The map below illustrates the principal components seen in this longitudinal section.

22200 X



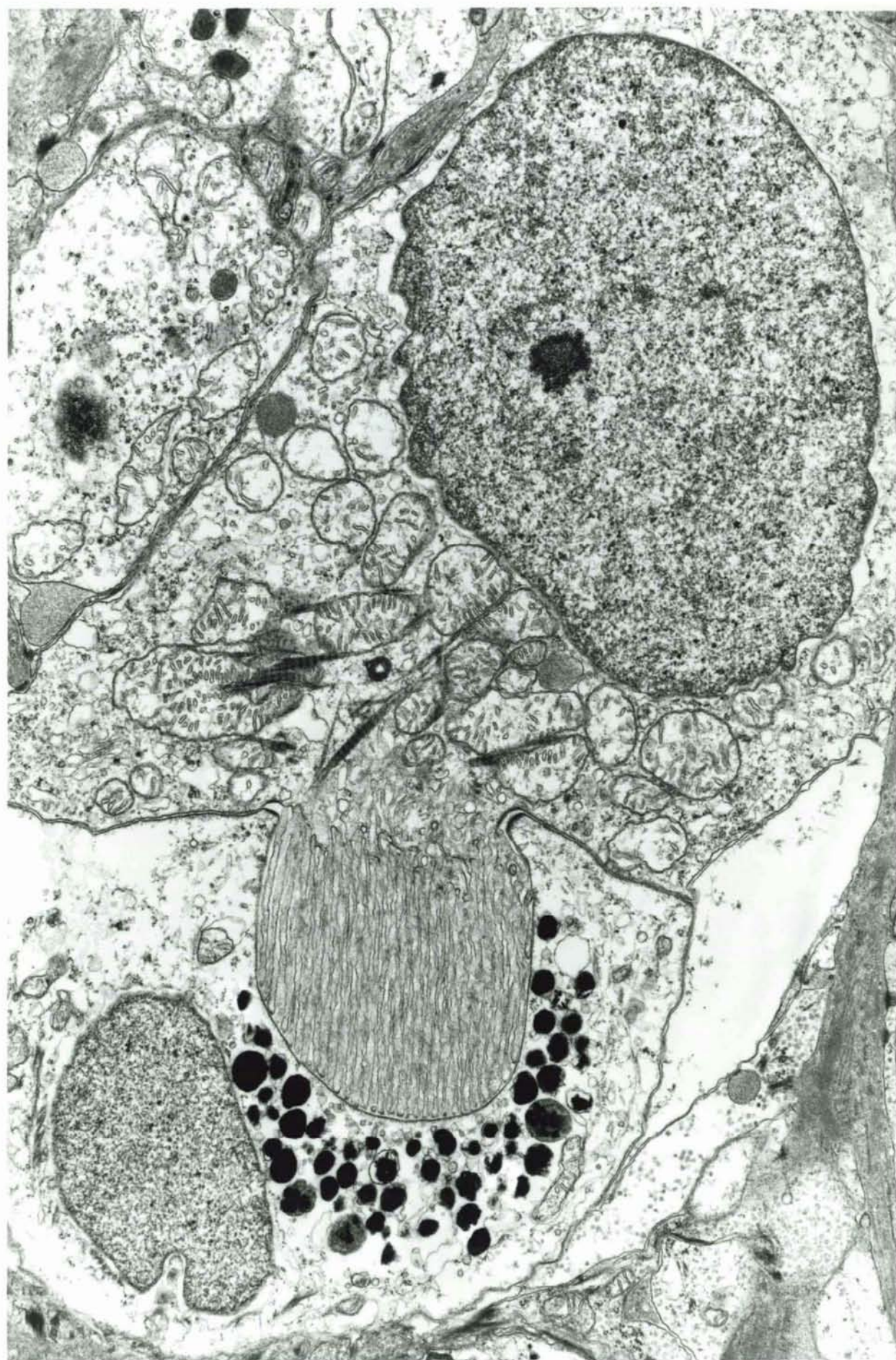


FIGURE 38 : THE CEREBRAL OCELLUS OF *S. GIGANTEUS* SP.A (T.E.M.)

- A - General view showing location of a major mitochondria-rootlet (R) assemblage. Note the angle of entry of the rhabdom (Rh) into the sensory cavity of the pigmented cell (PC). (SC, sensory cell; Nu, nucleus). Scale bar = 1 μ m.
- B - General view of another ocellus displaying poorly developed pigment cup but considerable development of sub-microvillar cisternae (Smc). Scale bar = 1 μ m.

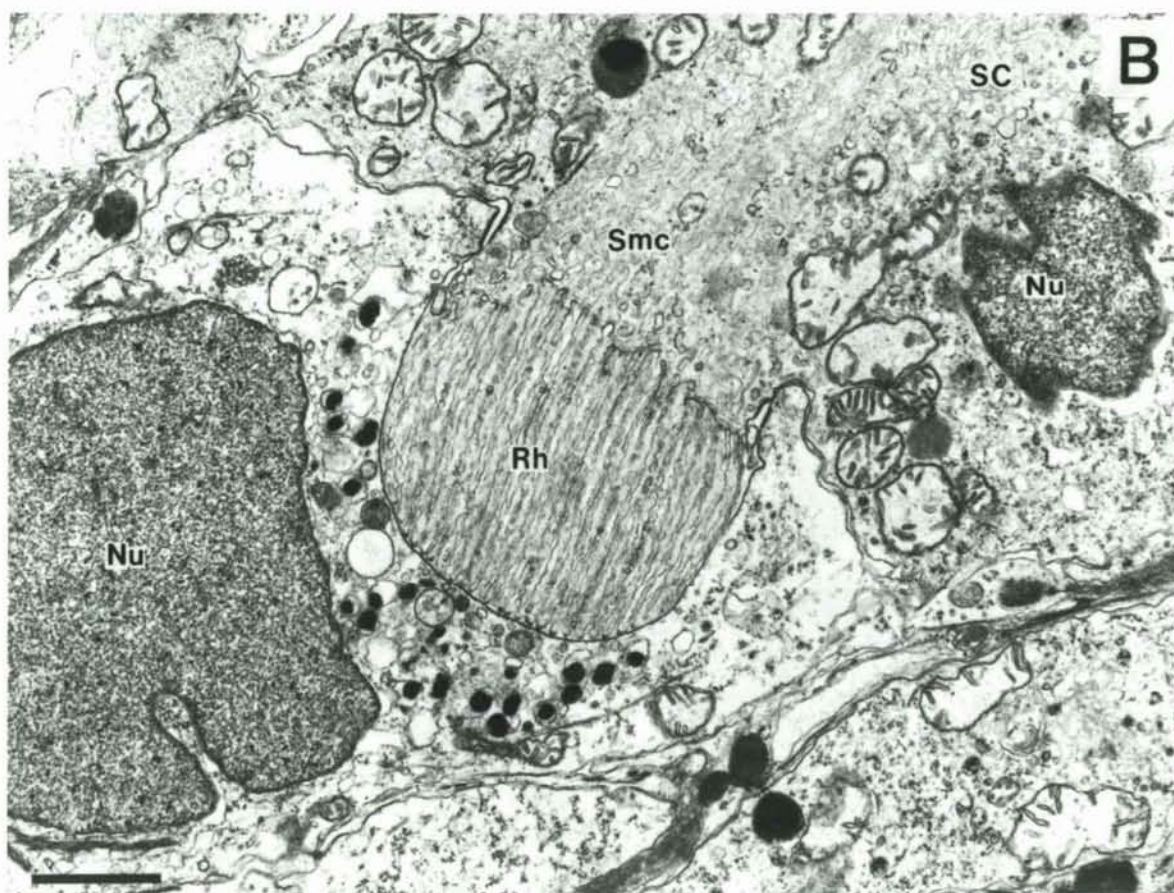


FIGURE 39 : THE CEREBRAL OCELLUS OF *S. GIGANTEUS* SP.A (T.E.M.)

- A - An ocellus with two flanking pigmented cells and a split rhabdom. The sensory projection is elongated and contains numerous prominent mitochondria-rootlet assemblages. (Ly, lysosomes; SC, sensory cell; PC, major pigmented cell). Scale bar = 1 μ m.
- B - Another ocellus with two pigmented cells (PC₁ and PC₂), both contributing screening pigment granules. Scale bar = 1 μ m.
- C - Detail of the split rhabdom (Rh₁ and Rh₂) from the ocellus shown in A. Scale bar = 0.5 μ m.
- D - Detail of the rhabdom (Rh) and associated submicrovillar cisternae (Smc). Note the numerous vesicles (V) near the base of the microvilli and the mitochondria (M) of the sensory projection. Scale bar = 0.5 μ m.

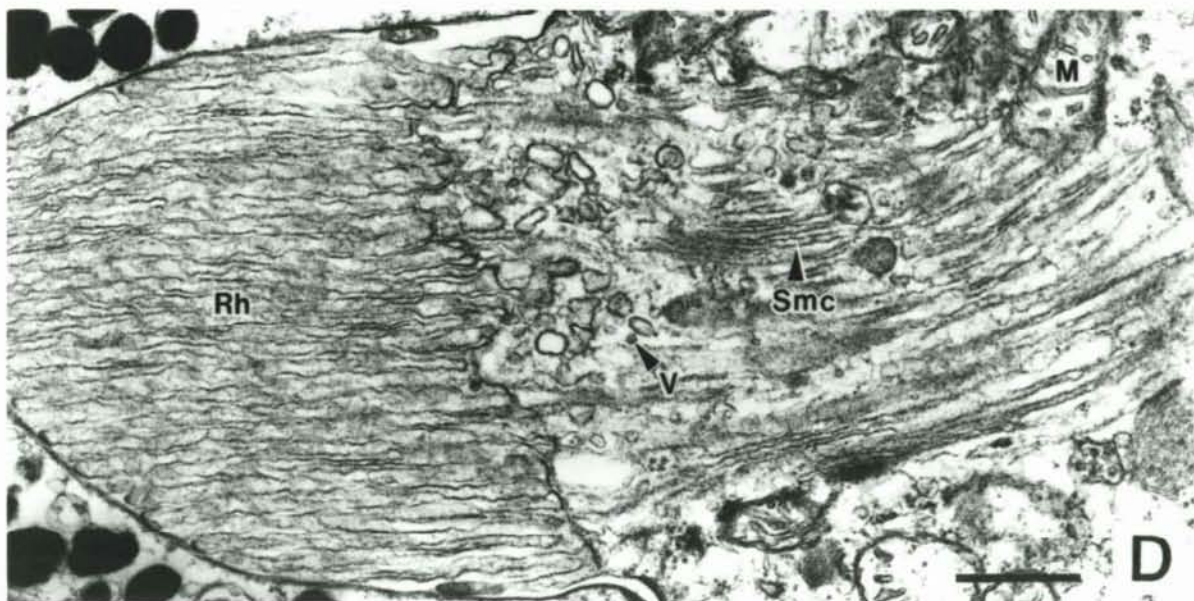
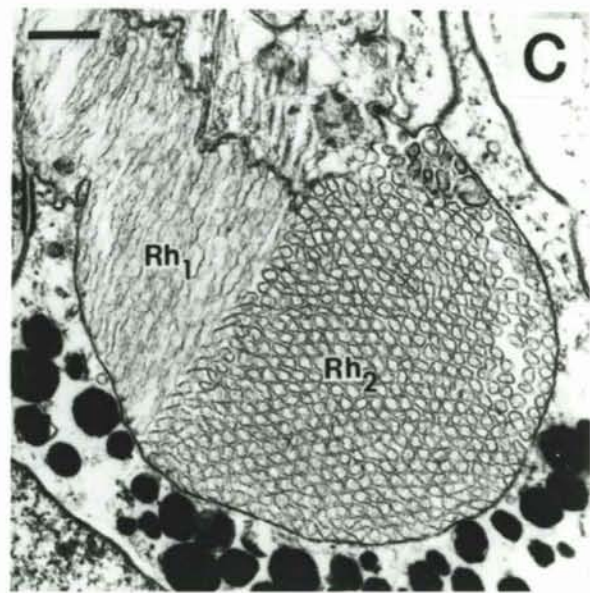
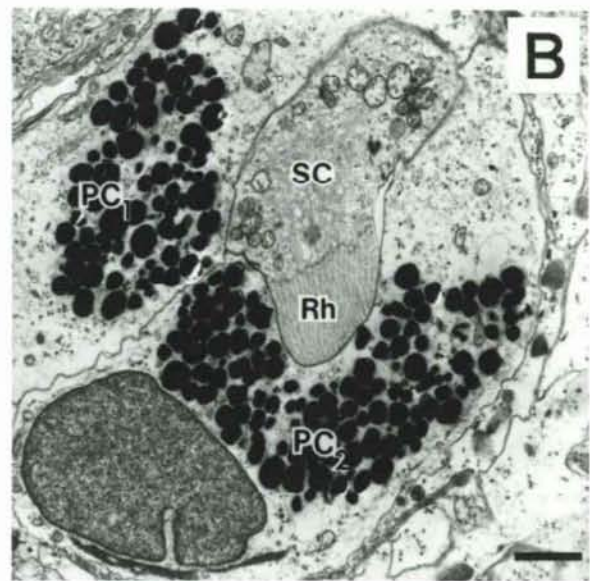
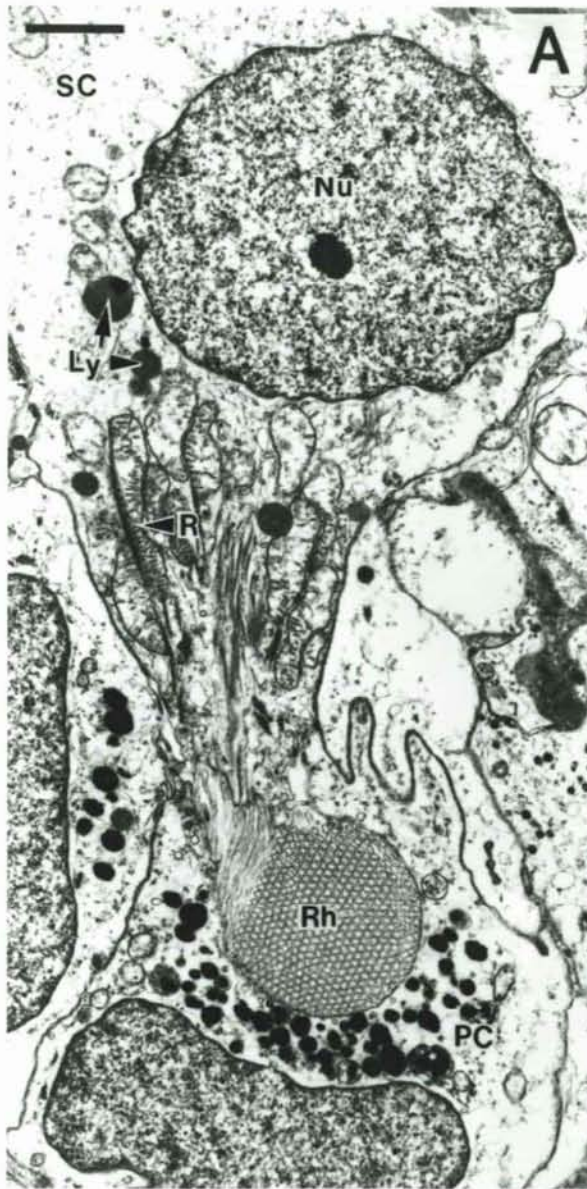


FIGURE 40 : THE CEREBRAL OCELLUS OF *S. GIGANTEUS* SP.A (T.E.M.)
= MITOCHONDRIA-ROOTLET ASSOCIATIONS

- A - A centriole (C) occupies a central position in the sensory projection above the rhabdom (Rh) in this micrograph. Rootlets (R) pass between mitochondria (M) and within mitochondrial furrows. Several of the rootlets can be seen to branch and the one lying vertical in the centre of the micrograph appears to pass towards the corner of the rhabdom. (Za, adhering zonule). Scale bar = 0.5 μ m.
- B - This micrograph shows a section cut at a slightly deeper level through the same region as A. Note that the rootlets pass close to, but seem to bypass, the centriole. Scale bar = 0.5 μ m.

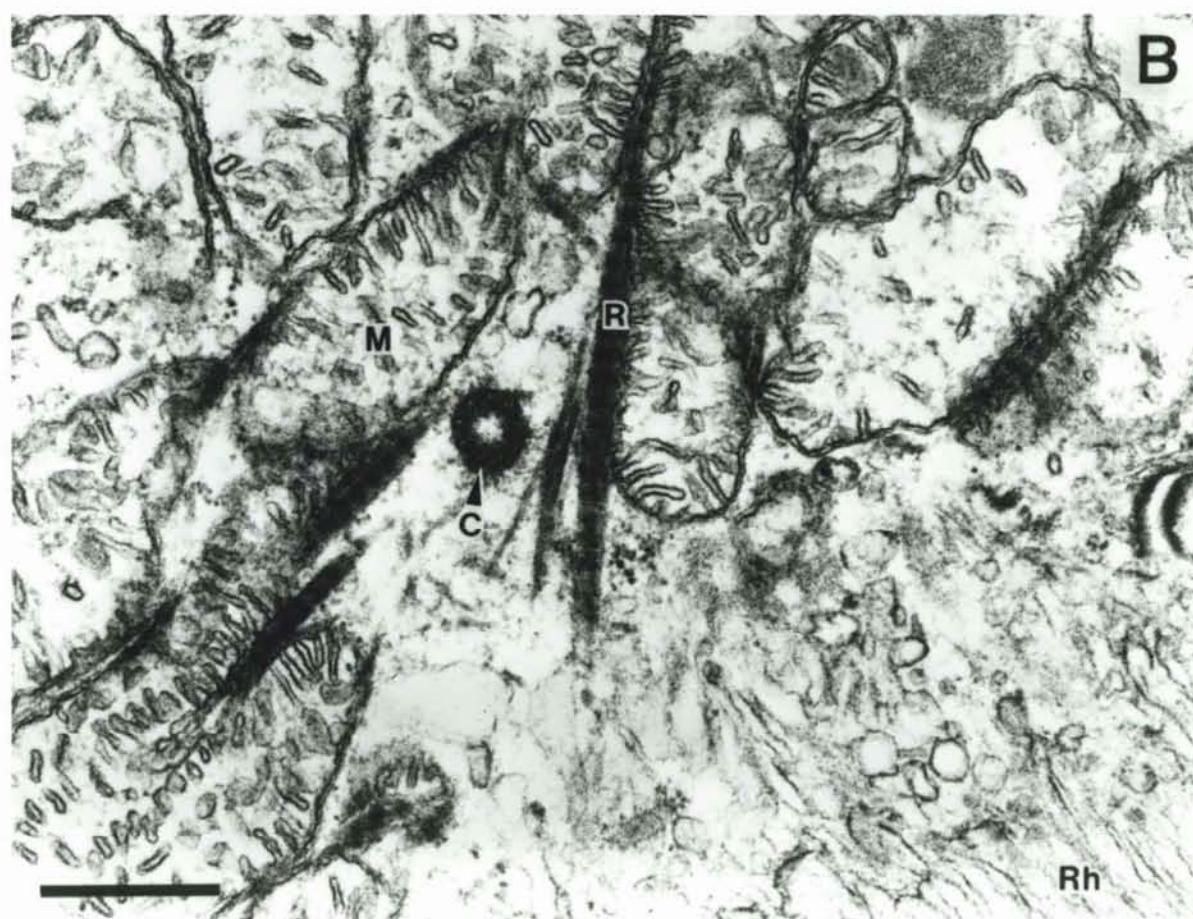


FIGURE 41 : THE CEREBRAL OCELLUS OF *S. GIGANTEUS* SP.A (T.E.M.)
- MITOCHONDRIA-ROOTLET ASSOCIATIONS

- A - Mitochondria-rootlet association (M,R) showing the aggregation of cristae on the surface adjacent to the rootlet. The banding periodicity of the rootlet closely matches the alignment of cristae. The sensory cell nucleus (Nu) is uppermost. Scale bar = 0.5 μ m.
- B - The rootlet continues beyond the mitochondria and appears to terminate at the base of the rhabdom (Rh) close to the adhering zonule (Za) delimiting the sensory cavity. To the left of the micrograph the rootlet becomes vesicular. Note also the interdigitations of stout microvilli from the pigmented cell in the neck region. (Smc, submicrovillar cisternae; PC, pigmented cell; Ly, Lysosome). Scale bar = 0.5 μ m.

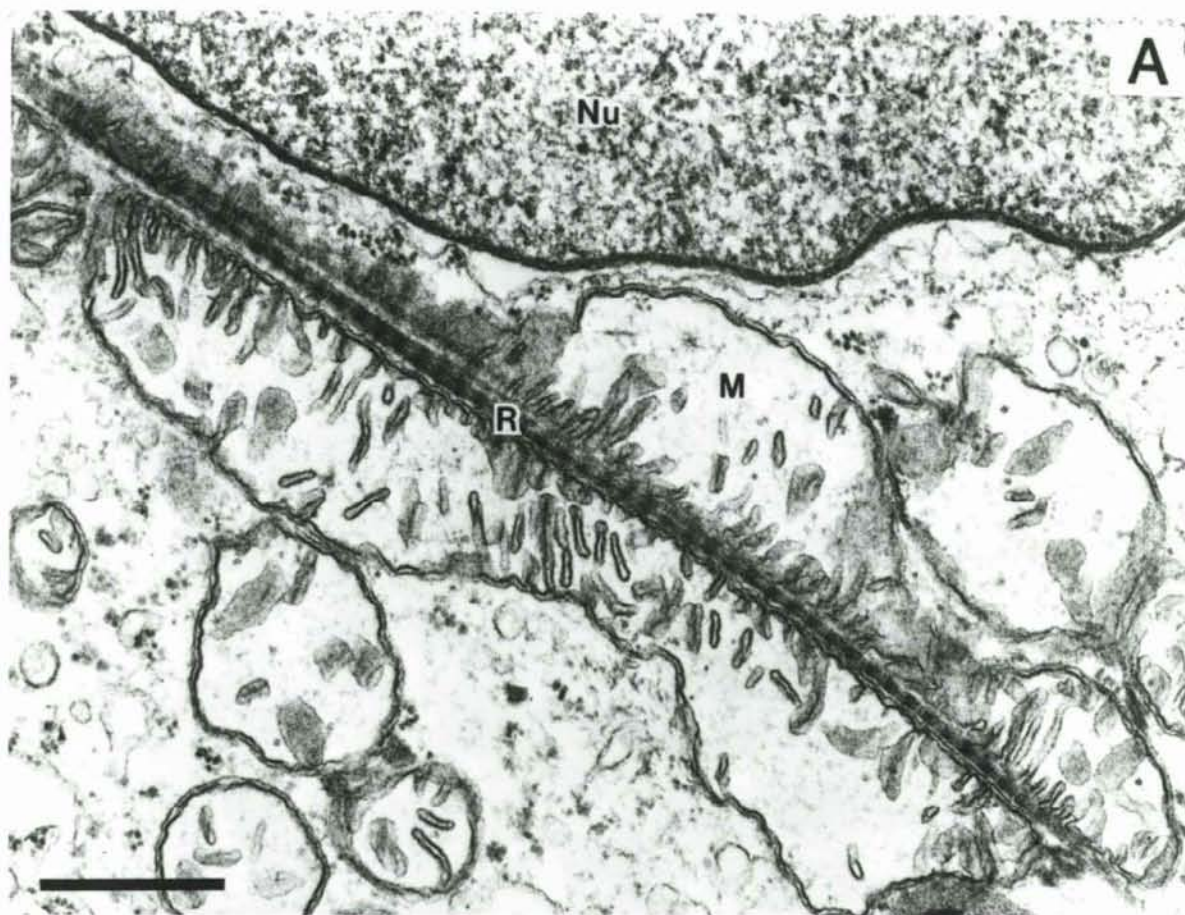


FIGURE 42 : THE CEREBRAL OCELLUS OF *S. GIGANTEUS* SP.A (T.E.M.)
= MITOCHONDRIA-ROOTLET ASSOCIATION

- A - Oblique section through sensory projection showing the density of the mitochondria-rootlet assemblages (M,R). Scale bar = 0.5 μ m.
- B - A longitudinal section of a mitochondria-rootlet association which illustrates the regular arrangement of cristae adjacent to the bundle of rootlets. The rootlets pass close to the adhering zonule at the base of the rhabdom (Rh) and close to the sensory cell nucleus (Nu). This detail is from a different section of the same ocellus shown in figure 38A. (V, vesicles close to the base of the rhabdom). Scale bar = 0.5 μ m.

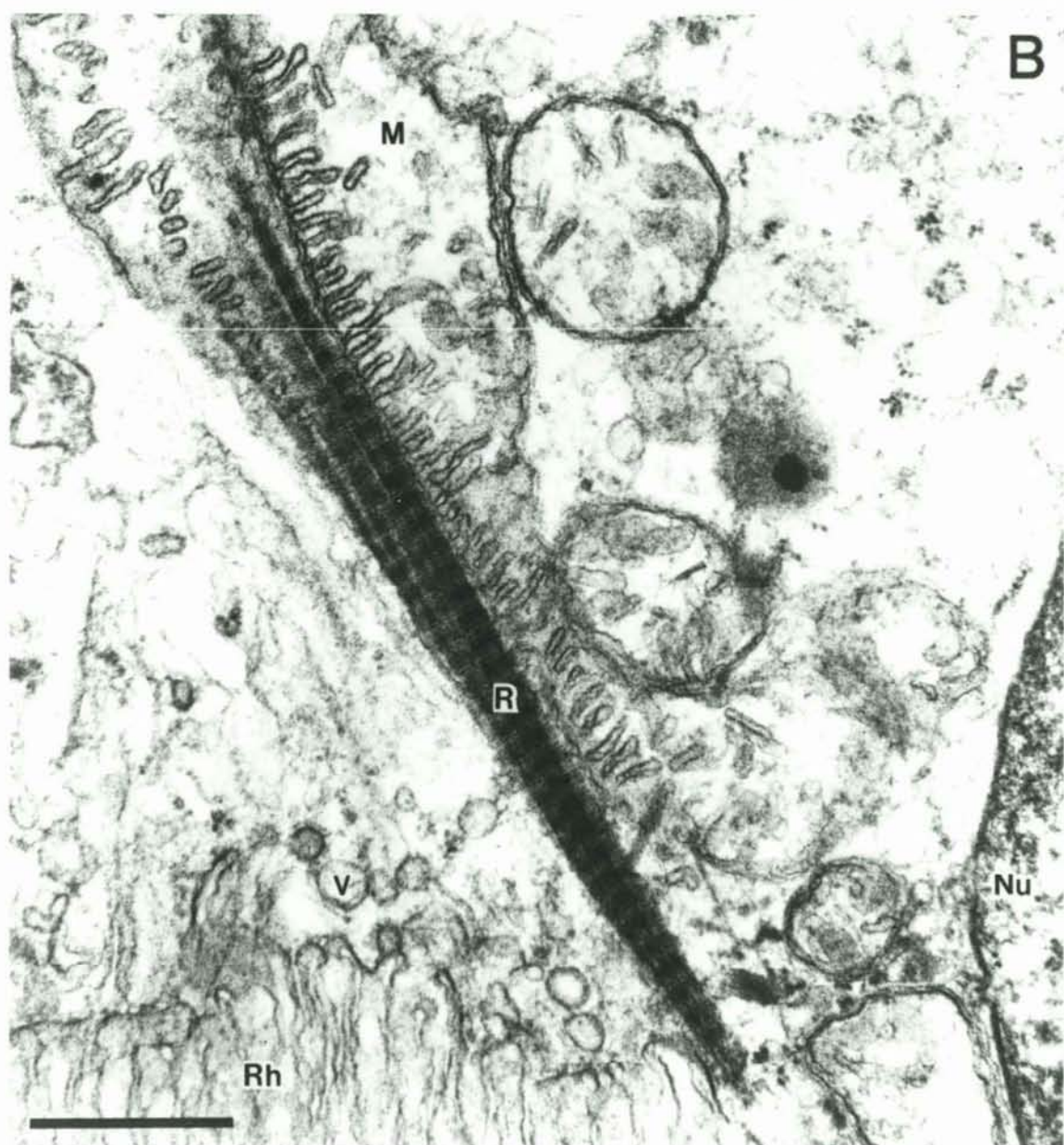
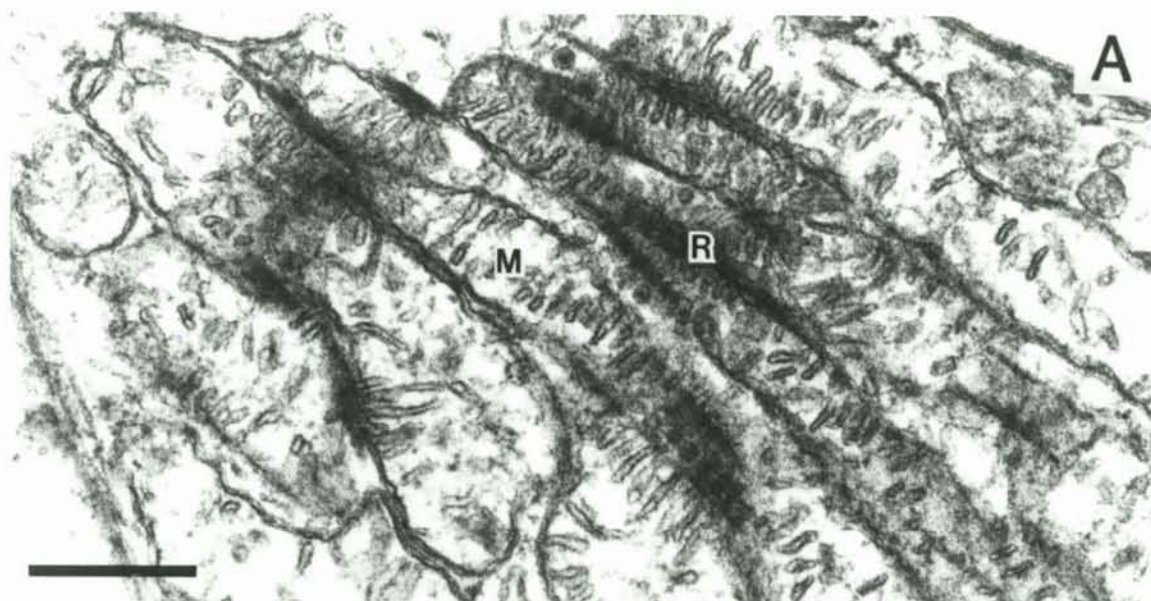


FIGURE 43 : DIAGRAMMATIC REPRESENTATION OF A MITOCHONDRIA-ROOTLET ASSOCIATION

The mitochondrial cristae are presumed to be massed adjacent to the furrow containing the rootlet as shown in the cutaway section.

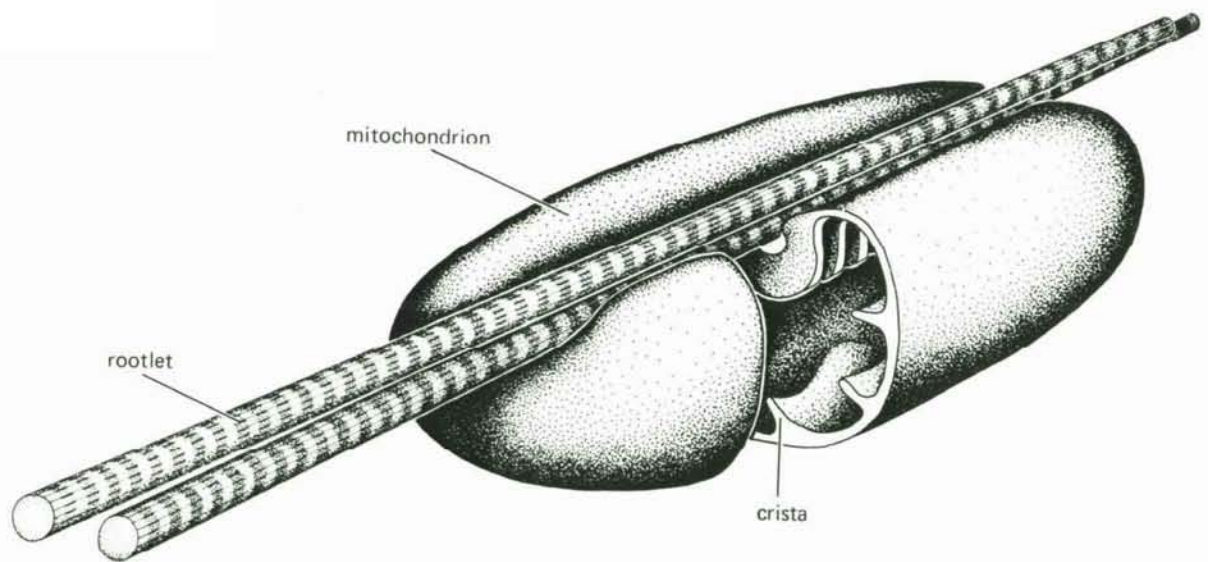


FIGURE 44 : LIVE APPEARANCE OF *SPIROBRANCHUS* EYES (COLOUR PLATE)

- A - The two eyed metatrochophore, apical view. Apart from the ocelli, some of the larval musculature is visible in this micrograph (refer to Chapter 3).
Scale bar = 50µm.
- B - *S. giganteus* sp.D showing the location of the two compound branchial eyes (arrowed) on the initial radiole at the base of each branchial spire. Scale bar = 1mm.
- C - The compound branchial eye of the *S. giganteus* complex. Each of the dark pits visible is the apex of a receptor unit, capped by a transparent cuticular lens. The orange-red pigmentation of the organ is provided by the pigmented cells. This eye is from *S. gardineri*.
Scale bar = 0.25mm.
- D - The branchial eyespots of *S. tetraceros* sp.A. The eyespots (arrowed) are inconspicuous and situated in a paired row along the proximal radiole, immediately above the branchial membrane. Scale bar = 0.25mm.
- E - The branchial eyespots of *S. tetraceros* sp.C. The prominent red eyespots of this species are widely distributed along the aboral aspects of the radioles.
Scale bar = 0.25mm.

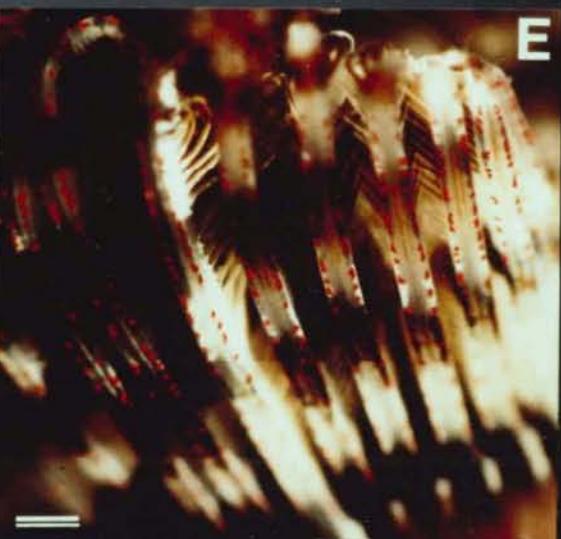
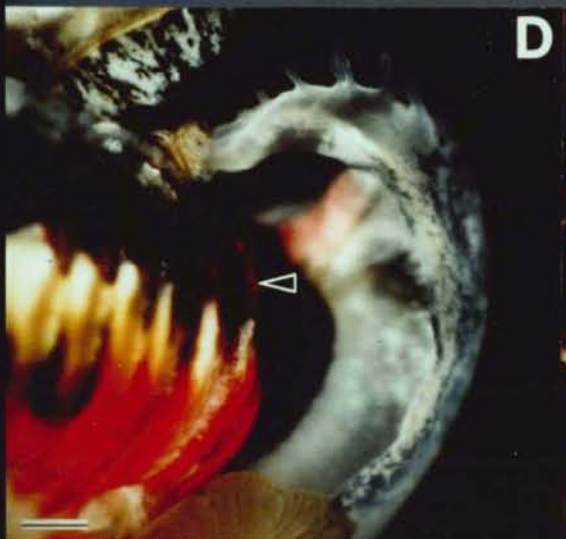
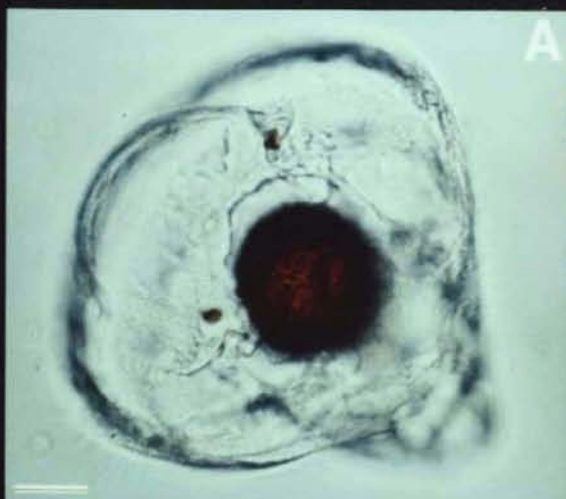


FIGURE 45 : THE COMPOUND BRANCHIAL EYE OF *SPIROBRANCHUS*
(OPTICAL & S.E.M.)

- A - Transverse section through the mid-region of the compound eye showing radial arrangement of the elongated receptor units (Ru). The external branchial nerve (Bn), functioning as the optic nerve, can be seen located to one side at the base of the eye. (Ce, columnar epithelium of aboral surface of radiole; Fg, food groove of radiole). 1 μ m resin optical section stained with toluidine blue. Scale bar = 50 μ m.
- B - Longitudinal section through the compound eye showing lengthwise variation in orientation of cells. The sensory cells appear dark distally and are surrounded by a paler zone. The basal knob (Bk) marks the proximal termination of the organ. 6 μ m wax optical section with trichrome stain. Scale bar = 50 μ m.
- C - S.E.M. of compound eye viewed from the proximal end. Note the multitude of small hemispherical lenses overlying the sensory cells. (P, pinnules; Rad, radioles). Scale bar = 50 μ m.

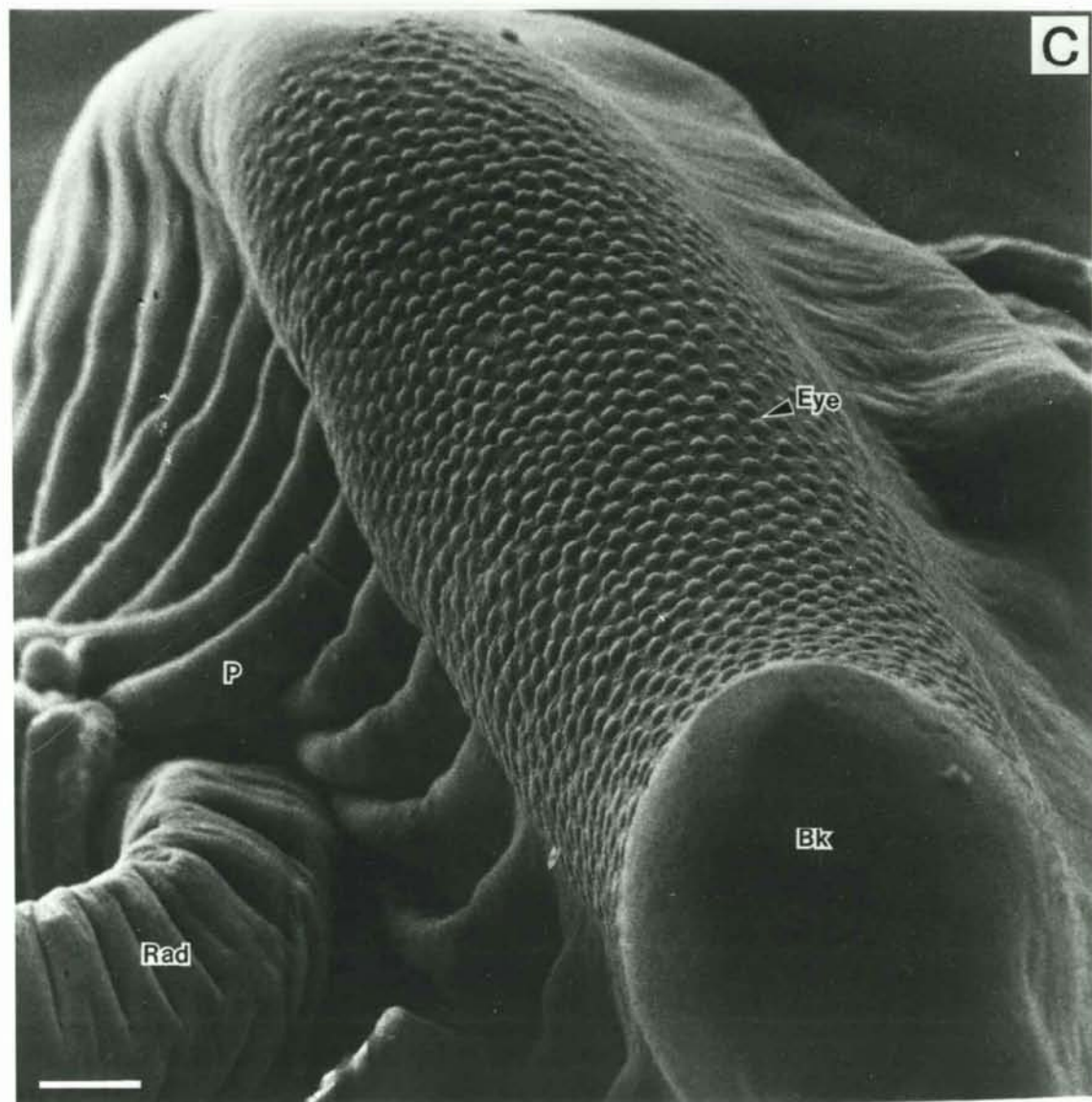
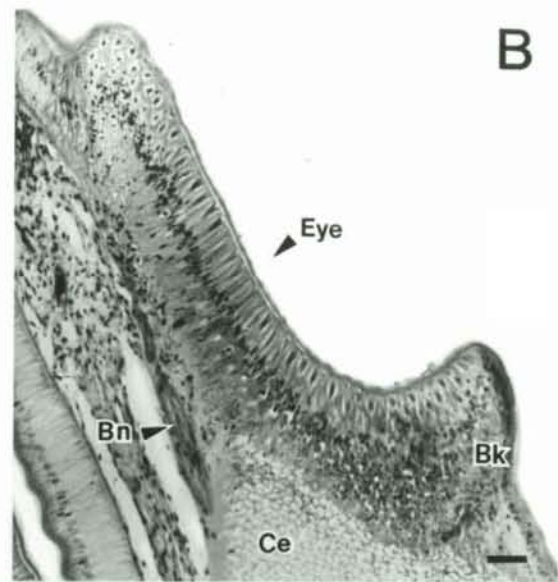
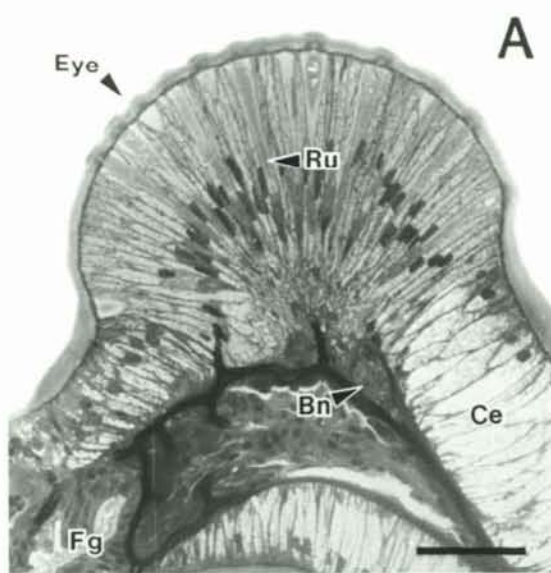


FIGURE 46 : DIAGRAM OF A SINGLE PHOTORECEPTOR UNIT FROM THE
COMPOUND EYE OF *SPIROBRANCHUS*

- A - Schematic cross section of eye.
- B - Longitudinal section of an entire receptor unit.
- C - Longitudinal section through the rhabdom region. The central dark shaft is the column of material continuous with the cuticle.
- D - Longitudinal section through the lamellar region.
- E - Longitudinal section through endchamber/nuclear region.
- F - Longitudinal section through lower soma.

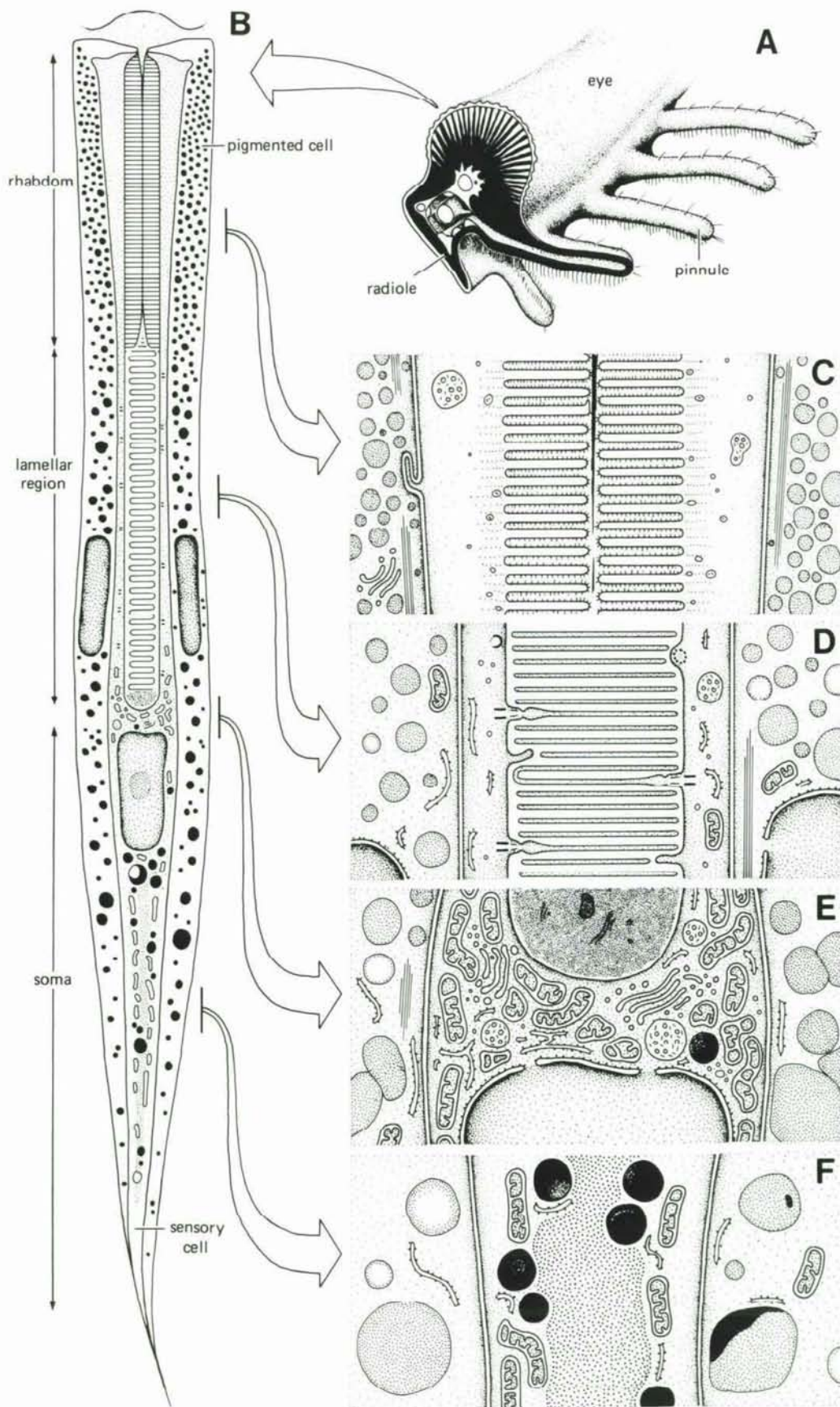


FIGURE 47 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) :
DISTAL SENSORY CELL

- A - Distal end of sensory cell (SC) showing lens and supporting pigmented cells (PC). Note the thickened cuticle of the lens and the lateral processes of the pigmented cells capping the top of the sensory cell. The rhabdom (Rh) is shown in longitudinal section. (Epi, epicuticle). Scale bar = 1 μ m.
- B - Detail showing adhering zonules (Za) between adjacent pigmented cell processes. Scale bar = 0.5 μ m.
- C - Similar to B but also showing a septate desmosome (D) linking a pigmented cell with a sensory cell. Scale bar = 0.5 μ m.

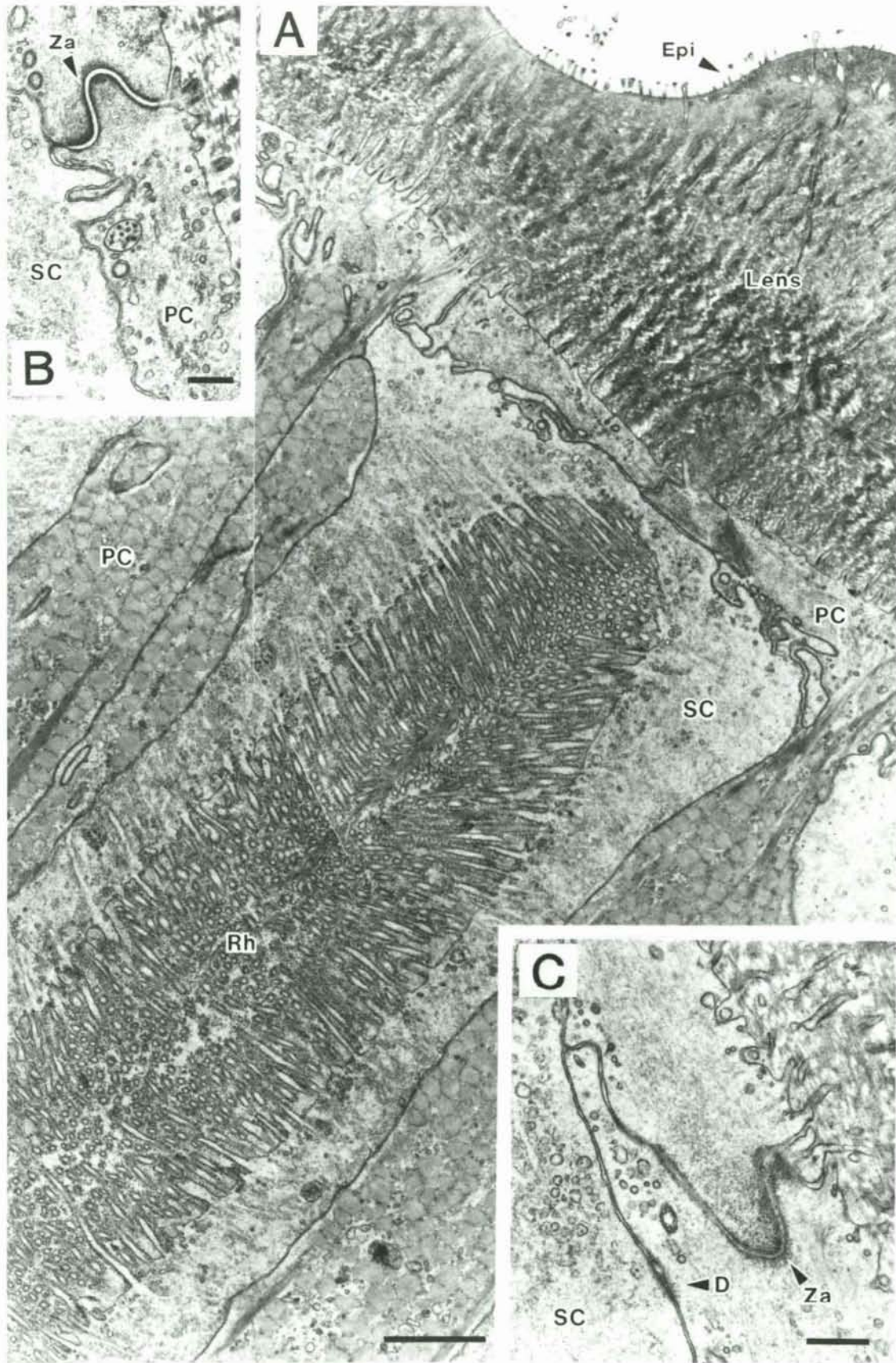


FIGURE 48 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) :
DISTAL SENSORY CELL

The map below illustrates the principal components seen in
this longitudinal section.

18000 X

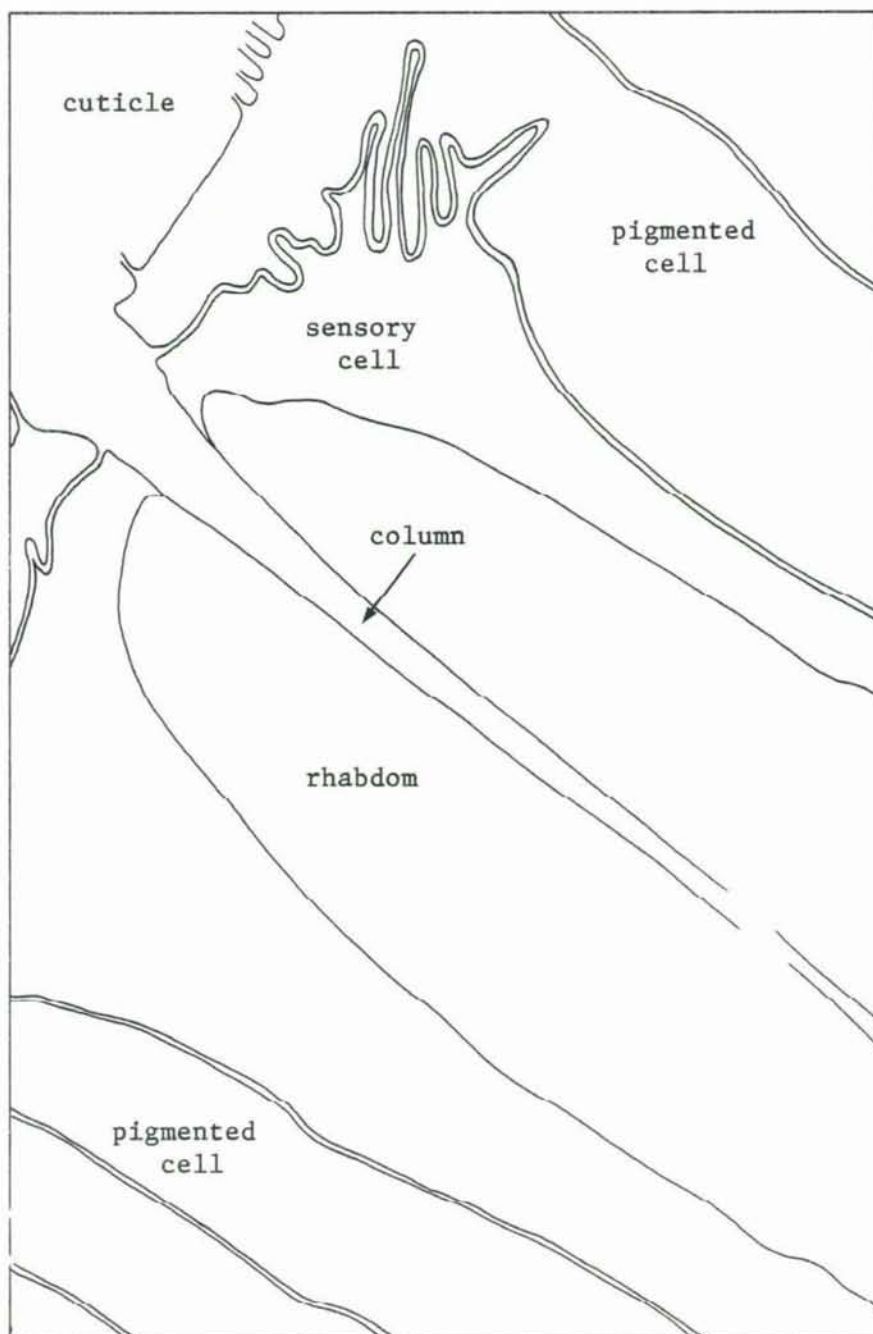




FIGURE 49 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) :
DISTAL SENSORY CELL

- A - Finger-like interdigitations (I) which anchor the sensory cell apex (SC) to the pigmented cell lateral processes. (V, vesicles associated with lens formation; Ct, cuticle; Tf, tonofilaments of the pigmented cell).
Scale bar = 0.5 μ m.
- B - Distal sensory cell showing rhabdom (Rh). Note the central column of fine fibrous material (Fm).
Scale bar = 1 μ m.
- C - Oblique transverse section through rhabdom.
Scale bar = 0.5 μ m.

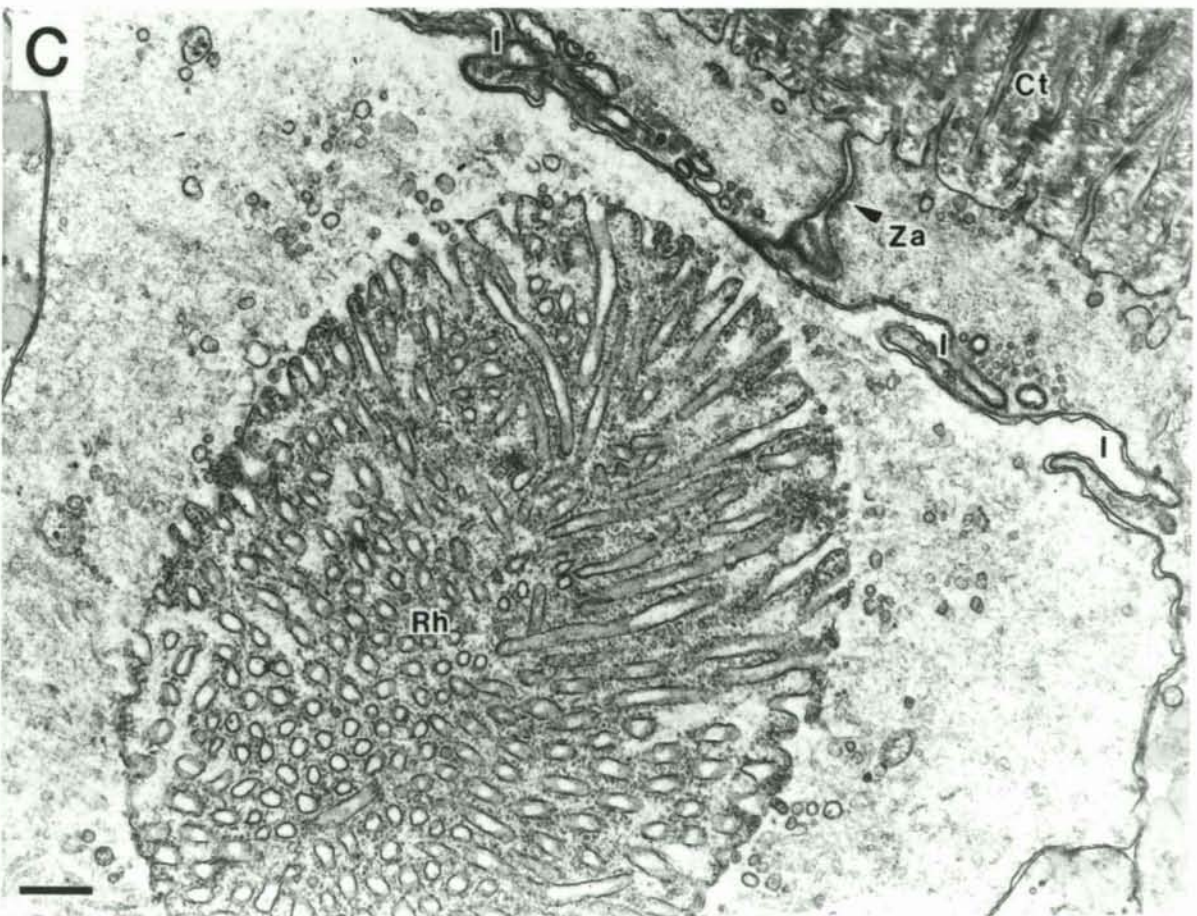
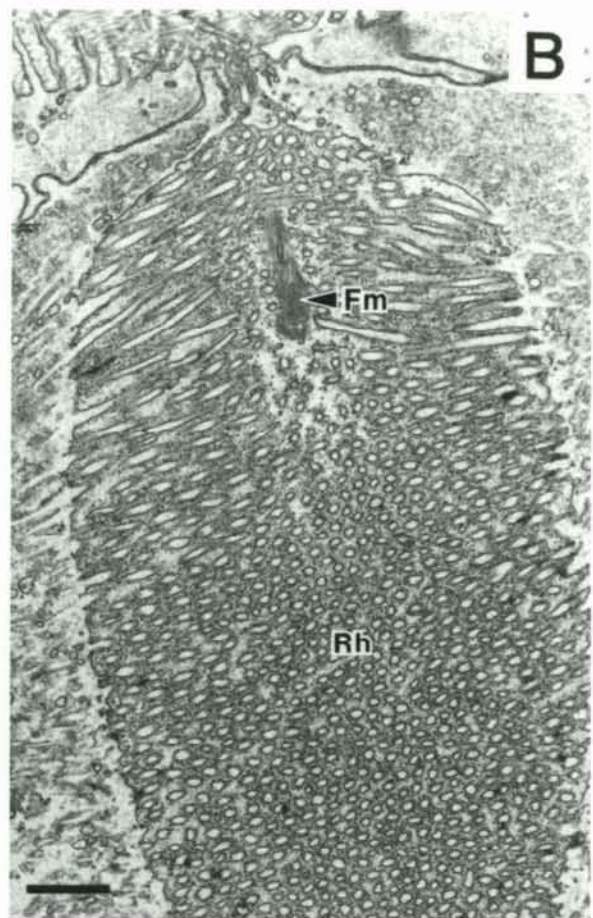
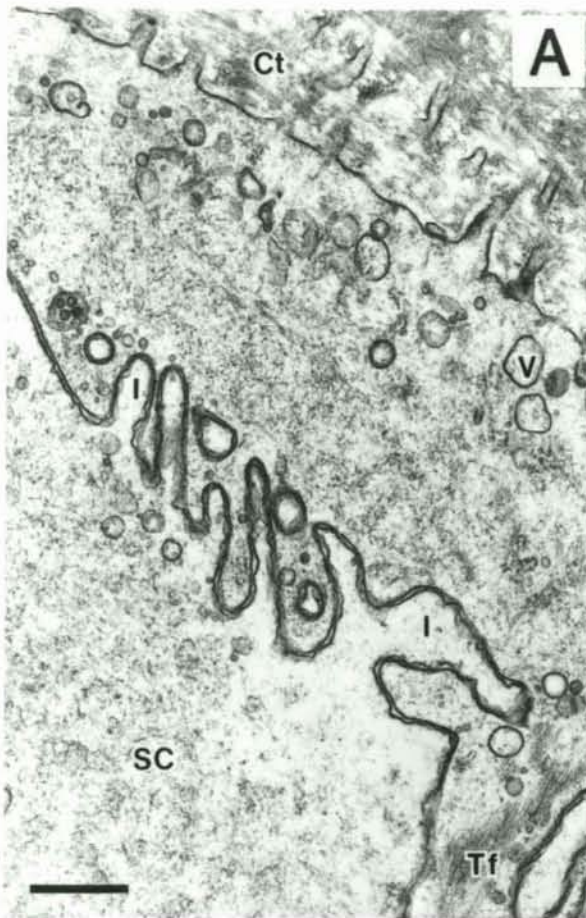


FIGURE 50 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) =
RHABDOM

- A - The sensory cell is widest at its distal end. Note the greater density of the cytoplasm closest to the microvilli of the rhabdom. Note also the column of fibrous material (Fm). Scale bar = $1\mu\text{m}$.
- B - The column of fibrous material is continuous through the aperture (Ap) between the pigmented cell processes (PC), and into the cuticle. Notice that in this (and other) micrograph these lateral processes are non-pigmented. The microvilli of the rhabdom (Rh) can be seen to be arranged in rows in this micrograph. Scale bar = $1\mu\text{m}$.
- C - A similar micrograph to B. Note the apparent spiral arrangement of the microvilli, especially around the column. Note also the multi-inclusion bodies (Mib) in the sensory cell cytoplasm. Scale bar = $1\mu\text{m}$.

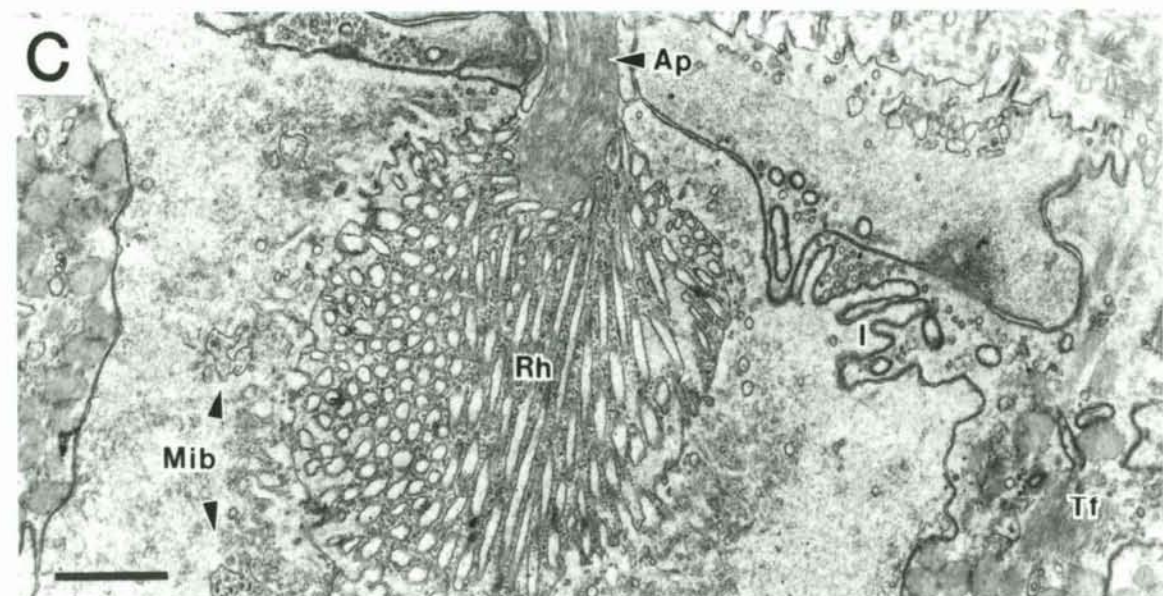
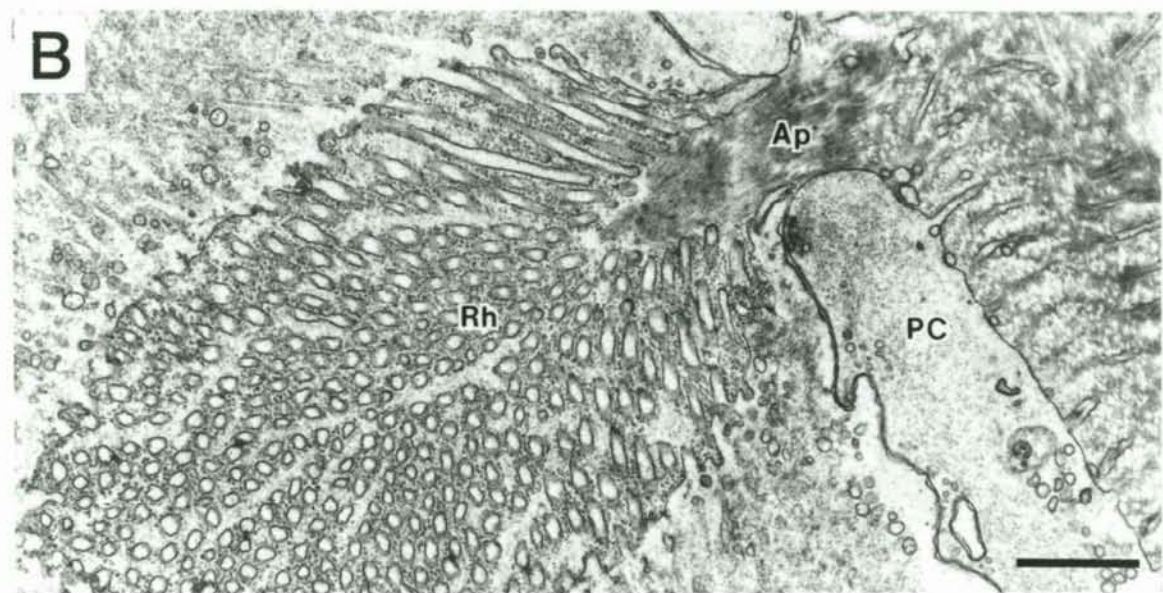
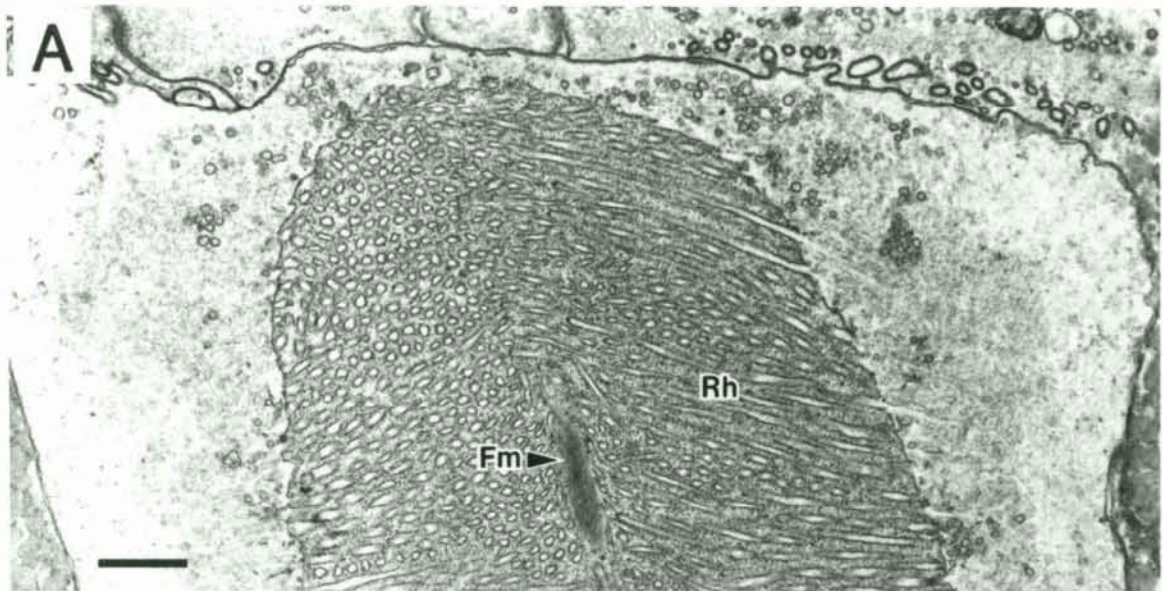


FIGURE 51 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) =
RHABDOM

- A - Distal end of sensory cell. Note the apparent termination of the column of fibrous material (Fm) immediately below the aperture (asterisk).
Scale bar = $1\mu\text{m}$.
- B - Detail of the central region of the rhabdom showing the production of the fibrous material by elongated tips of the microvilli (Mv). The microvillar tips are all deflected upwards towards the lens. Scale bar = $0.25\mu\text{m}$.
- C - Microvilli may travel alongside the column of fibrous material as shown in this micrograph. The lens is to the left of the figure. Scale bar = $1\mu\text{m}$.
- D - Micrograph of a well-developed rhabdom, longitudinal section. Note the considerable length of some of the microvilli and the change in deflection along the cell. Scale bar = $1\mu\text{m}$.

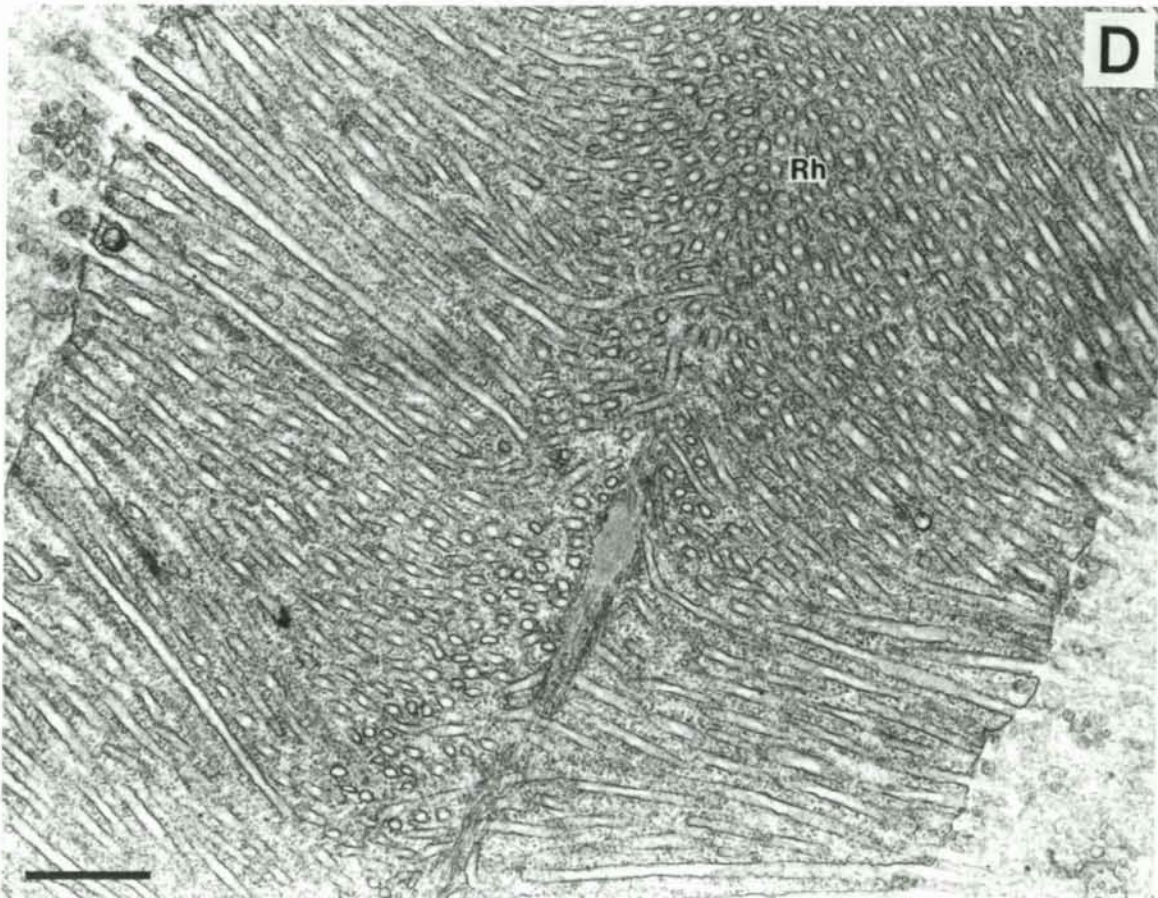
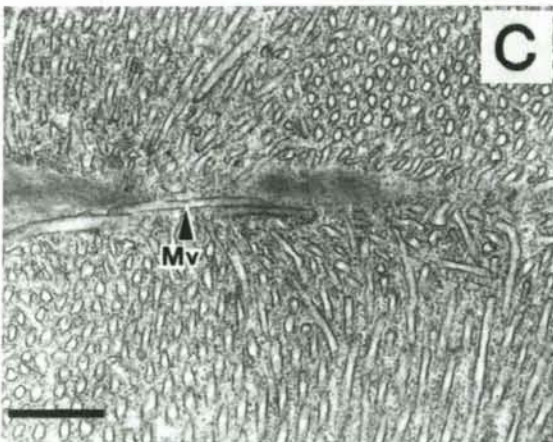
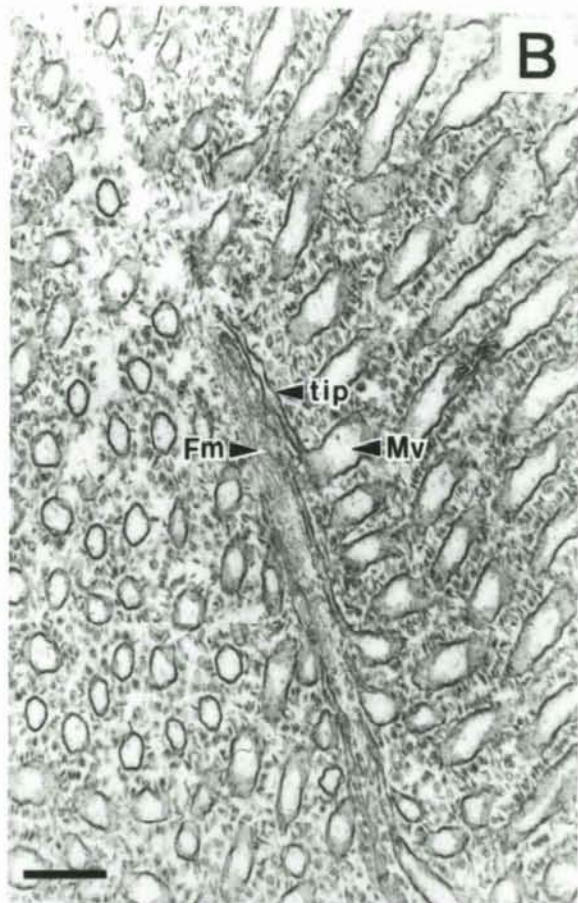
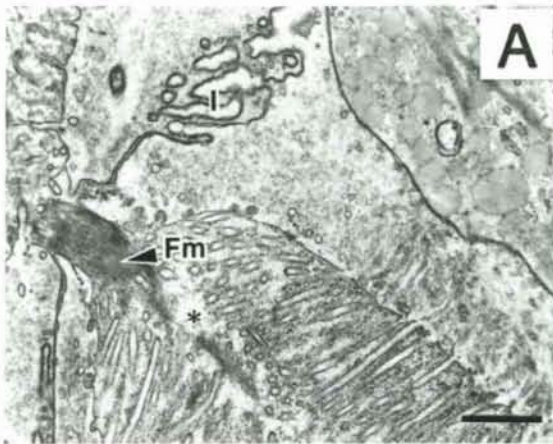


FIGURE 52 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) =
RHABDOM

- A - A high magnification image of the rhabdomic microvilli (Mv). Note in particular the numerous membrane rodlet particles aligned along the outside of each microvillus. Their trilaminar nature and regular size is evident. They appear not to attach directly to the microvilli. (V, vesicles near base of microvilli). Scale bar = 0.25 μ m.
- B - Detail of the rhabdom showing accessory organelles in the adjacent cytoplasm. A pinocytosing vesicle (V) containing membrane rodlets can be seen associated with the plasma membrane at the base of the microvilli. A multi-inclusion body containing membrane rodlets and vesicles is evident in the lower centre of the micrograph. Scale bar = 0.25 μ m.
- C - Transverse section of microvilli showing the electron lucent lumens and radial arrangement of the extracellular membrane rodlets around their peripheries. Scale bar = 0.25 μ m.
- D - Appearance of rhabdom following tannic acid mordanting. Scale bar = 0.5 μ m.

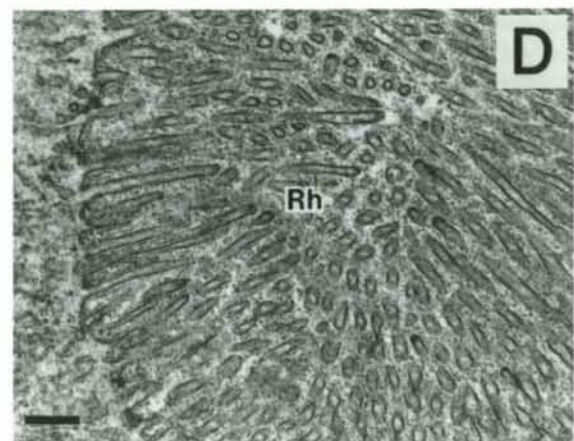
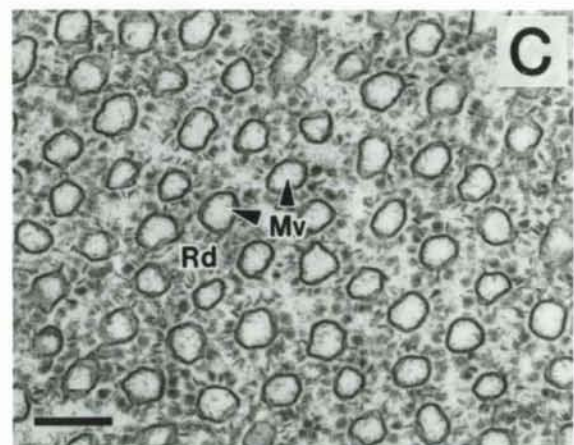
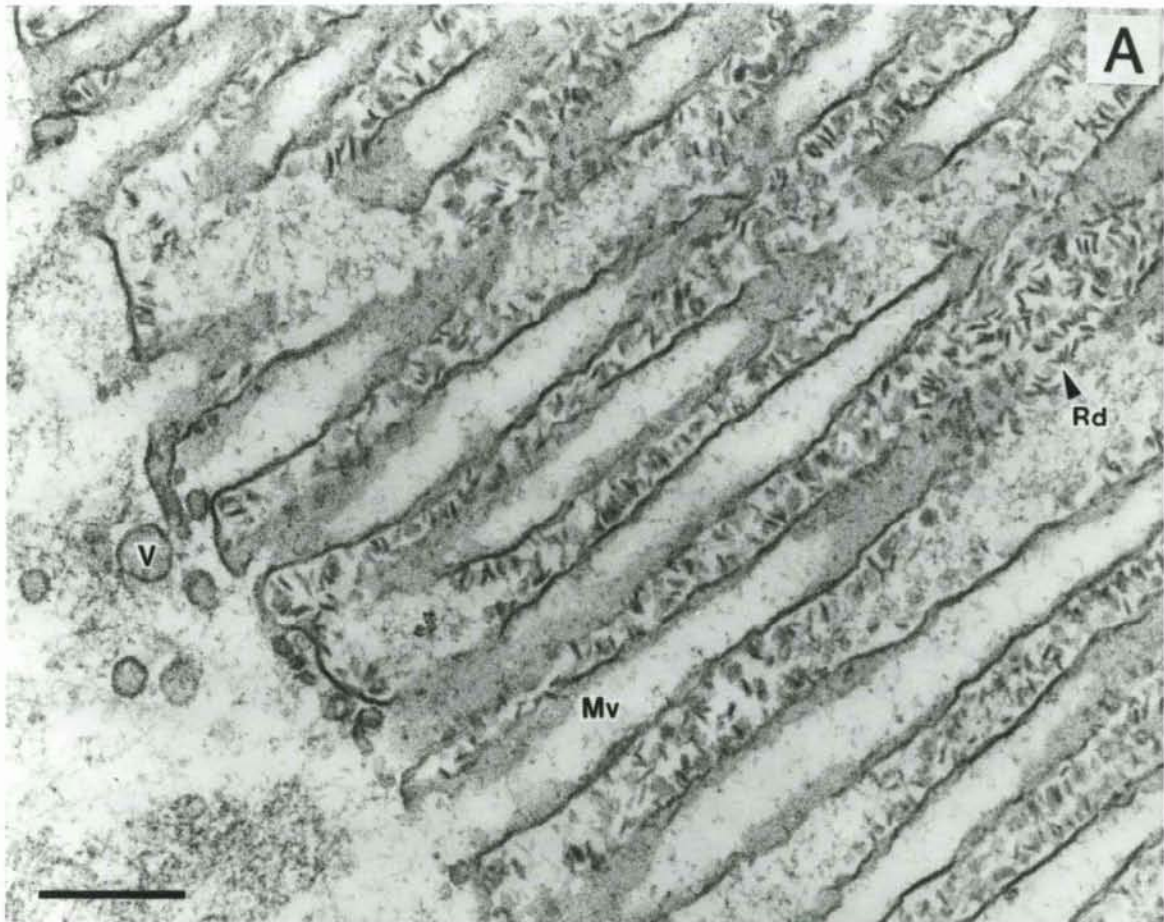


FIGURE 53 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) =
RHABDOM

- A - Micrograph showing the two major types of extracellular structures in the rhabdom; membrane rodlets (Rd) and vesicles (V) of equivalent dimensions. The vesicles are more abundant towards the centre of the rhabdom. The relationship between these two particle types is unclear. Scale bar = 0.5 μ m.
- B - Detail of the extracellular vesicles and rodlets. Scale bar = 0.25 μ m.
- C&D - Comparison of the appearance of the submicrovillar tubules of endoplasmic reticulum (Er) with different fixations. C shows the appearance with OsO₄ primary fixation. The microvillar lumen (Mv) is pale as is the lumen of the tubules (Lu), the membranes of which are poorly preserved. D shows the result of a gluteraldehyde primary fixation. The endoplasmic reticulum is well preserved and electron dense material is continuous from the lumen of the microvillus into the lumen of the tubules. Scale bars for both = 0.5 μ m.
- E - Detail of accessory organelles. A vesiculated tubule (Tu) can be seen passing to the plasma membrane between two adjacent reticulum profiles (Er). The lumen of the reticulum tubules remains free of such structures. (Mib, multi-inclusion body). Scale bar = 0.25 μ m.
- F - Rows of vesicles below microvilli. Most of the vesicles shown contain membrane rodlets (1). One vesicle has opened to the extracellular space (2) and above it a cluster of much smaller vesicles can be seen. Scale bar = 0.25 μ m.

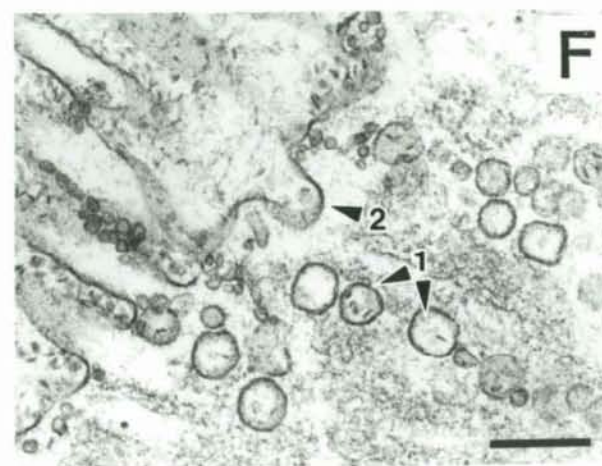
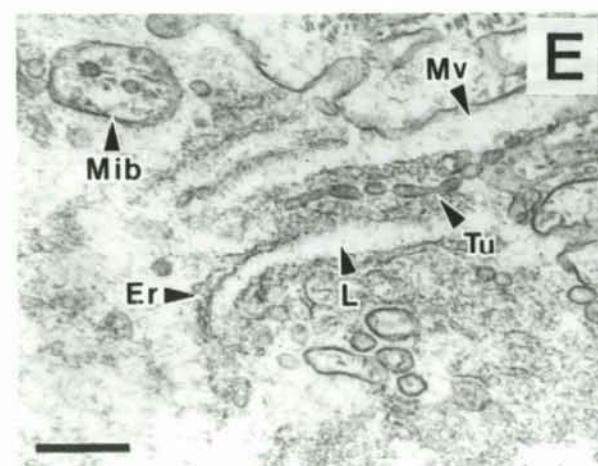
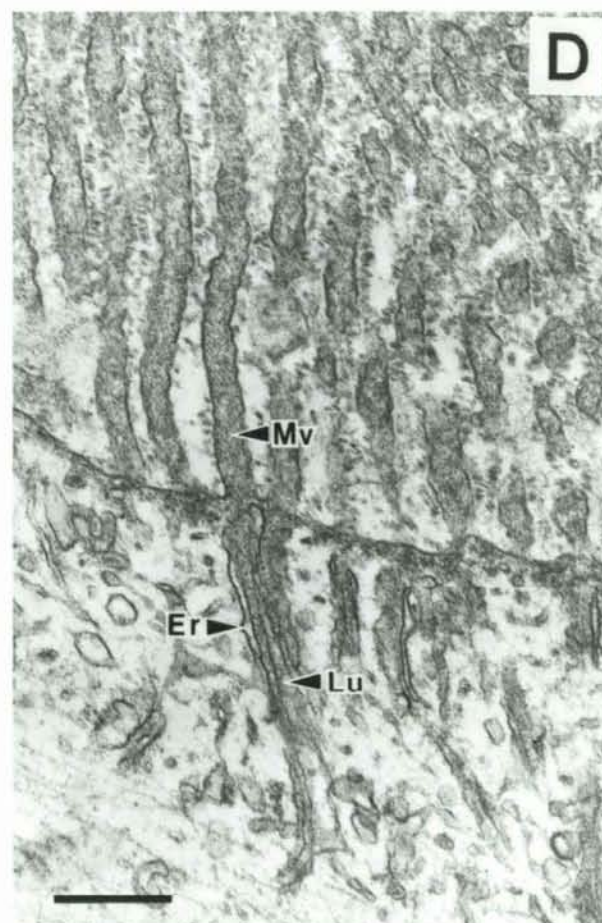
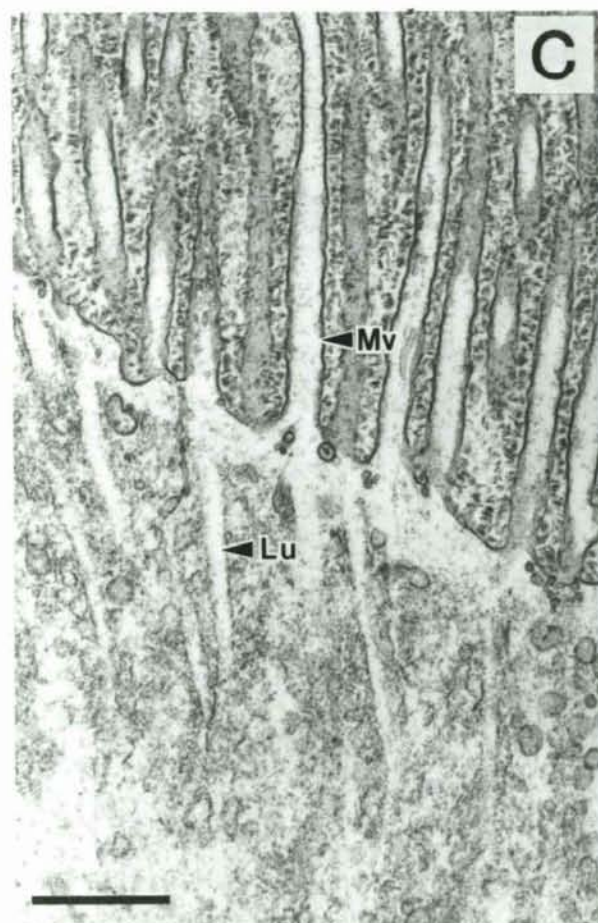
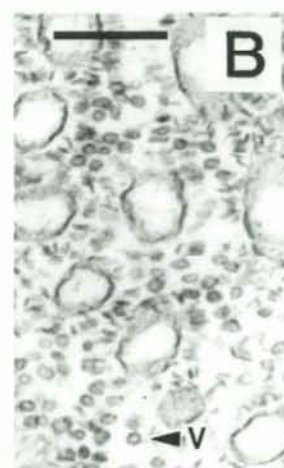
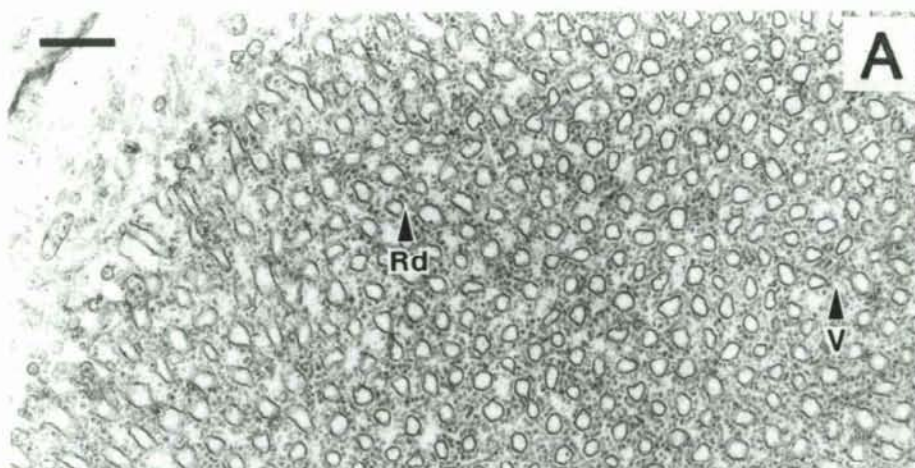


FIGURE 54 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) =
ACCESSORY ORGANELLES OF RHABDOM

- A - Cytoplasmic accessory organelles. Note the two types of vesicle (V_1 and V_2) and the tubular nature of the endoplasmic reticulum (Er), here transversely sectioned. Scale bar = $0.25\mu\text{m}$.
- B - Multi-inclusion bodies (Mib) in the sensory segment cytoplasm. Scale bar = $1\mu\text{m}$.
- C - A multi-vesicular body apparently releasing small vesicles by pinocytosis (arrowed). Scale bar = $0.5\mu\text{m}$.
- D - A multi-vesicular body apparently releasing vesicles by rupture of its limiting membrane (arrowed). Scale bar = $0.25\mu\text{m}$.
- E - The cyto-skeletal network (Sk) of the sensory cell cytoplasm. (Gl, Glycogen; Er, endoplasmic reticulum). Scale bar = $0.25\mu\text{m}$.
- F - Transition zone between rhabdom (Rh) and lamellar region (L) of the sensory segment. Scale bar = $1\mu\text{m}$.

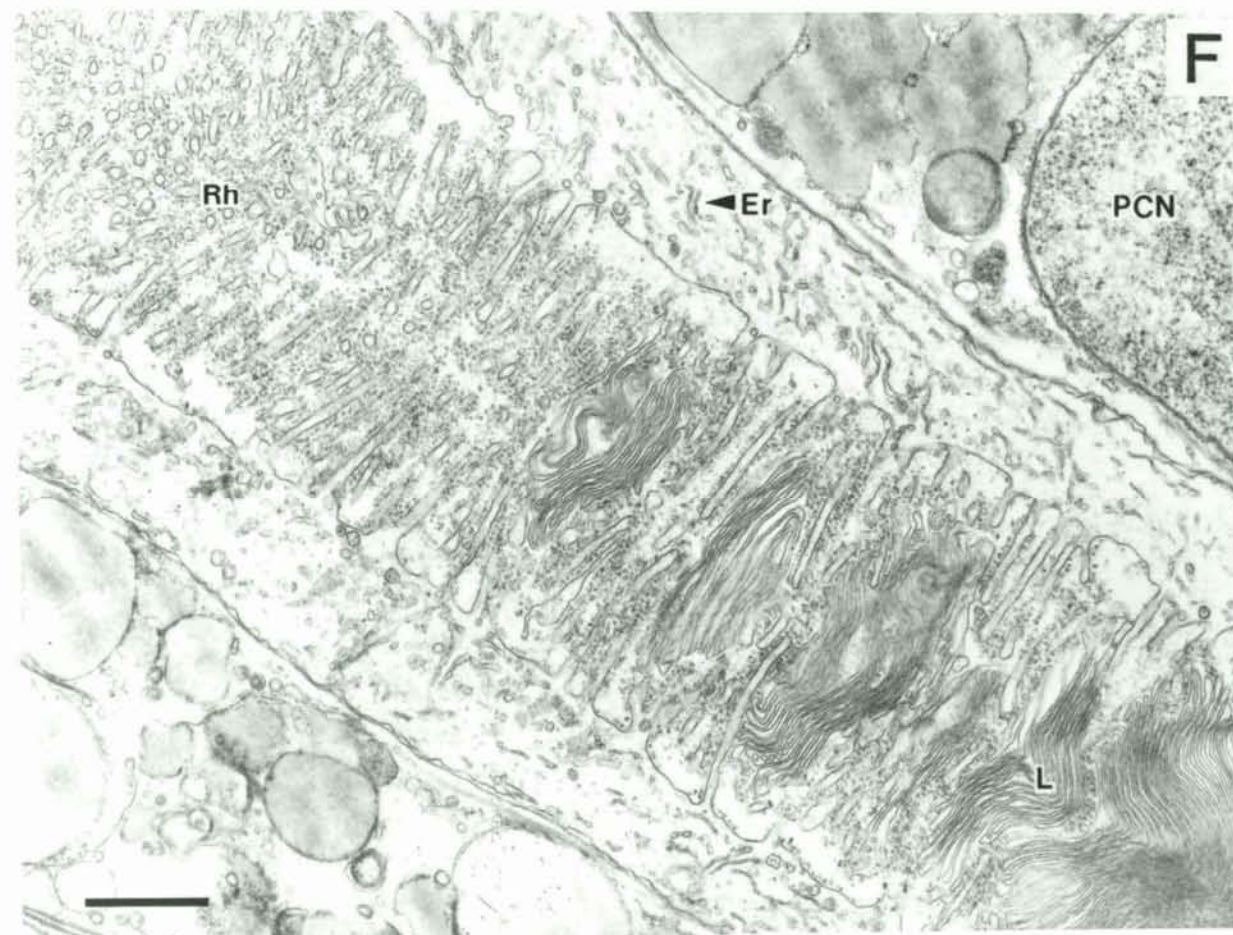
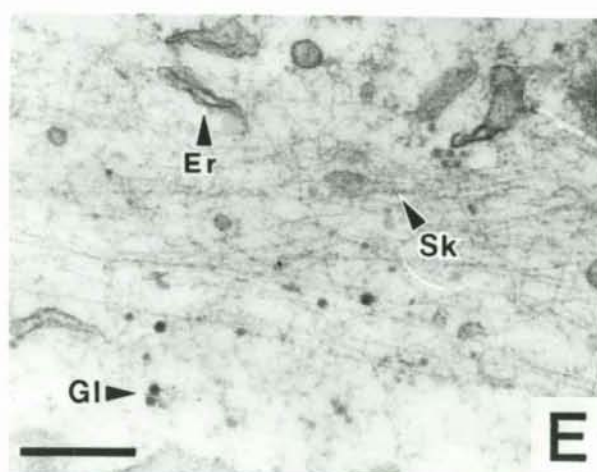
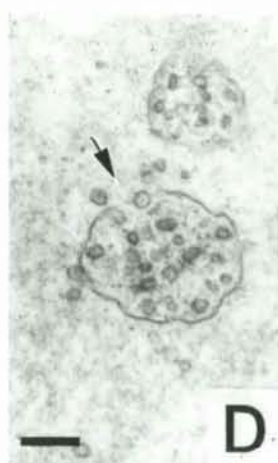
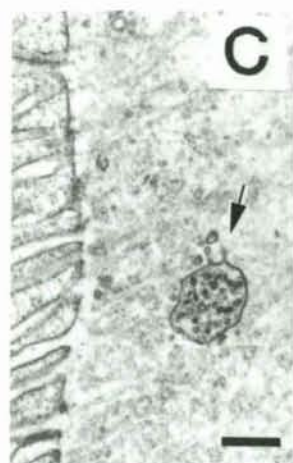
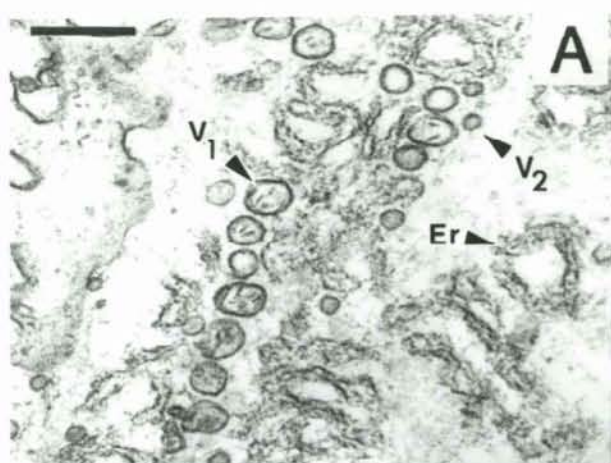


FIGURE 55 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) =
PROXIMAL SENSORY SEGMENT AND UPPER SOMA

A&B - Longitudinal section through the lamellar region and soma of the photosensory cell (SC). The arrows make the point of overlap, the top of B continuing from the bottom of A. The transition zone lies about a further 3 μ m above the top of A. The main features of this montage are: the horizontally arranged stack of lamellae (L) of the proximal half of the sensory segment, the terminal end-chamber (Ec), and the dense packing of organelles in the soma around the nucleus (Nu). (M, mitochondria; Ly, lysosomes; Gl, glycogen; Er, endoplasmic reticulum). Note the extracellular space between the lamellae and the sensory segment cytoplasm (Esp) and the well-developed tonofilaments (Tf) of the pigmented cells (PC) running alongside the sensory cell. Both scale bars = 1 μ m.

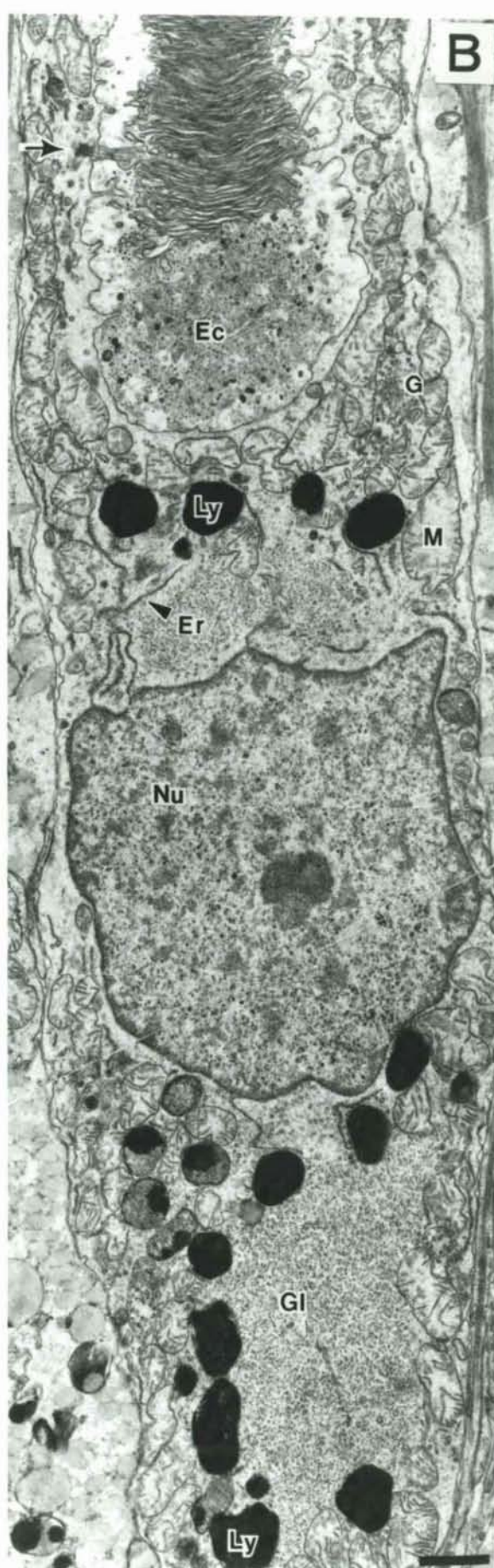
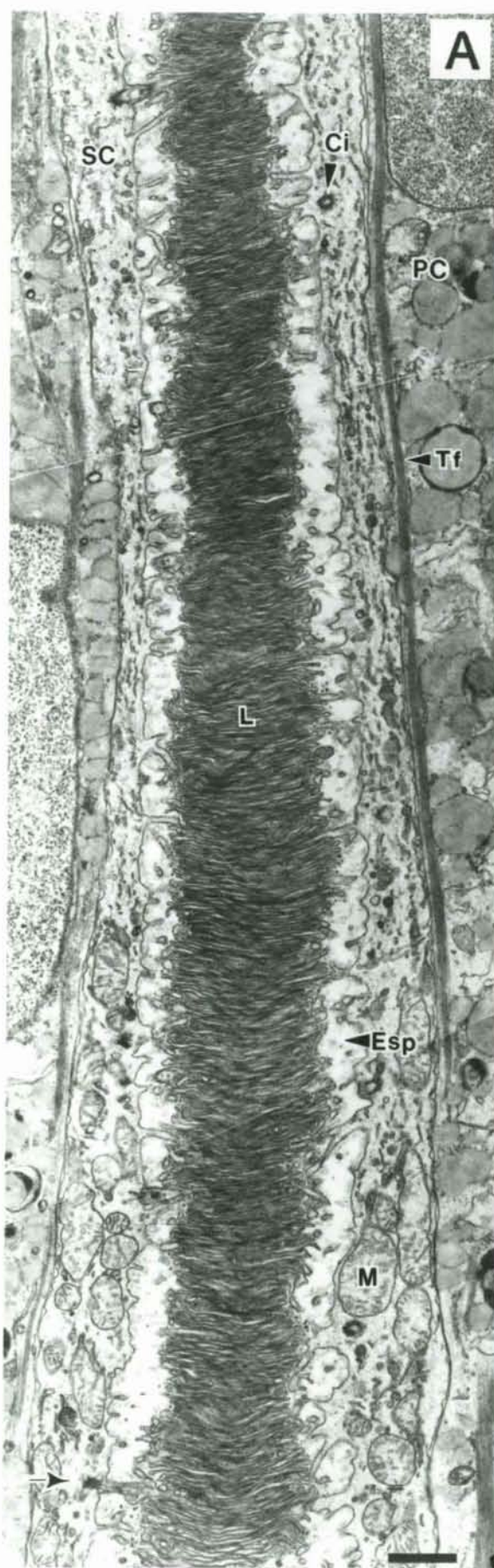


FIGURE 56 : THE COMPOUND EYE OF *SPIROBRANCHUS* (T.E.M.) =
LAMELLAR REGION

- A - A sensory cilium (Ci) extending into the extracellular space to produce ciliary lamellae (L). This cilium can be seen to produce at least 2 lamellae (arrowed). Scale bar = 0.5 μ m.
- B - Sensory cilium. Compare this micrograph with figure 57. A lamella sac is produced at the level of the arrow. Scale bar = 0.5 μ m.
- C - Motile cilia of the epithelium for comparison. The major differences are the development of 9+2 microtubule doublets (Mt) in the shaft, and rootlets (R) from the basal body. Scale bar = 0.5 μ m.
- D - Lamellar region of sensory segment. Note the cilia producing the lamellae and the swollen lamellar profiles (asterisks) probably containing microtubules. Note also the microvilli (Mv) projecting into the extracellular space, the small extracellular vesicles and the larger vesicles within the cytoplasm (V). Scale bar = 0.5 μ m.

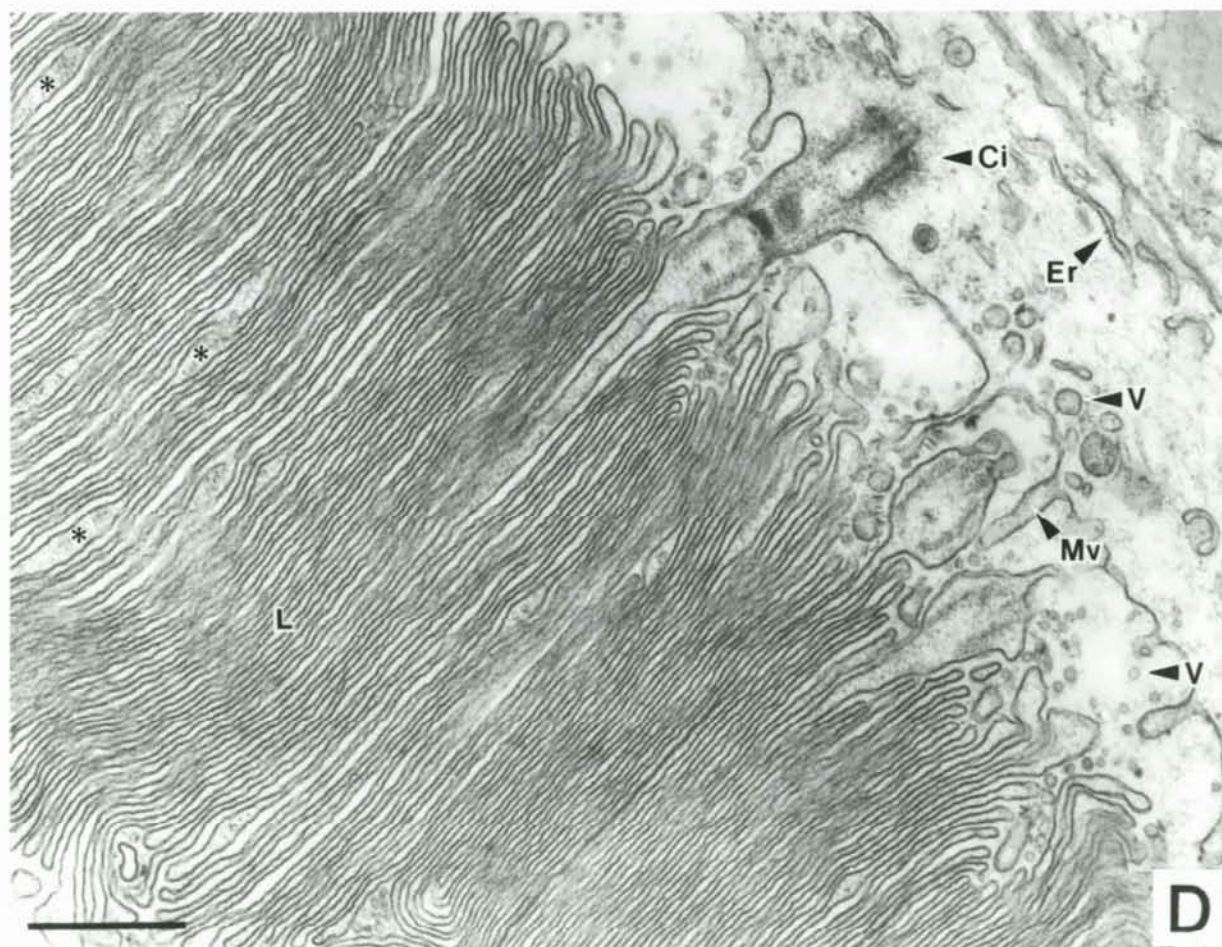
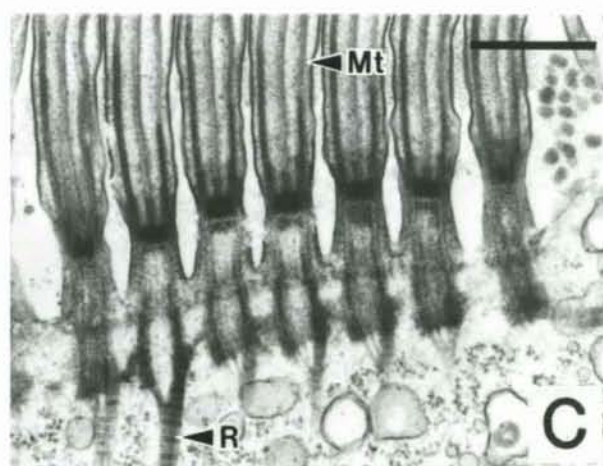
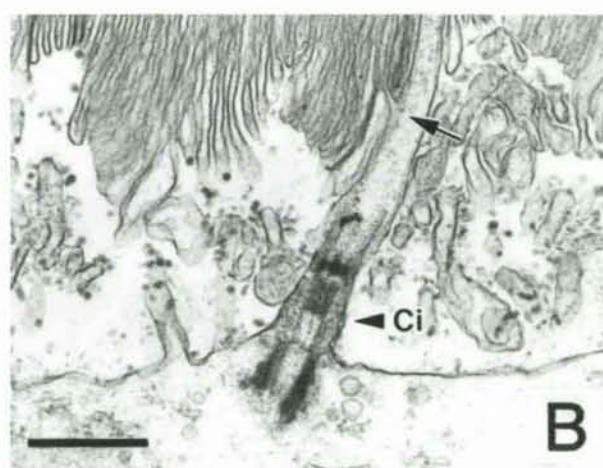
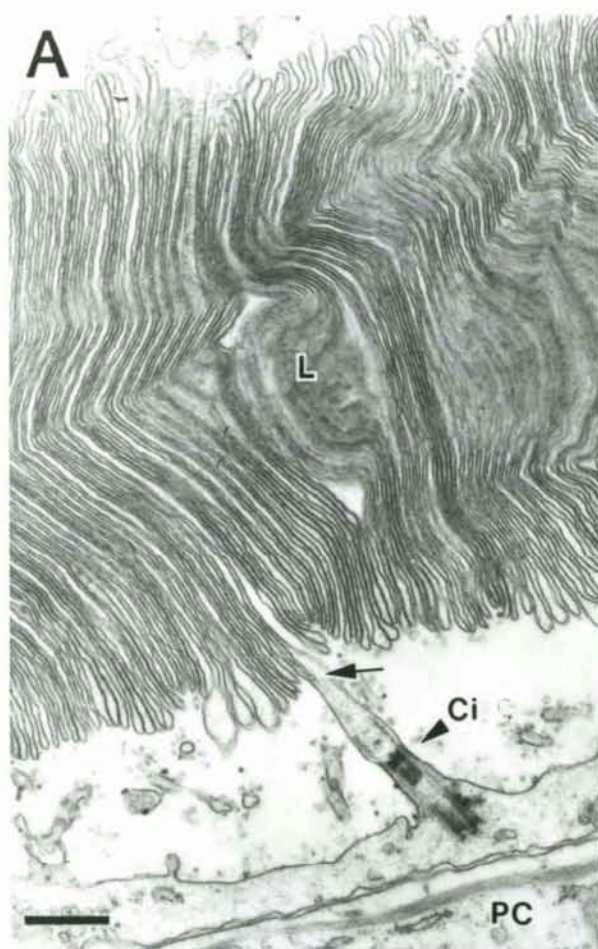


FIGURE 57 : DIAGRAM OF A SENSORY CILIUM OF THE PHOTORECEPTOR CELL

(terminology from Sleight, 1974)

