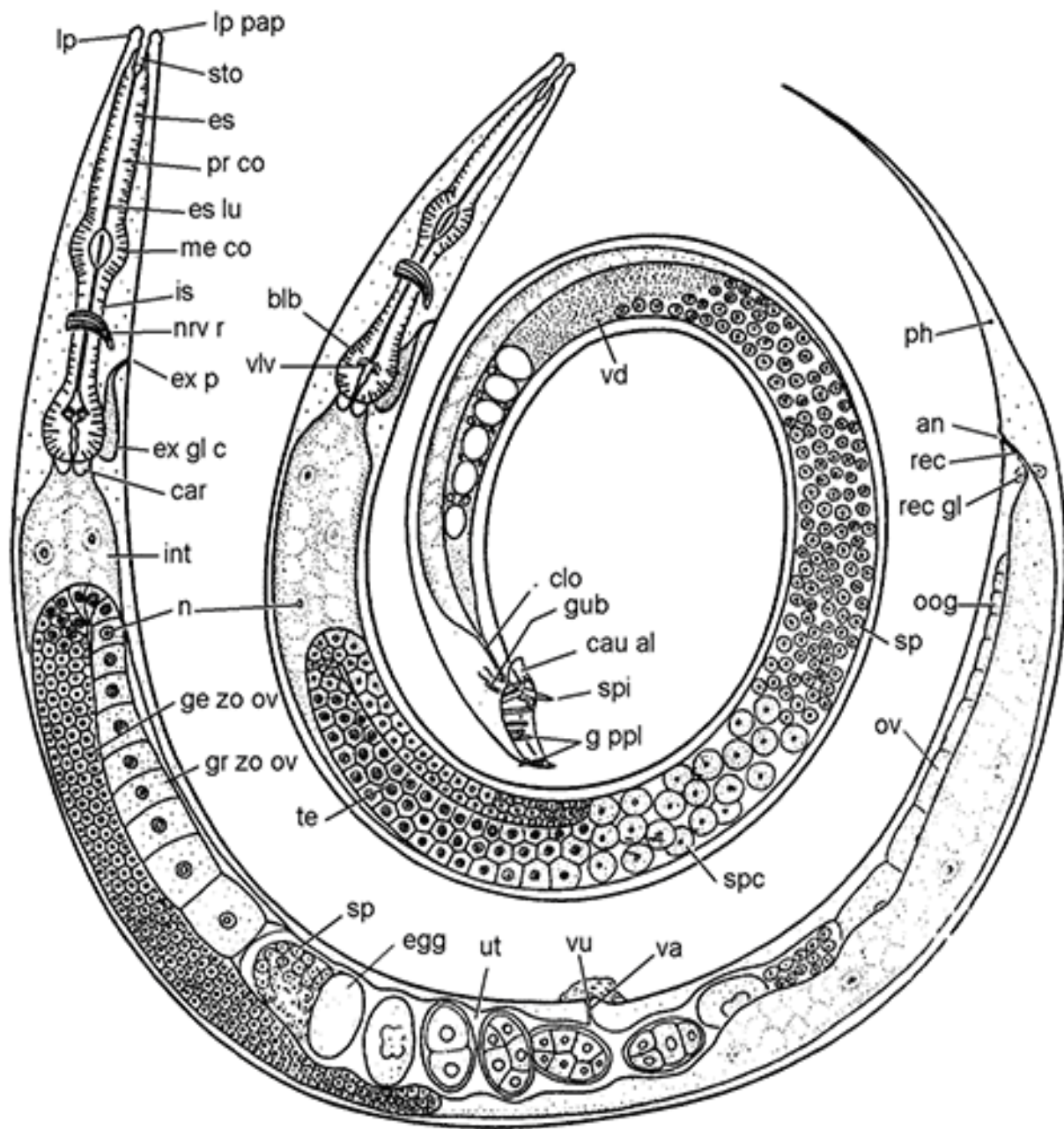


NEMATODE MORPHOLOGY





an	- anus	n	- nuclei
blb	- bulb	nrv r	- nerve ring
car	- oesophago-intestinal valve	oog	- oogonia
cau al	- caudal alae	ov	- ovary
clo	- cloaca	ph	- phasmid
egg	- egg	pr co	- procorpus of the oesophagus
es lu	- oesophageal lumen	rec gl	- rectal gland
es	- oesophagus	rec	- rectum
ex gl	- excretory gland	sp	- sperm
ex p	- excretory pore	spc	- sperm cell precursors
g ppl	- genital papillae	spi	- spicule
ge zo ov	- germinal zone of the ovary	sto	- stoma or buccal capsule
gr zo ov	- growth zone of the ovary	te	- testis
gub	- gubernaculum	ut	- uterus
int	- intestine	va	- vagina
is	- isthmus	vd	- vas deferens
lp ppl	- labial papillae	vlv	- oesophageal valve
lp	- lip	vu	- vulva
me co	- mesocorpus of the oesophagus		

INTRODUCTION

- **The nematode body organization possesses all the vital systems of higher invertebrates packed intricately even in tiny plant parasitic forms.**
- **Nematode taxonomy is based mainly on their morphology, hence a sound knowledge of the structure of nematodes is absolutely essential for their identification.**
- **Moreover, structural similarities often reflect functional and behavioural parity.**
- **The main morphological features, especially of the plant parasitic nematodes (tylenchids) is being discussed along with supporting information from other groups, wherever essential.**



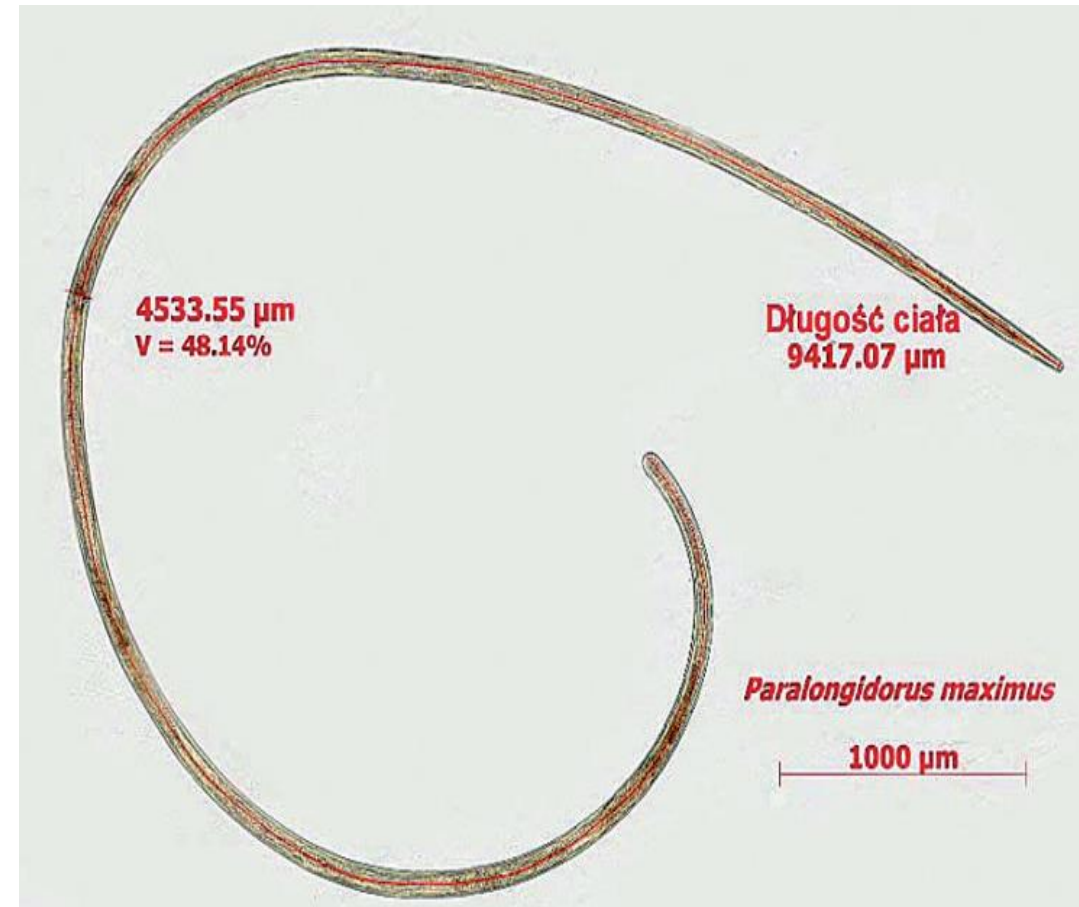
NEMATODE SHAPE AND SIZE

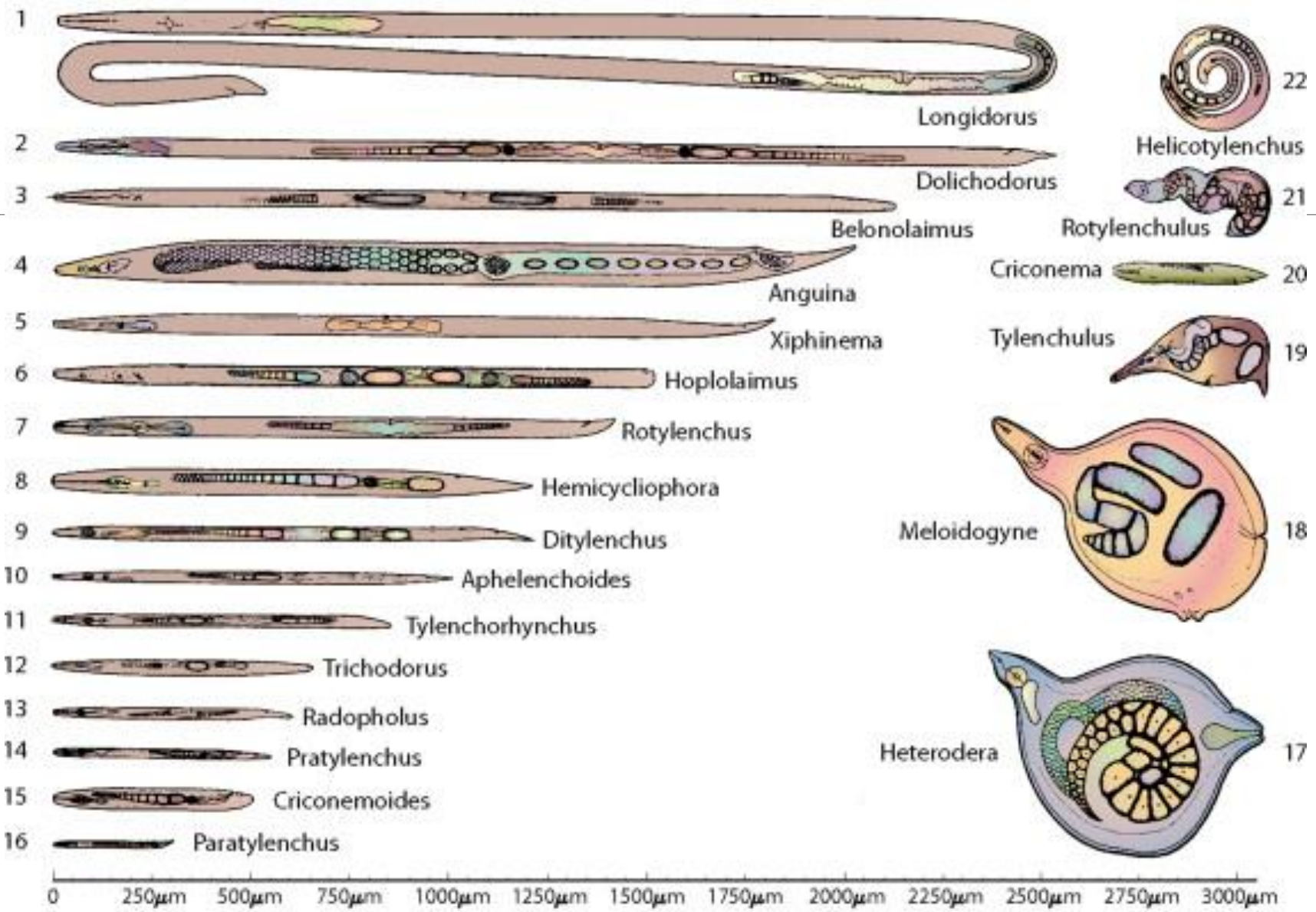
- The animal parasitic nematodes are quite large and easily visible to the naked eye.
- The common intestinal roundworm, *Ascaris lumbricoides* is about 30 cm long.
- The guinea worm, *Dracunculus medinensis* may reach up to 1 m in length.
- The largest nematode, *Placentonema gigantissima* is about 8 m long and is parasitic in the placenta of sperm whale.

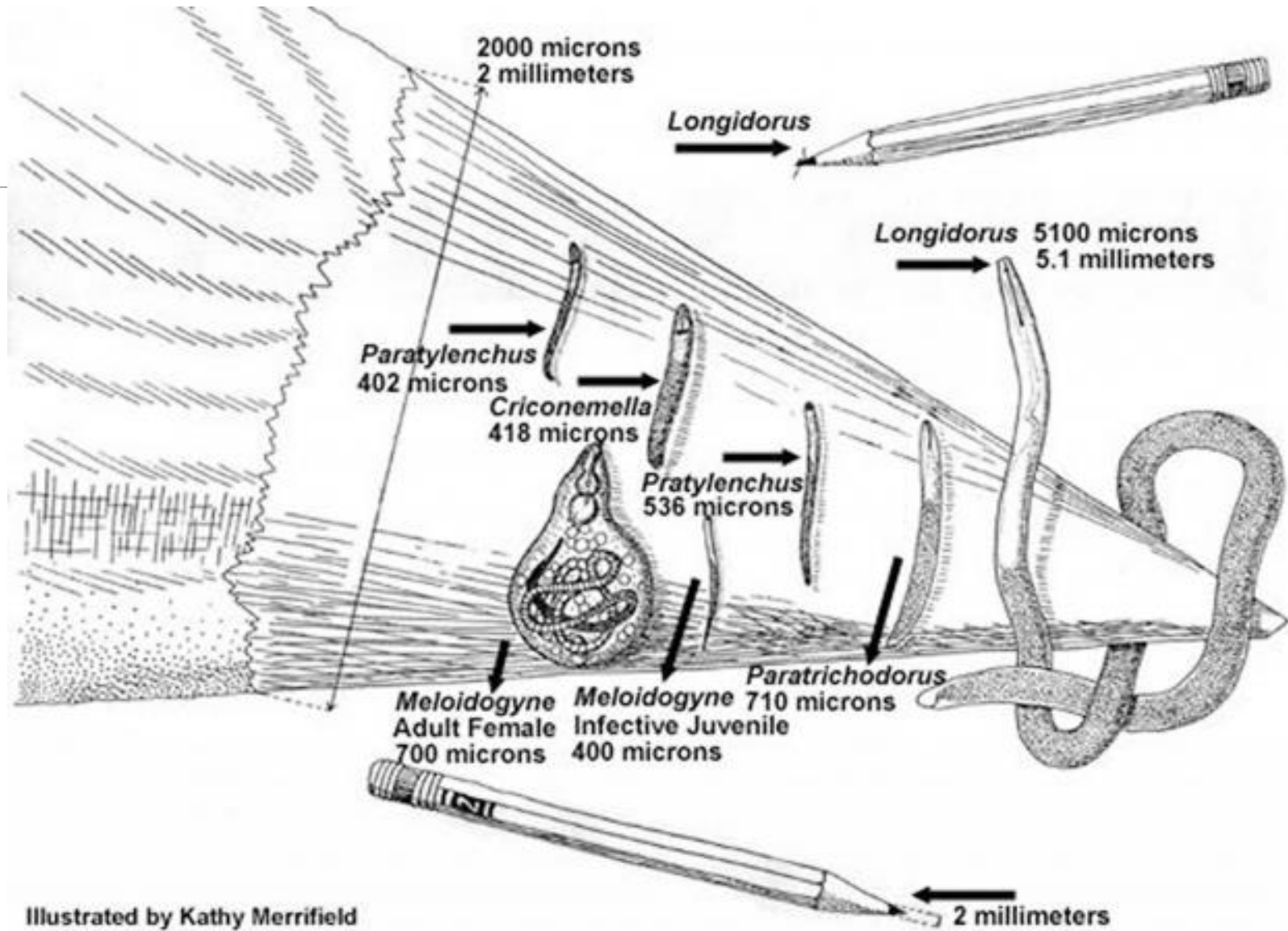


NEMATODE SHAPE AND SIZE

- The free-living and plant parasitic nematodes are comparatively very small and generally microscopic.
- *Greeffiella minutum*, a marine nematode, is only 82µm long and is the shortest nematode recorded so far.
- Plant parasitic tylenchid nematodes generally range between 0.3 and 2.0 mm in length, rarely up to 3.0 mm.
- *Paralongidorus epimikisis* the longest plant parasitic nematode, reaching up to 1.2 cm in length.
- *Paratylenchus* is the shortest plant parasitic nematode having length of 0.2 mm



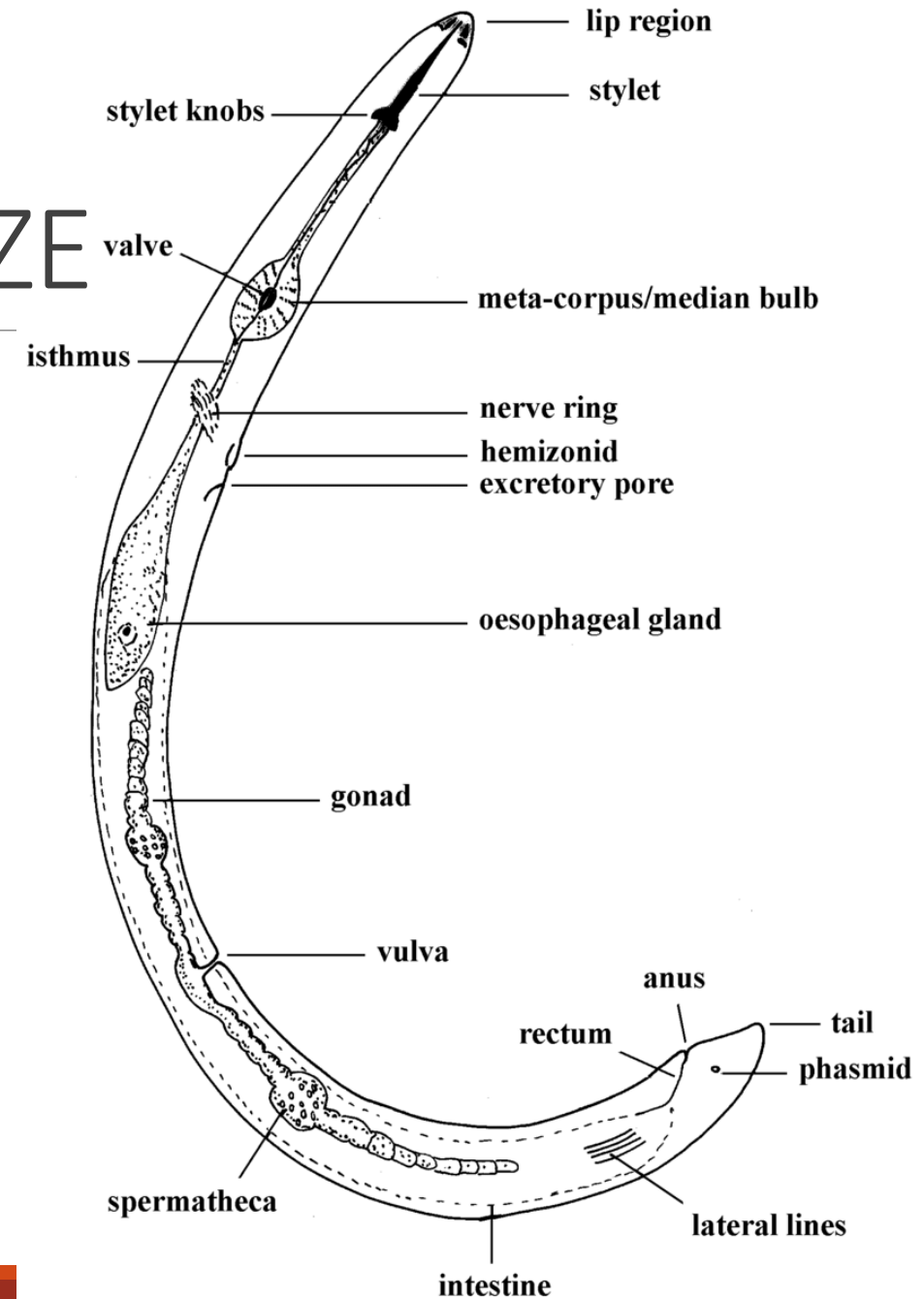




Illustrated by Kathy Merrifield

NEMATODE SHAPE AND SIZE

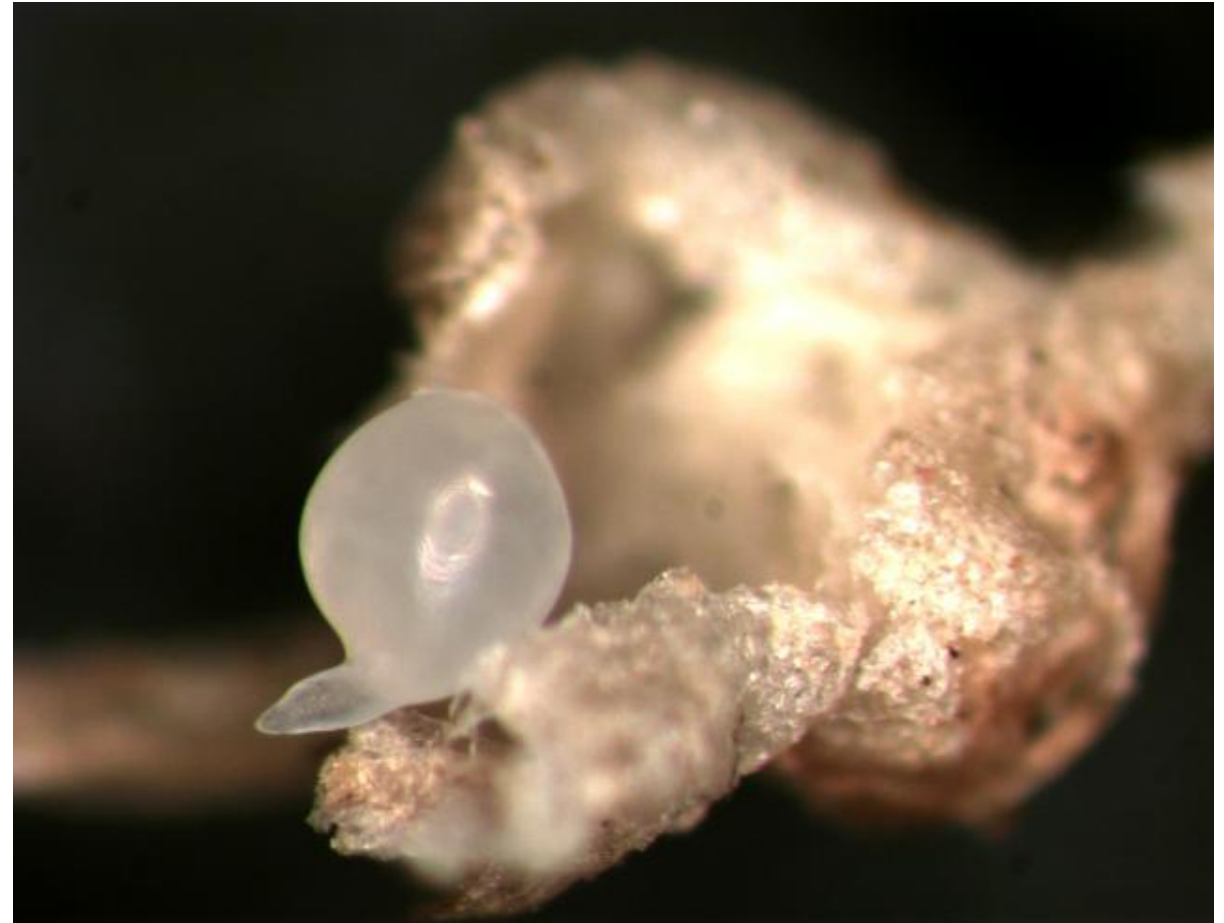
- Nematode body shape is typically vermiform, thread-like and tubular, tapering towards both ends.
- The principal axis is longitudinal.
- Males and females generally look alike.

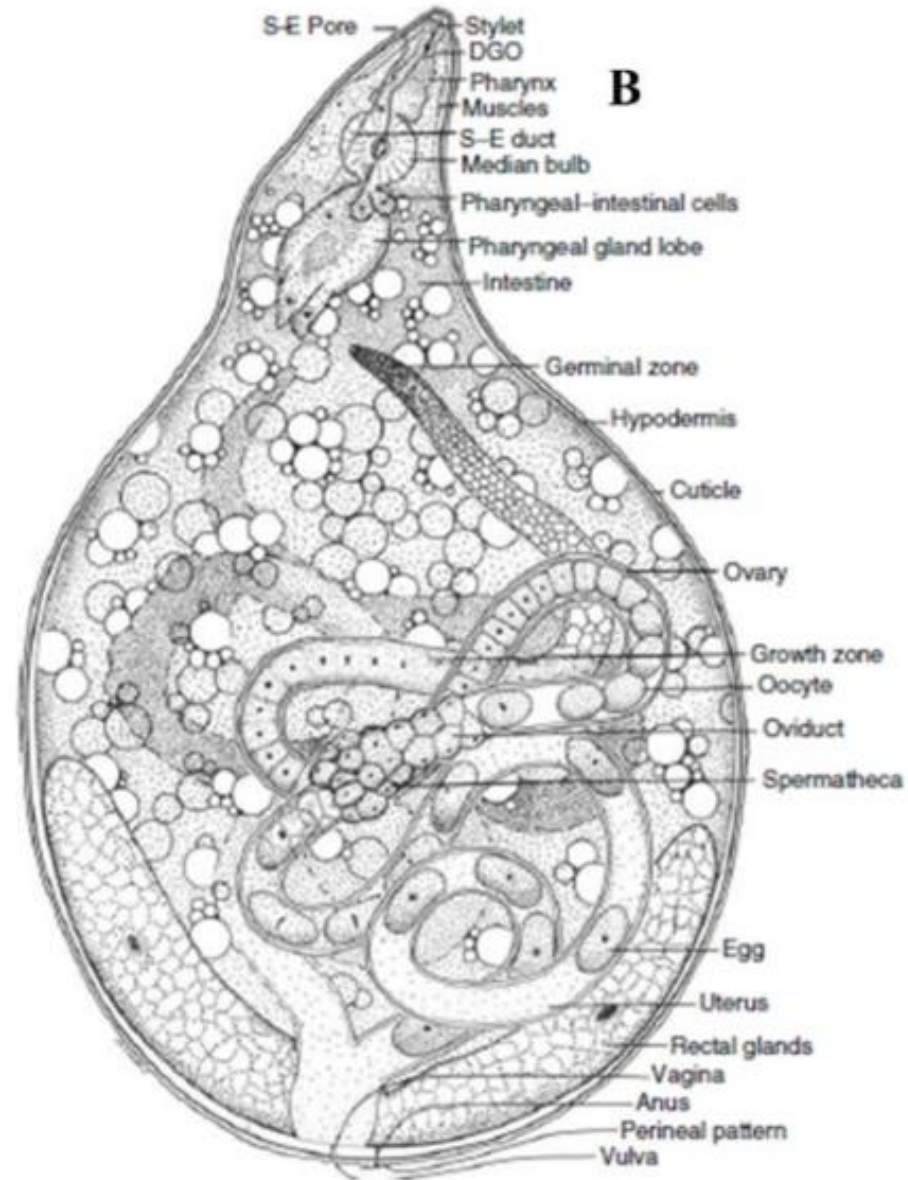
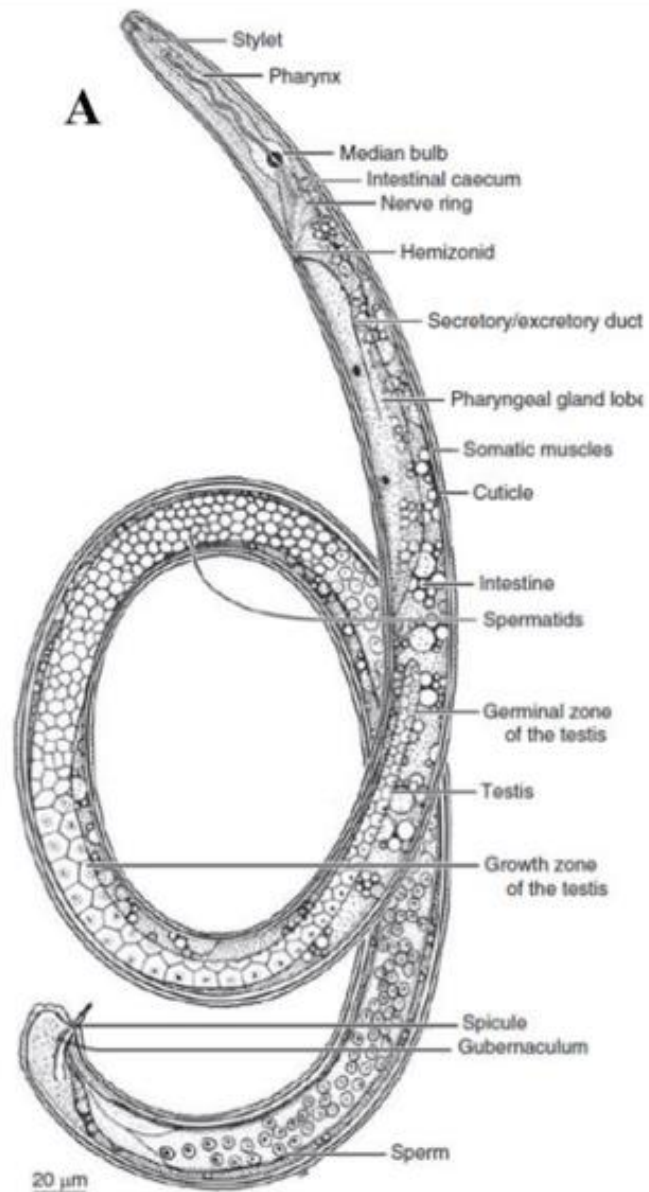


NEMATODE SHAPE AND SIZE

- In certain cases (**sedentary endoparasites/ semi-endoparasites**), the females may deviate from the normal cylindrical form and acquire atypical shapes (**swollen, saccate, lemon-shaped, reniform**) upon maturity, whereas the males remain vermiform.
- The females on maturity assume **pear shape** (*Meloidogyne*), **globular shape** (*Globodera*), **reniform** (*Rotylenchulus reniformis*) or saccate (*Tylenchulus semipenetrans*).
- Conversely, the males may be degenerated anteriorly and possess rudimentary feeding structure (e.g. *criconematids*), while the females retain the normal structure.
- Such a morphological dissimilarity in the general shapes of males and females within a species is known as **sexual dimorphism**

MELOIDOGYNE DIMORPHISM





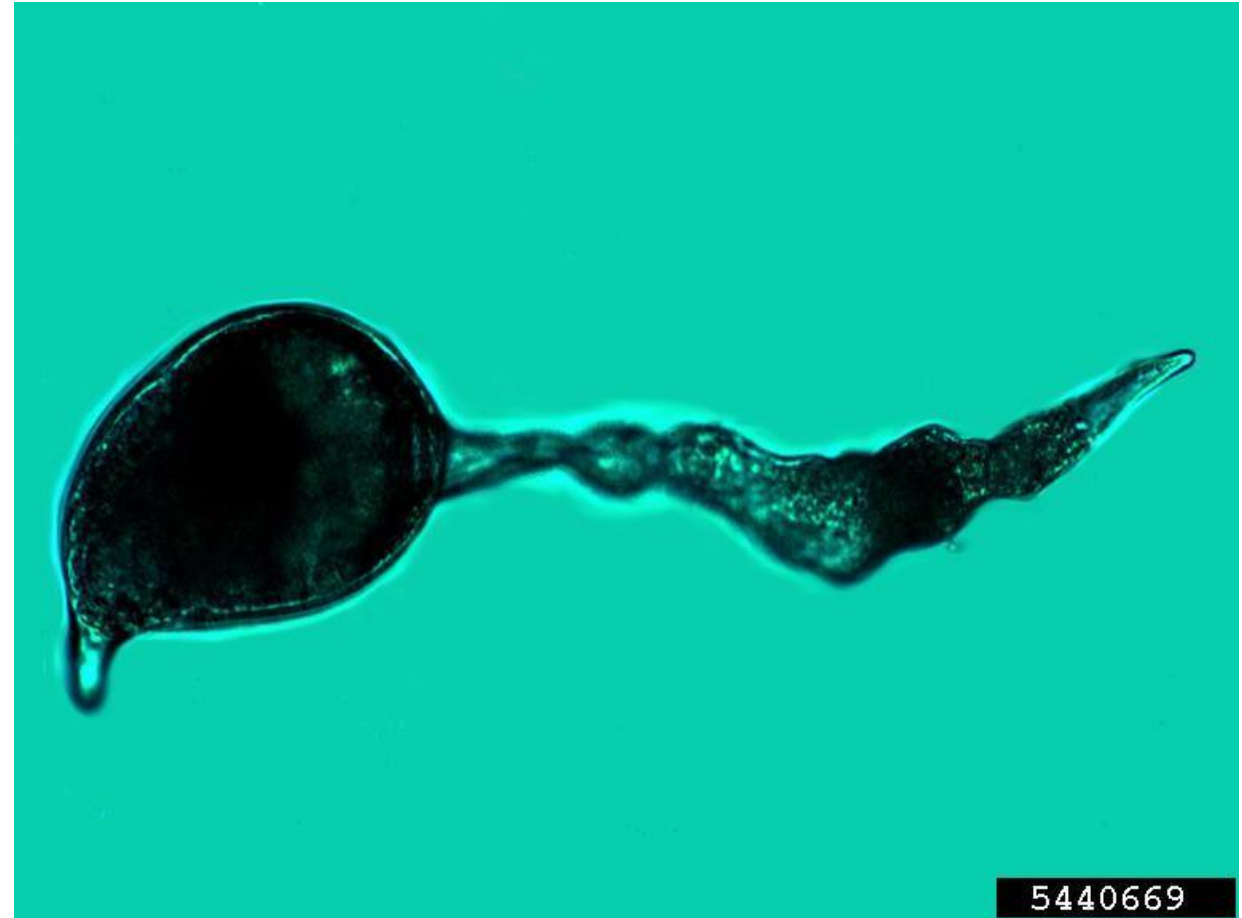
GLOBODERA DIMORPHISM



RENIFORM NEMATODE DIMORPHISM



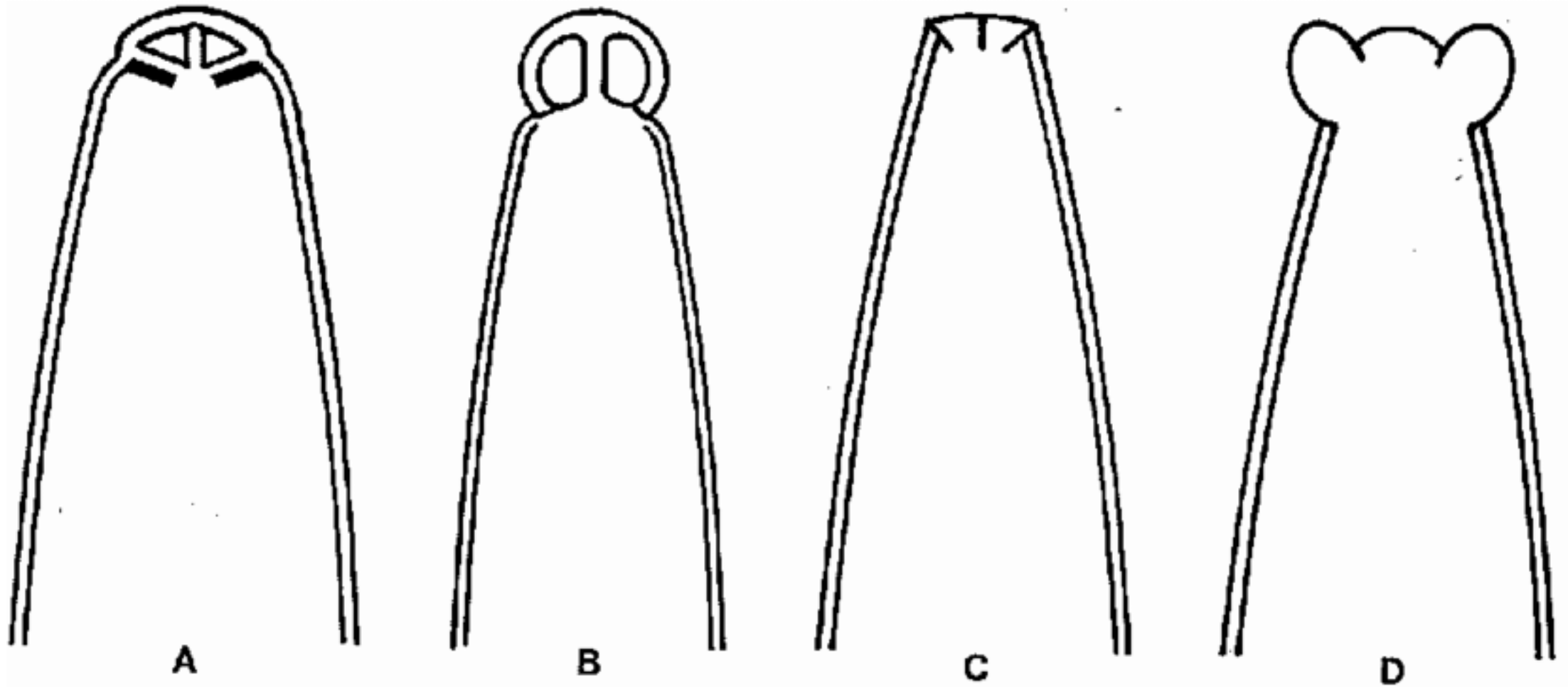
CITRUS NEMATODE DIMORPHISM



BODY REGIONS AND SEGMENTATION

- The body of a nematode cannot easily be divided into head, thorax and abdomen.
- Often, the anterior most extremity of the body bearing the mouth and lips is called head and it is continuous with the main body.
- Sometimes, it is set off by a constriction



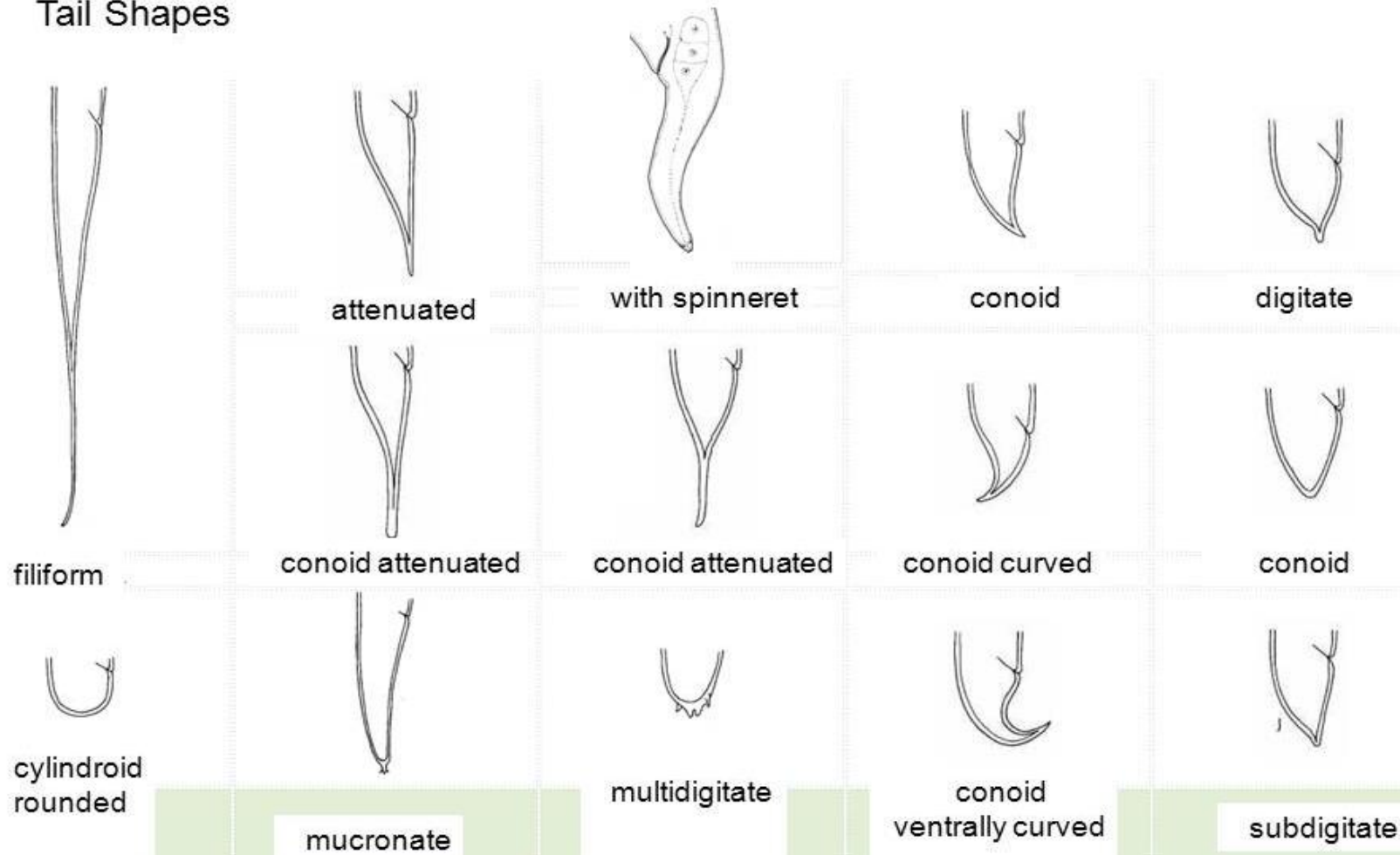


Variations in head structure. A, flat; B, raised; C, continuous; D, offset

BODY REGIONS AND SEGMENTATION

- The portion of the body beyond anus (cloacal aperture in males) is known as tail.
- The tail shape is highly variable (cylindrical, conoid, filiform) even amongst plant parasitic nematodes

Tail Shapes



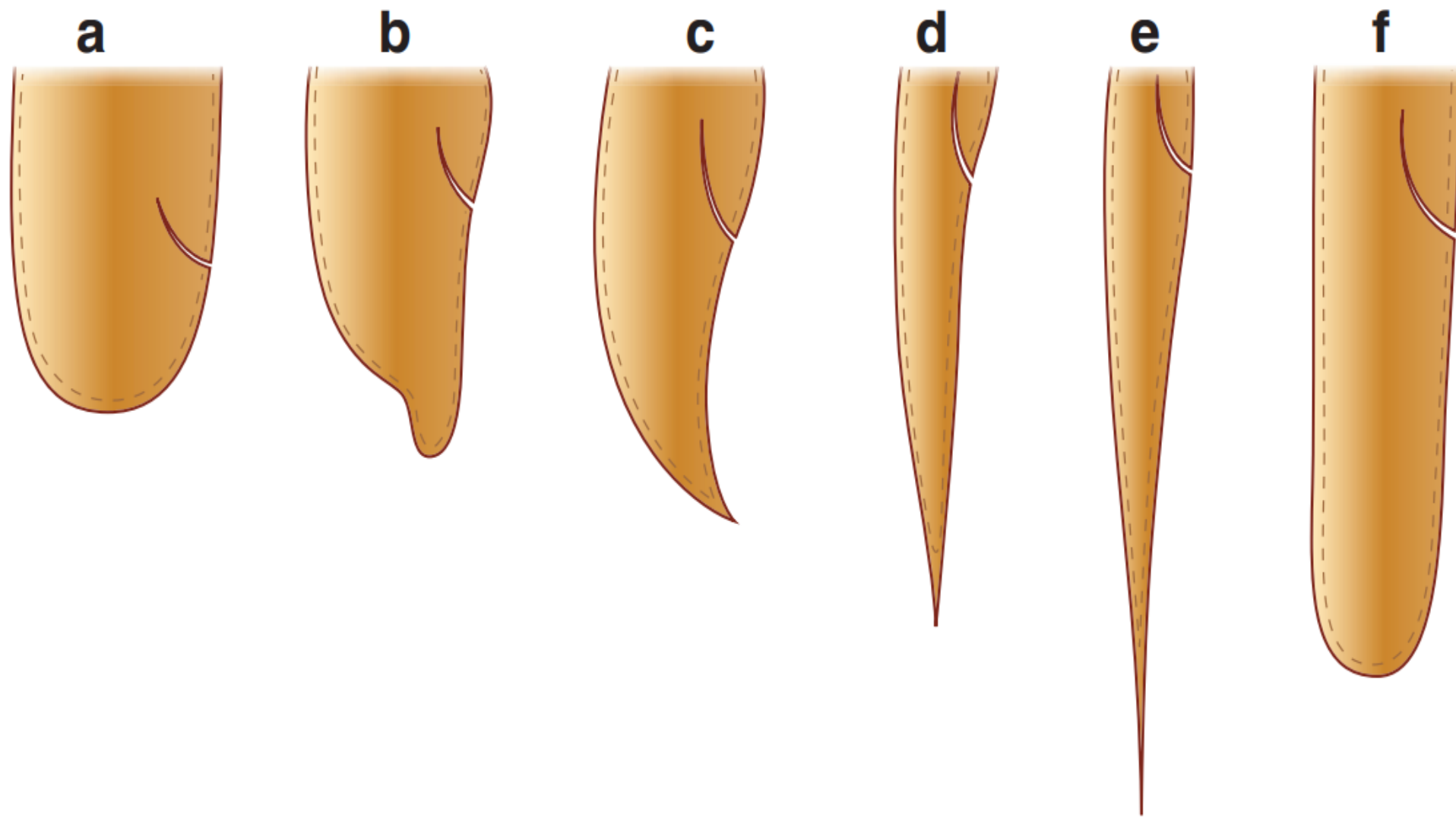
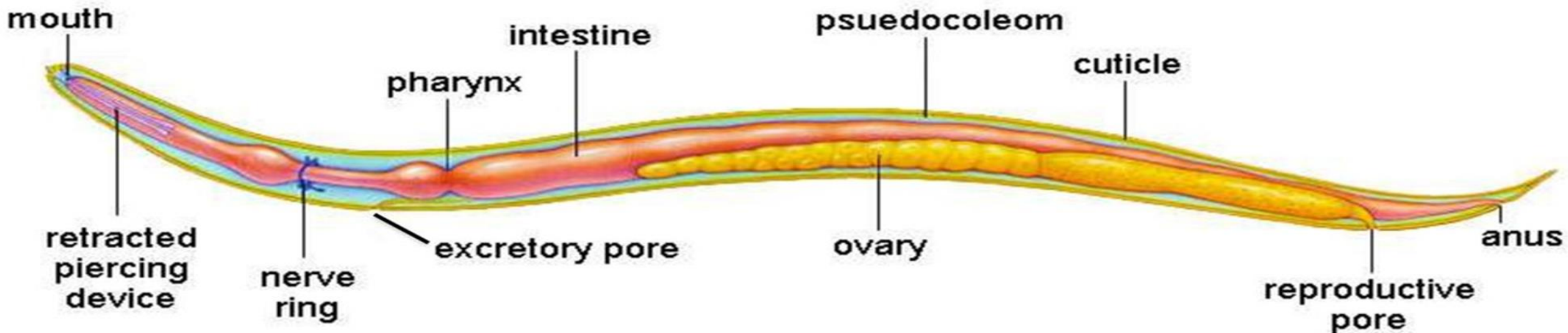


Fig. 3.3 Tail shapes: rounded or hemispherical (**a**), with a projection (**b**), convex-conoid (**c**), elongate-conoid (**d**), filiform (**e**) and cylindroid (**f**) (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

BODY REGIONS AND SEGMENTATION

- Longitudinally, the body can be divided into 4 zones.
- **The ventral side is identified by the location of the openings of digestive (anus), reproductive (vulva, cloacal aperture) and excretory (excretory pore) systems.**
- The side exactly opposite to it is the dorsal.
- The other two sides are right and left laterals situated at right angles to the dorsal and ventral sides.



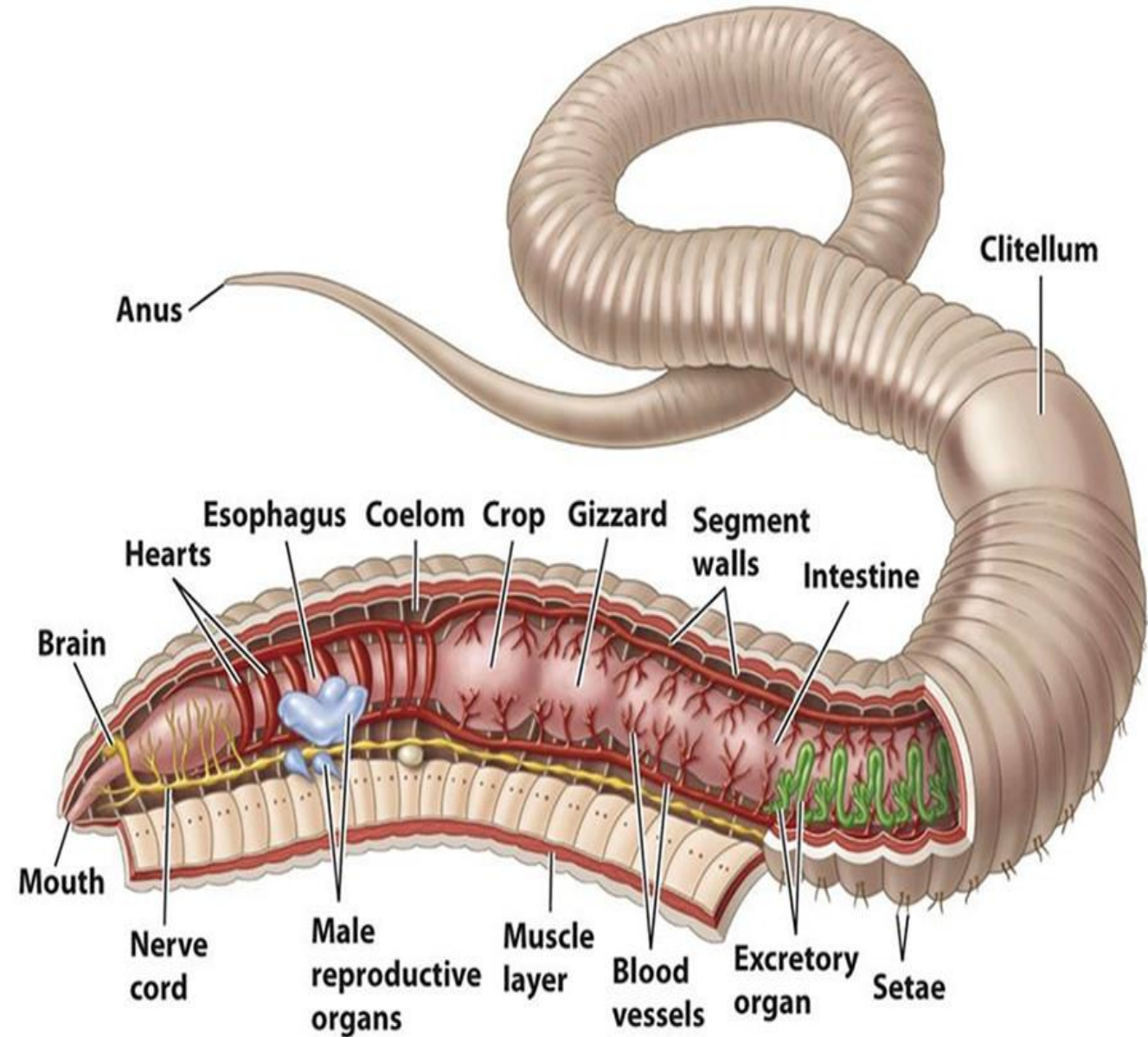
BODY REGIONS AND SEGMENTATION

- **Nematodes are appendageless.**
- **The body is not metamericly segmented internally, although some species may show apparent segmentation which is confined to cuticle only.**
- **In general, nematodes are colourless and their body wall is transparent.**
- **Some nematodes may appear variously tainted depending on the food material in their gut.**



METAMERISM

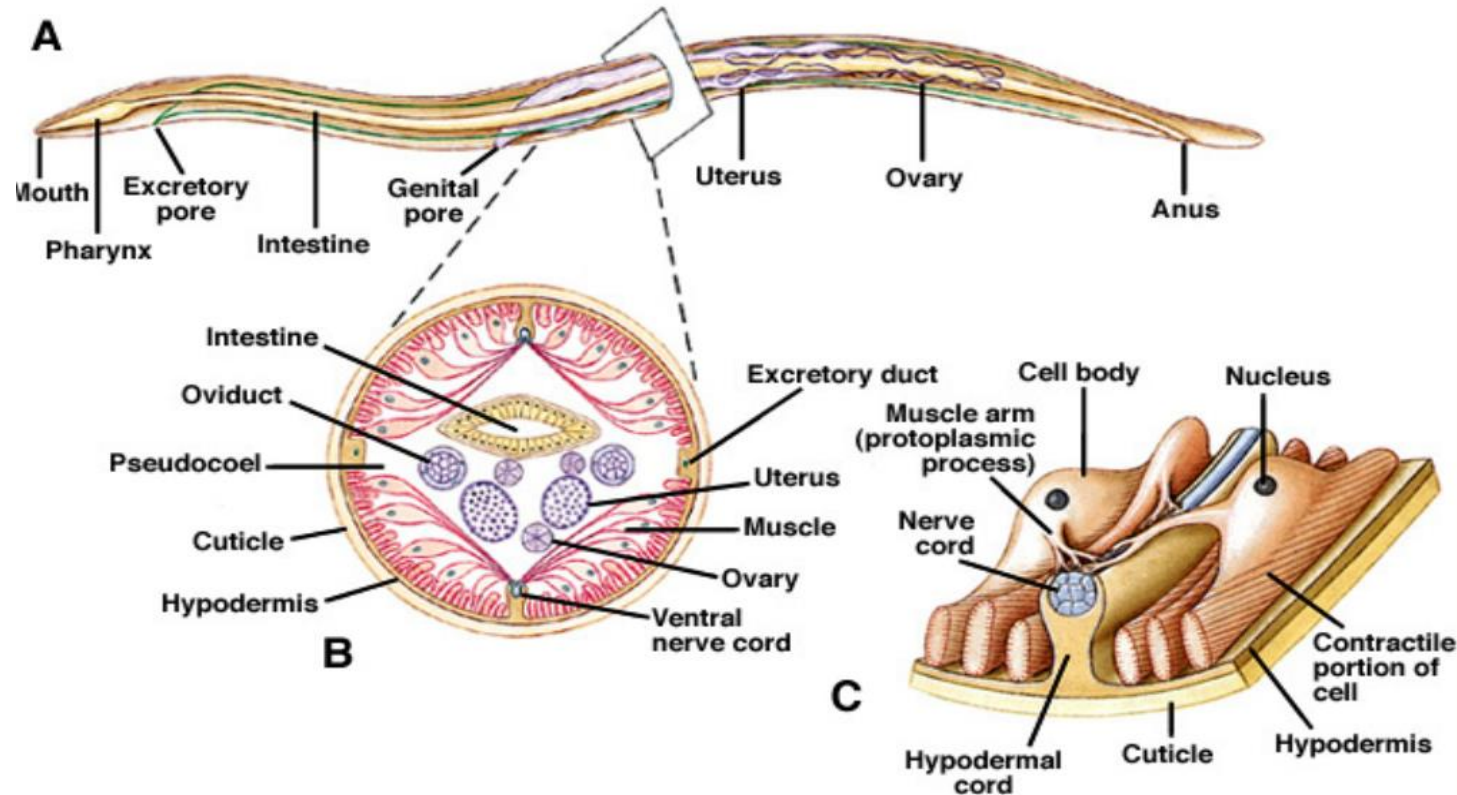
- A phenomenon where body is externally and internally divided into segments with a series of repetition of at least some organs.
- The body that shows this pattern is called metamERICALLY segmented



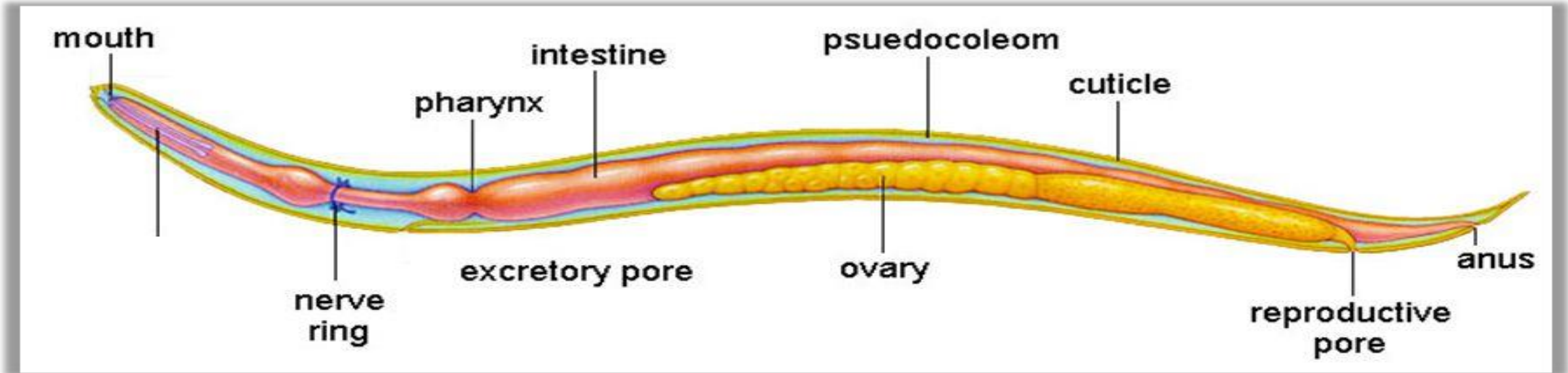
BODY ORGANIZATION AND SYMMETRY

- The nematode body organization is basically tubular and consists of 2 tubes.
- **The outer tube is wider and larger, and forms the body wall.**
- **It encloses a narrower and shorter inner tube, the alimentary canal.**
- **The two tubes join at the anterior extremity to form the lip region, and near the posterior region through rectum.**

Structures of a nematode



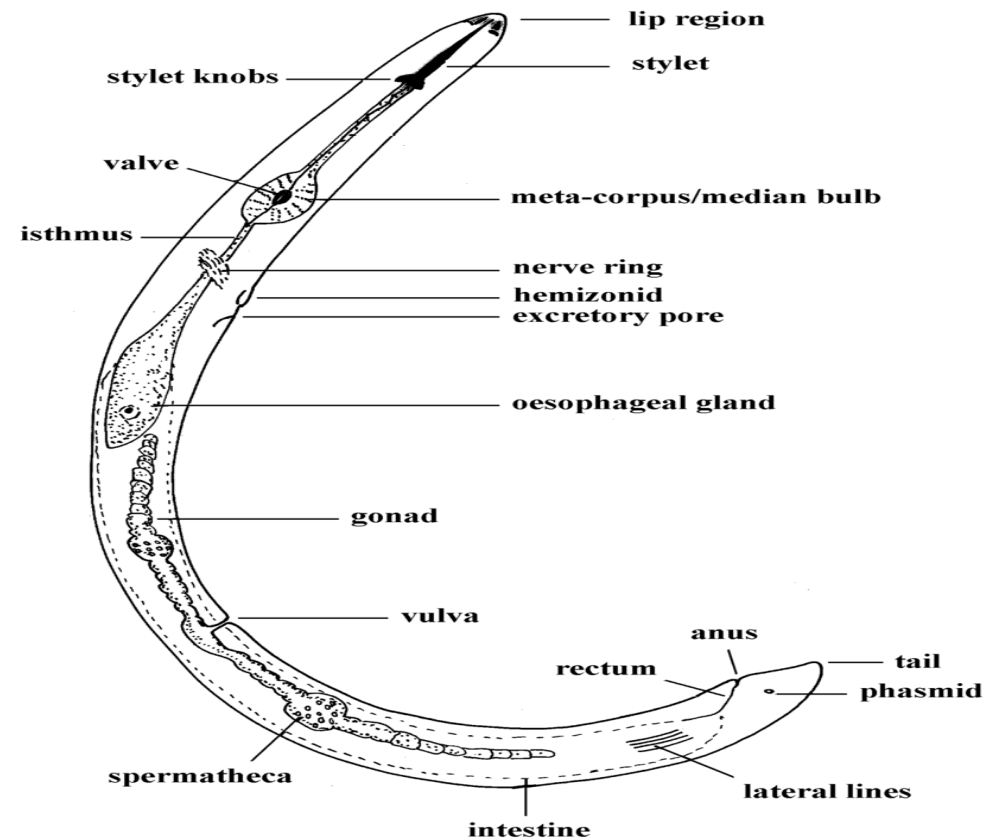
Nematode Anatomy



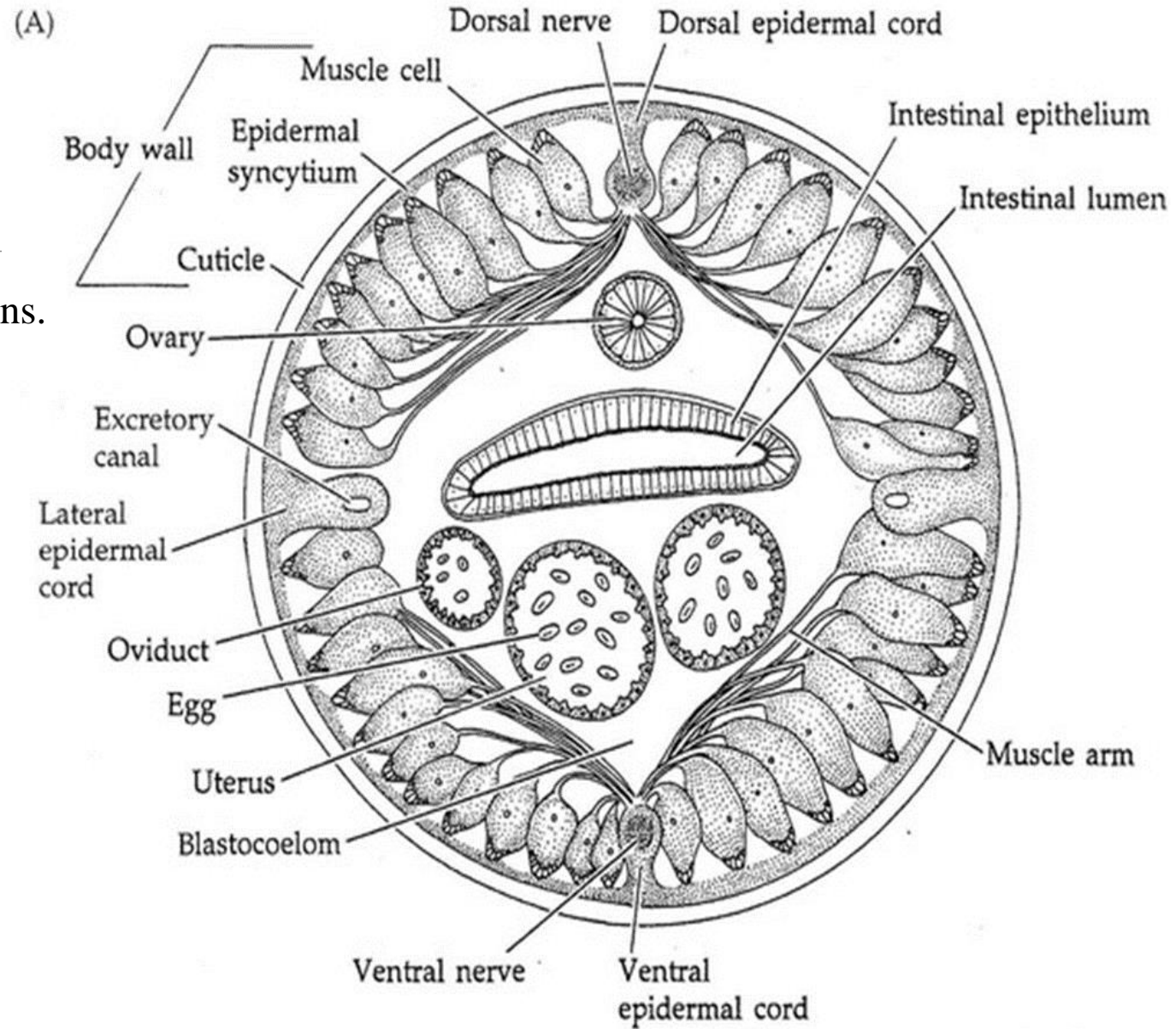
- “Tube within a tube” body plan

BODY ORGANIZATION AND SYMMETRY

- The space between the two tubes is called **body cavity or pseudocoelom**, as it is devoid of **mesodermal epithelial lining**.
- The **pseudocoelom** is filled with a **fluid (pseudocoelomic fluid)** which exerts **tremendous pressure on the body wall** to give it a **rounded outline in a cross-section**.
- The **reproductive, excretory and nervous systems** are located within the pseudocoelom.
- **Nematodes lack special organs for respiration and circulation.**

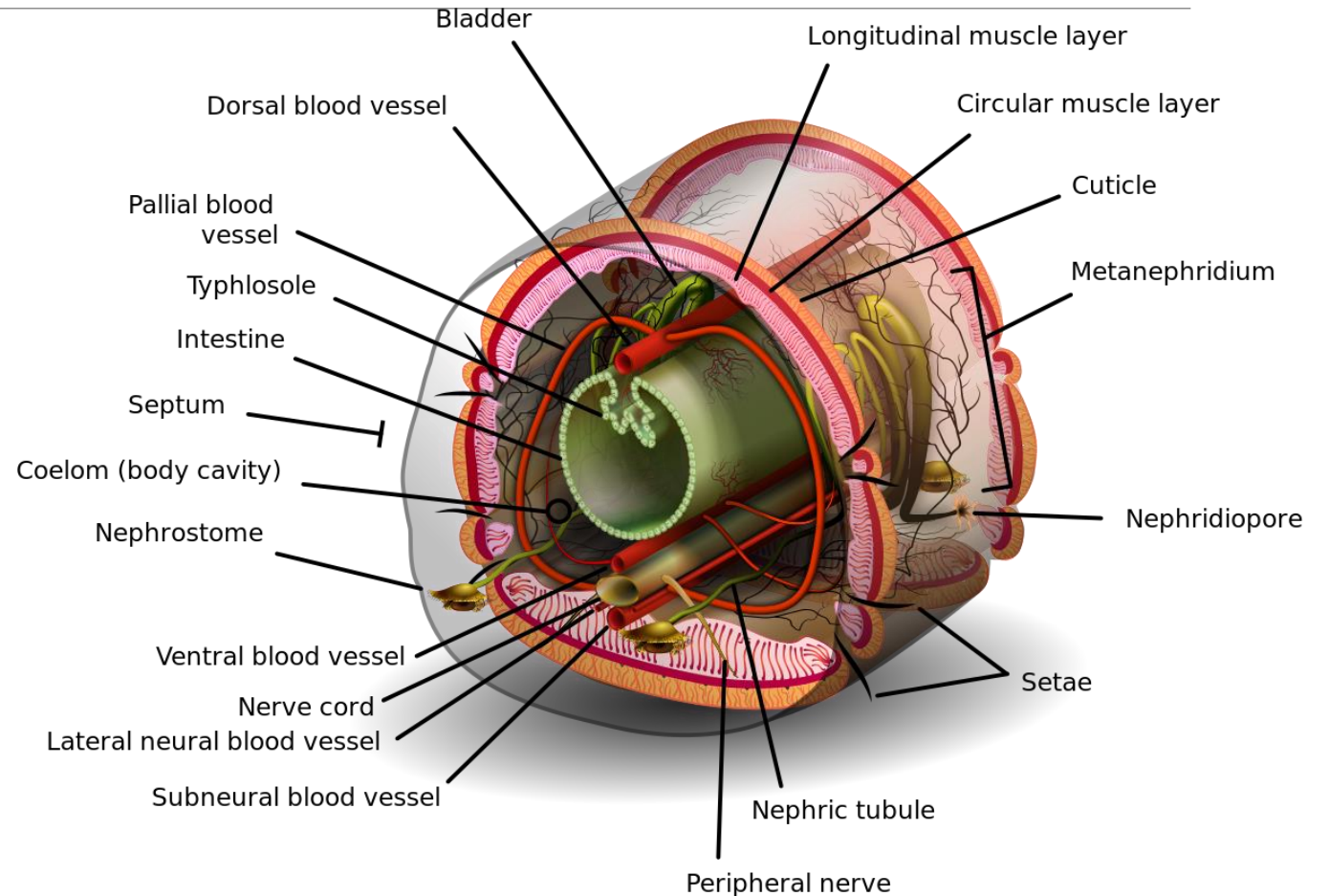


- The nematode body is divided into three regions.
- **outer body tube or body wall,**
- **inner body tube and**
- **body cavity or pseudocoelome.**



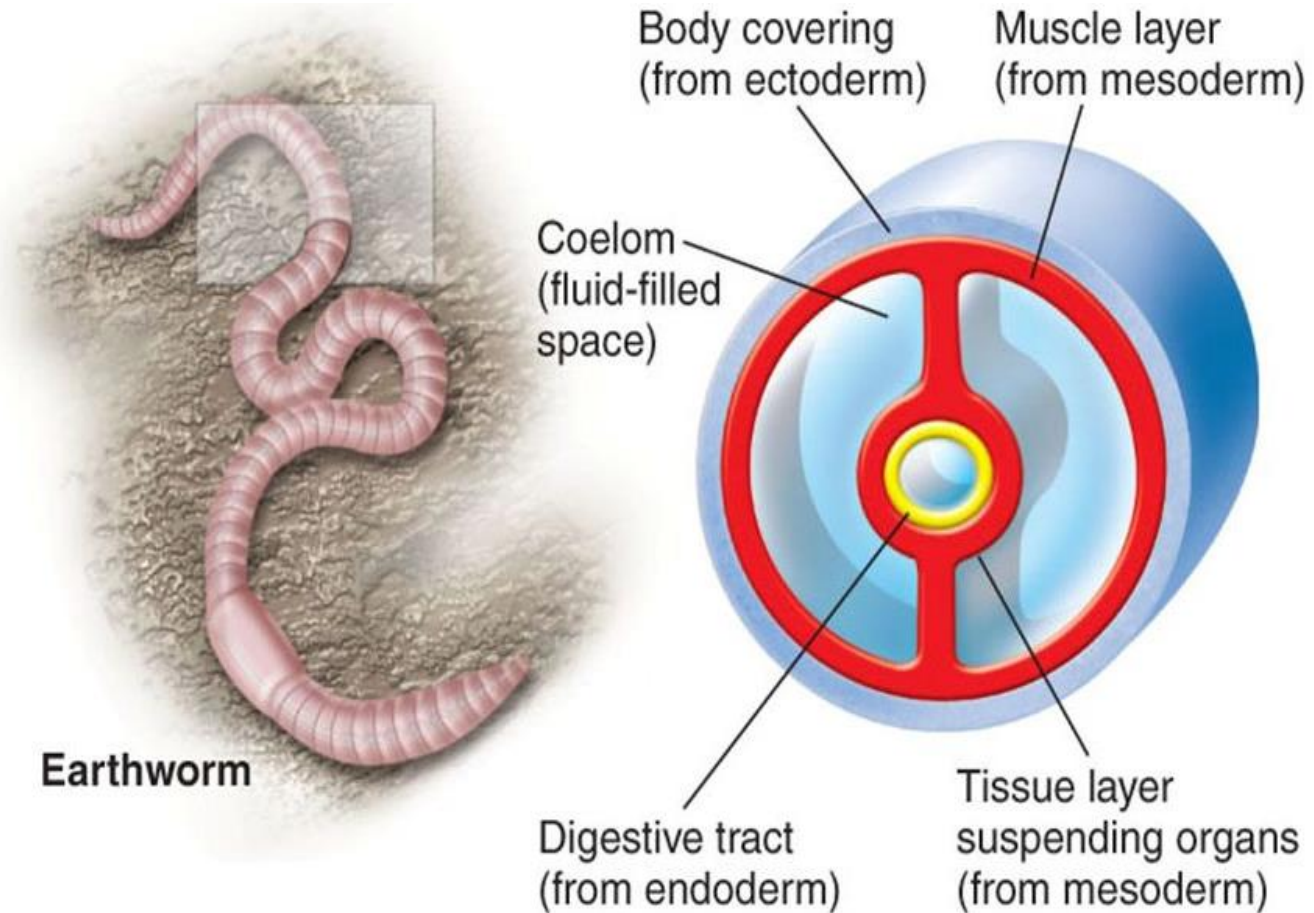
Body cavity or coelom

- The coelom (or celom) is the main body cavity in most animals and is positioned inside the body to surround and contain the digestive tract and other organs.
- Based on presence and absence of coelom organisms are classified into 3 categories i.e., **Eucoelomates**, **Pseudocoelomates** and **Acoelomates**.



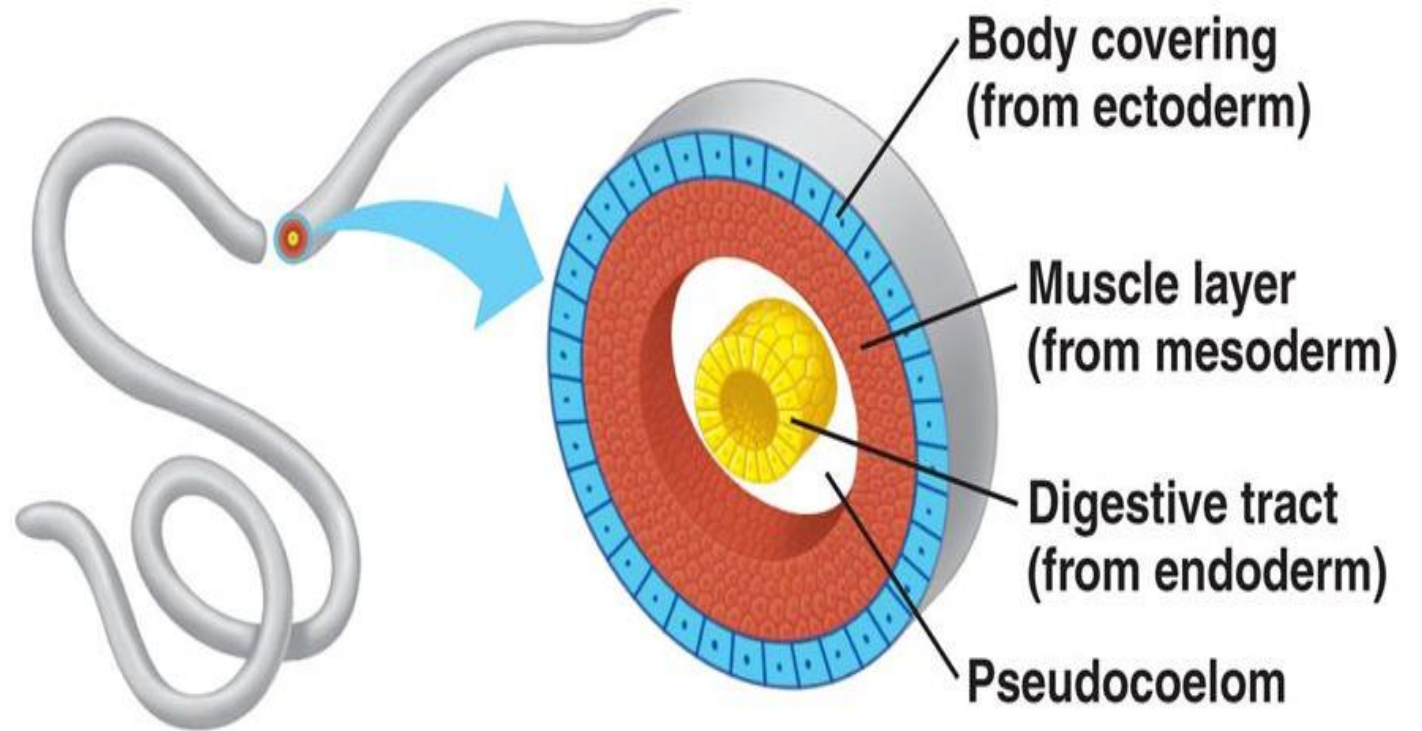
Eucoelomates

- **Eucoelomates ("true coelom") have a body cavity called a coelom with a complete lining called peritoneum derived from mesoderm (one of the three primary tissue layers).**
- **The complete mesoderm lining allows organs to be attached to each other so that they can be suspended in a particular order while still being able to move freely within the cavity.**
- **Most bilateral animals, including all the vertebrates, are coelomates**



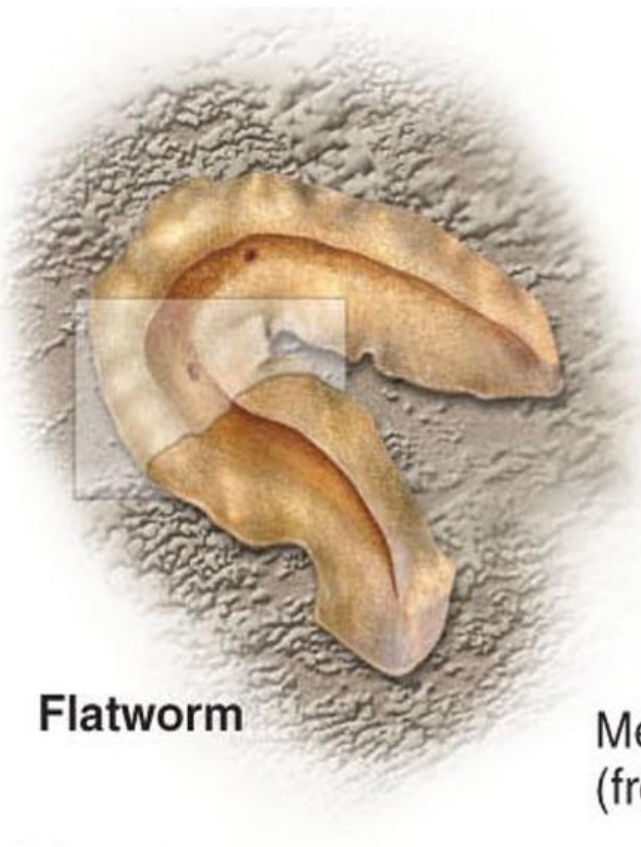
Pseudocoelomates

- Pseudocoelomate animals have a pseudocoelom "false cavity" which is a fluid filled body cavity.
- **Tissue derived from mesoderm partly lines the fluid filled body cavity of these animals.**
- Thus, although organs are held in place loosely, they are not as well organized as in a coelomate.
- **Example: Nematodes.**

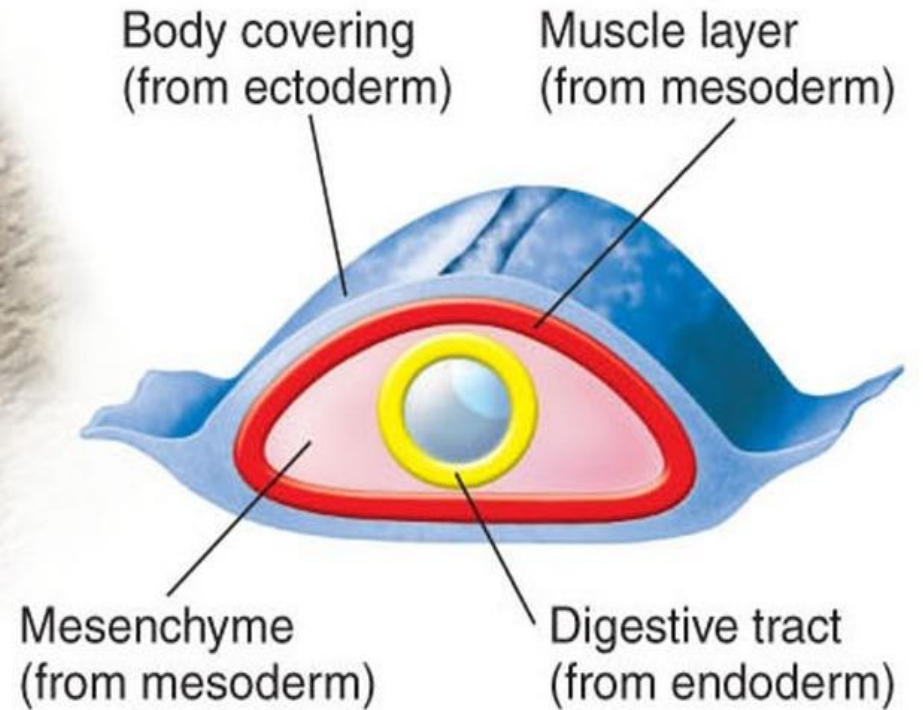


Acoelomates

- Acoelomate animals, like flatworms, **have no body cavity at all. Semi-solid mesodermal tissues between the gut and body wall hold their organs in place.**



Flatworm





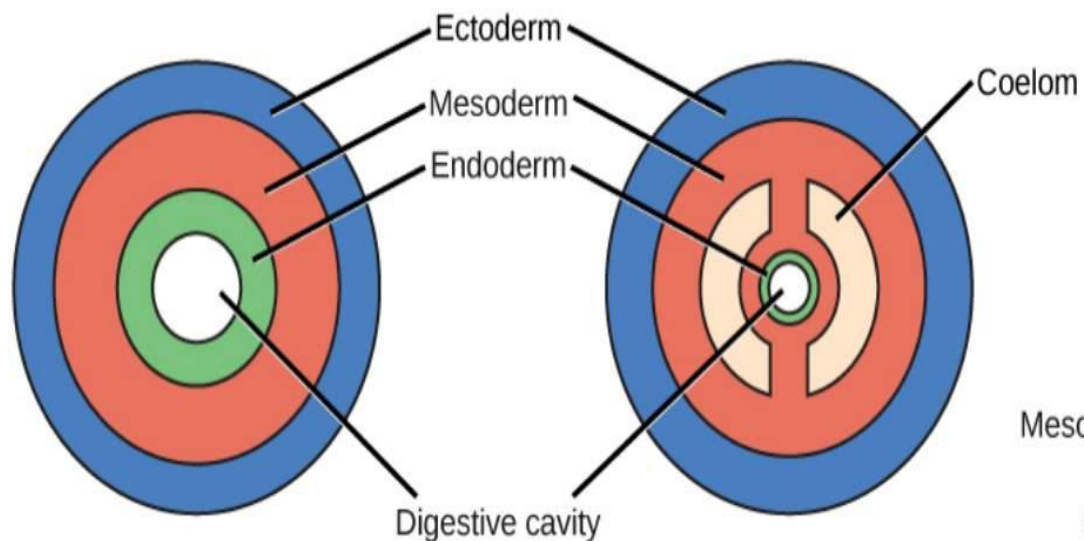
Flatworm: *Pseudobiceros bedfordi*



Annelid: *Glycera*

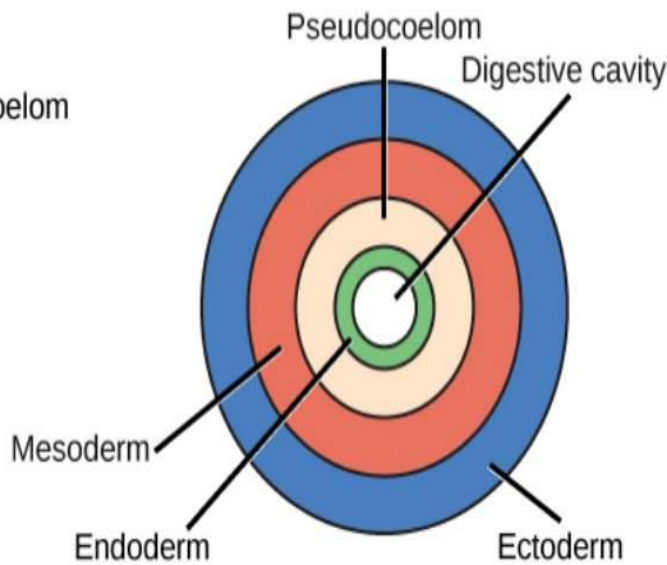


Nematode: *Heterodera glycines*

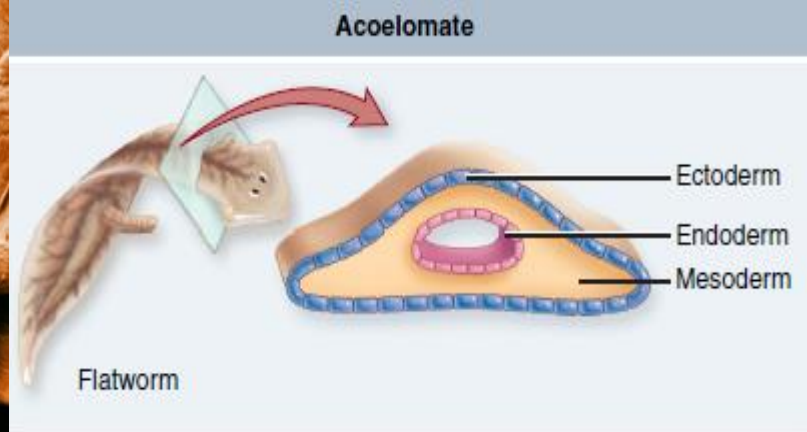


(a) **Acoelomate**
(flatworms)

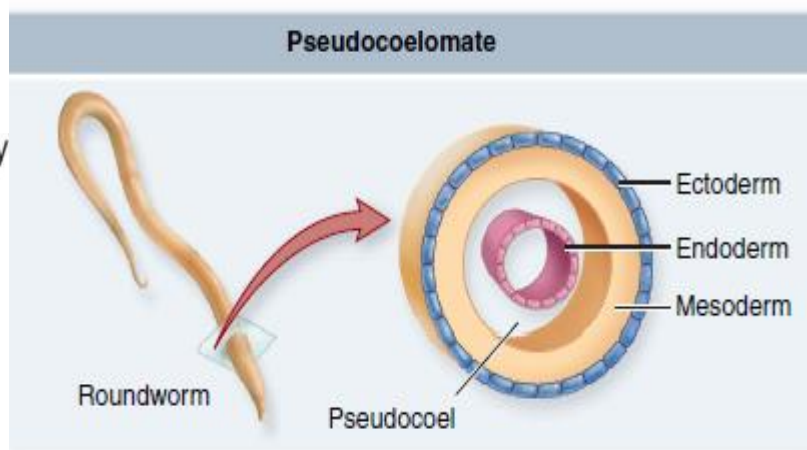
(b) **Eucoelomate**
(annelids,
mollusks,
arthropods,
echinoderms,
chordates)



(c) **Pseudocoelomate**
(roundworms)

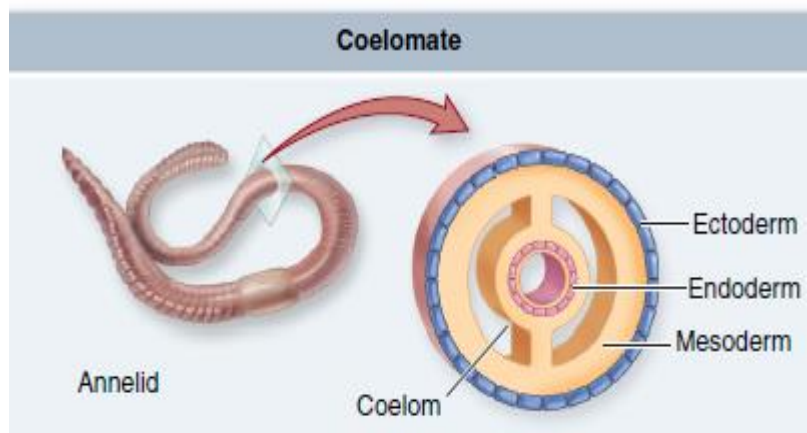


Flatworm



Roundworm

Pseudocoel

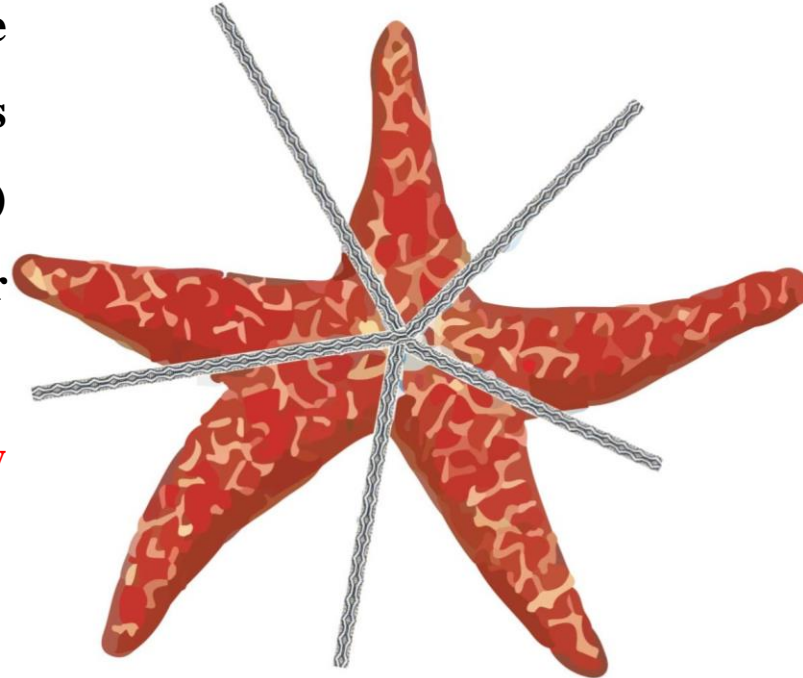


Annelid

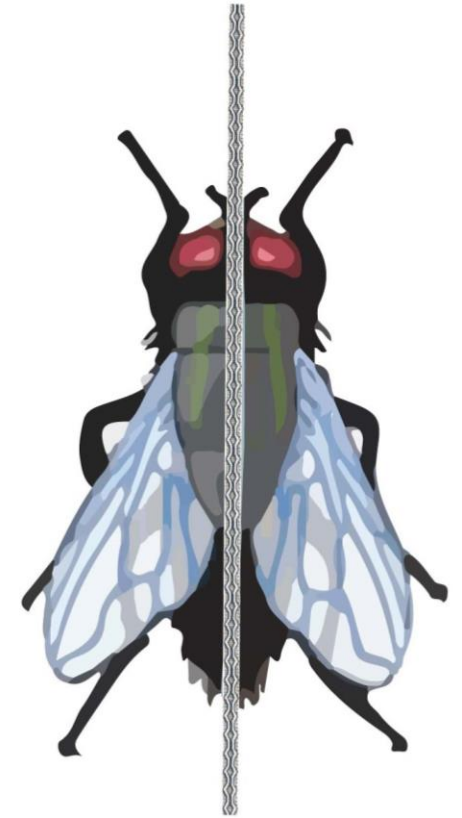
Coelom

BODY ORGANIZATION AND SYMMETRY

- **The nematode body is basically bilaterally symmetrical, i.e. if the body is cut into 2 equal halves through a dorso-ventral (sagittal) plane, the two halves are mirror images of each other.**
- **Other organs, however, also show radial symmetry or asymmetry.**



Radial symmetry

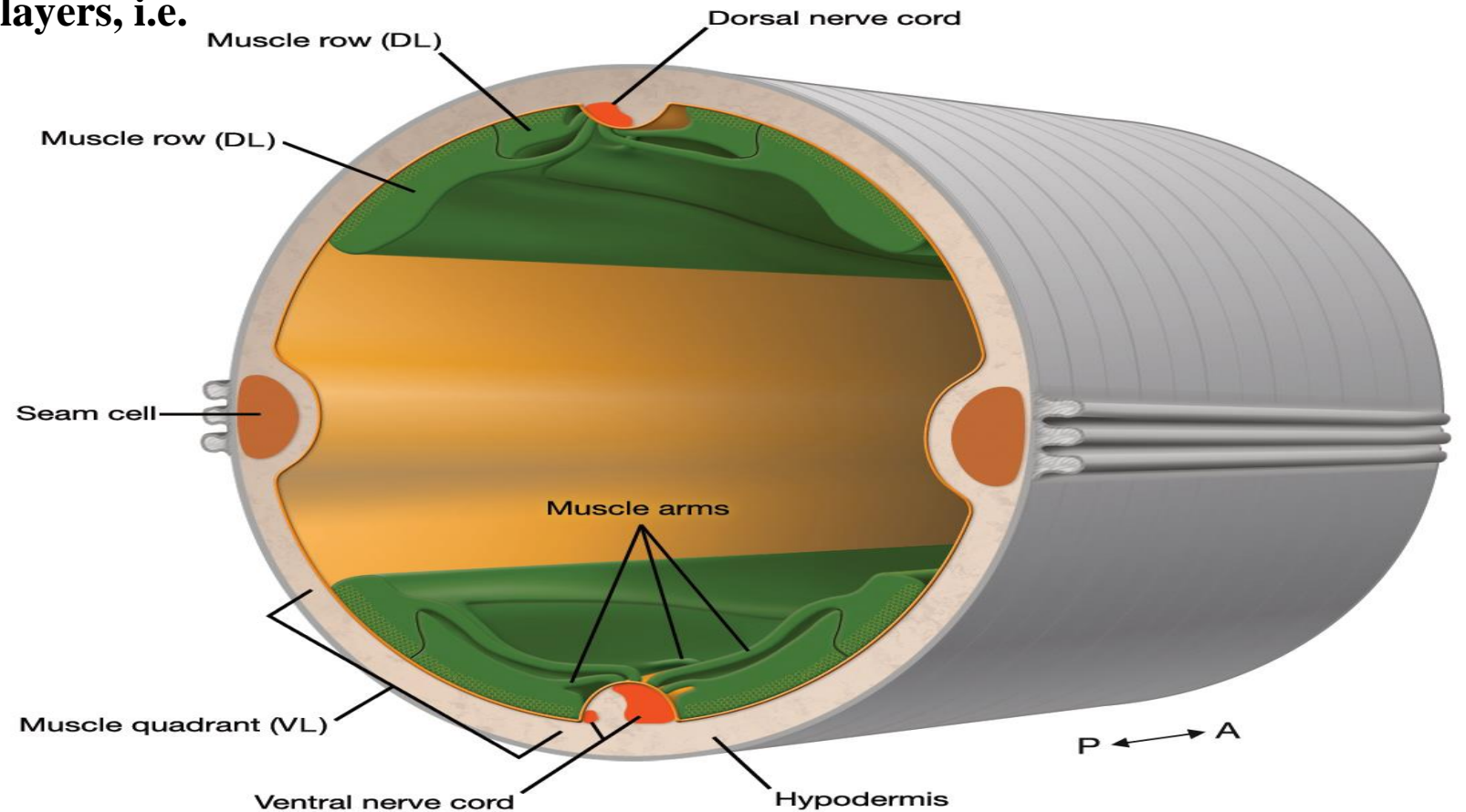


Bilateral symmetry

THE OUTER BODY TUBE (BODY WALL)

- The body wall consists of 3 layers, i.e.

- **Cuticle**
- **Hypodermis (epidermis)**
- **Muscle layer**



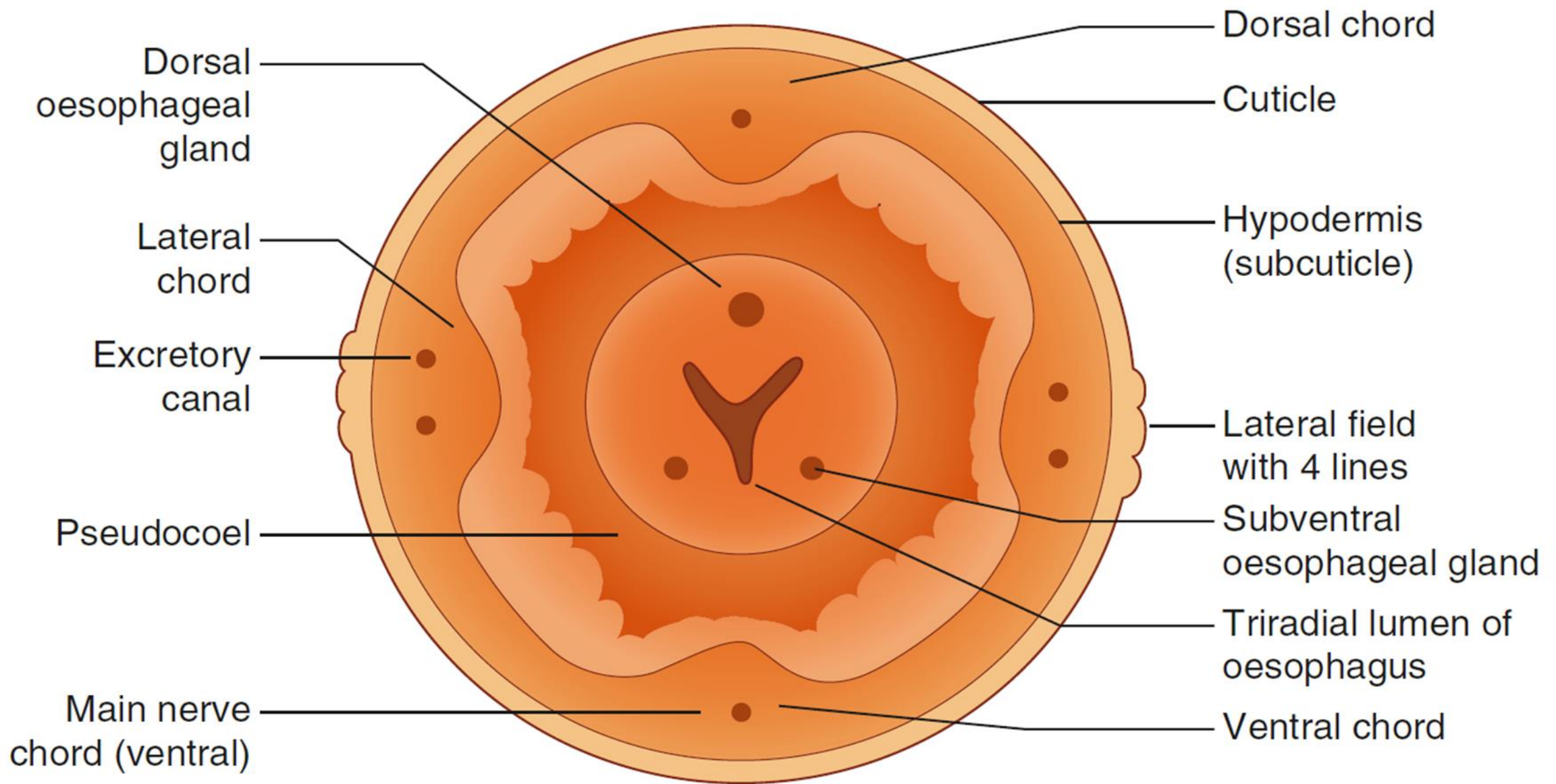
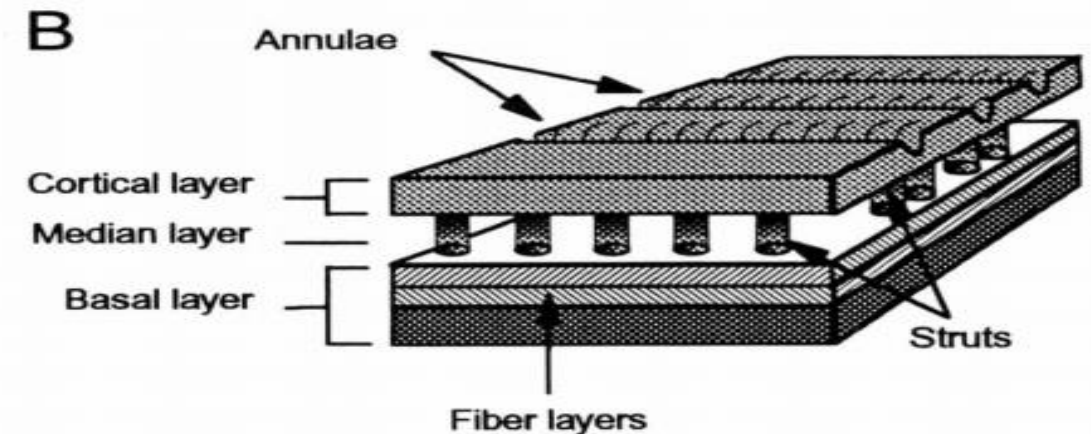
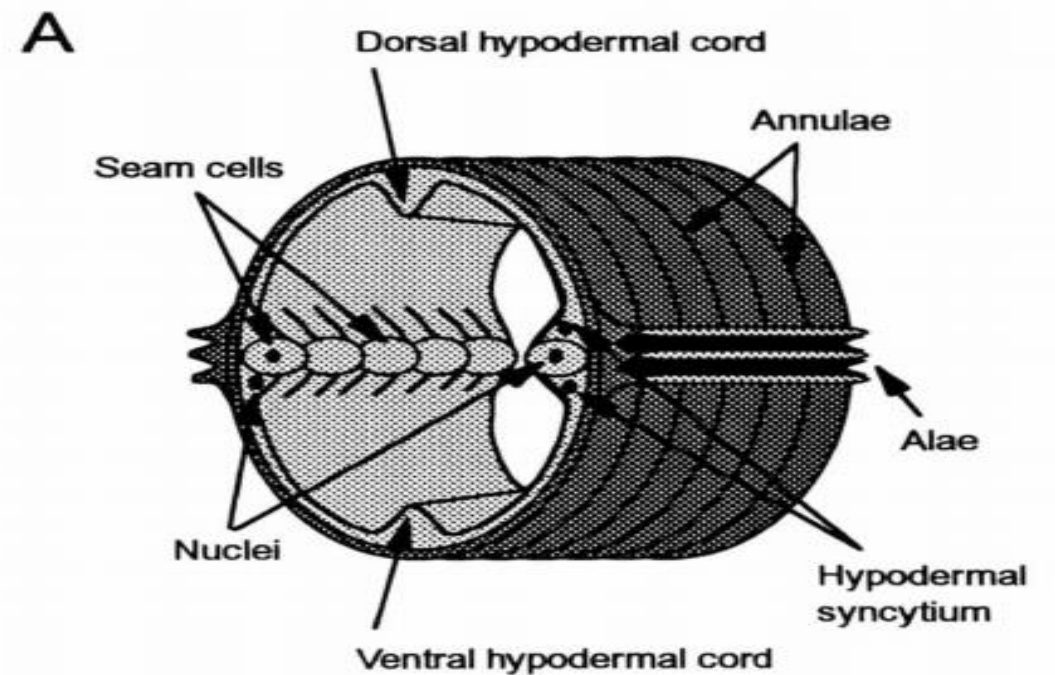


Fig. 3.10 Cross section through the oesophageal region of the body of a nematode (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

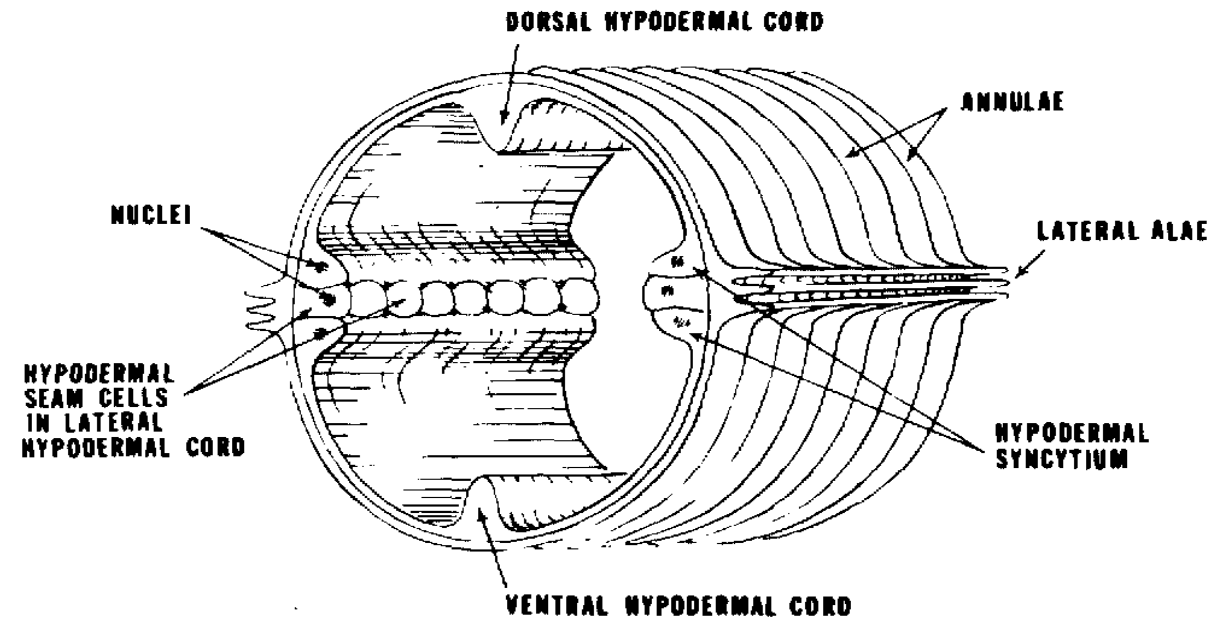
CUTICLE

- It is a non-cellular, non-living layer forming the outer covering of the animal.
- It is tough but elastic functions as an exoskeleton, regulates permeability (selectively permeable) and body growth, and helps in locomotion.
- It also plays an important role in the respiration and excretion.
- Cuticle is shed-off at each moult.
- The feeding stylet and copulatory spicules are formed from cuticle.

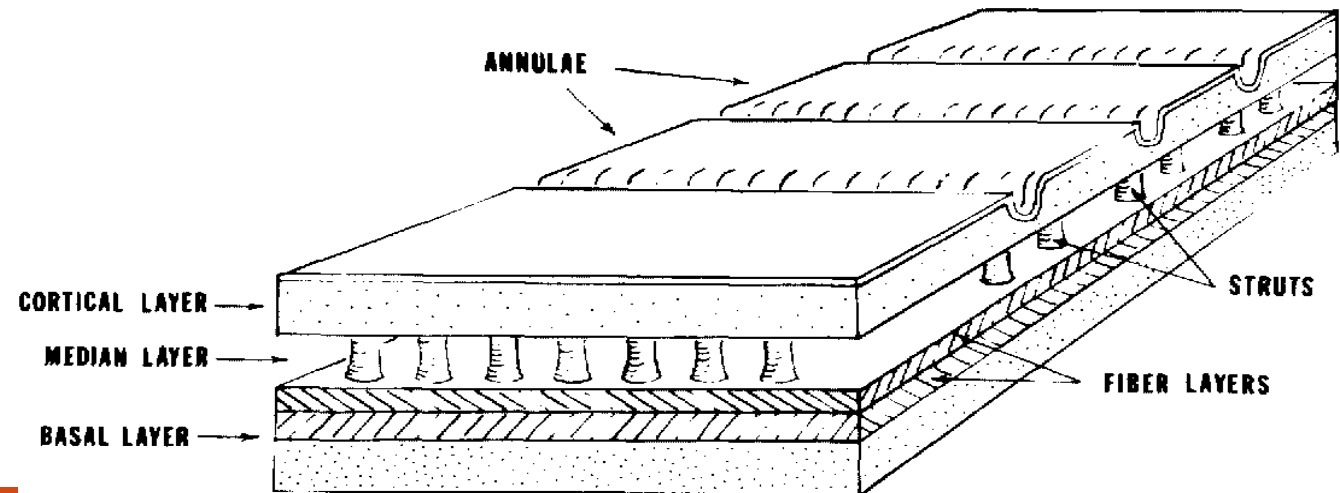


CUTICLE

- Cuticle itself is a multi-layered structure, which can be basically divided into 3 layers
- **Cortex or the cortical layer**
- **Matrix or the homogeneous layer**
- **Fibrillar or the basal layer**
- These layers are complicated chemically and are rich in structural proteins such as **keratin, collagen, matricin etc.**
- **Chitin is not found in nematode cuticle.**

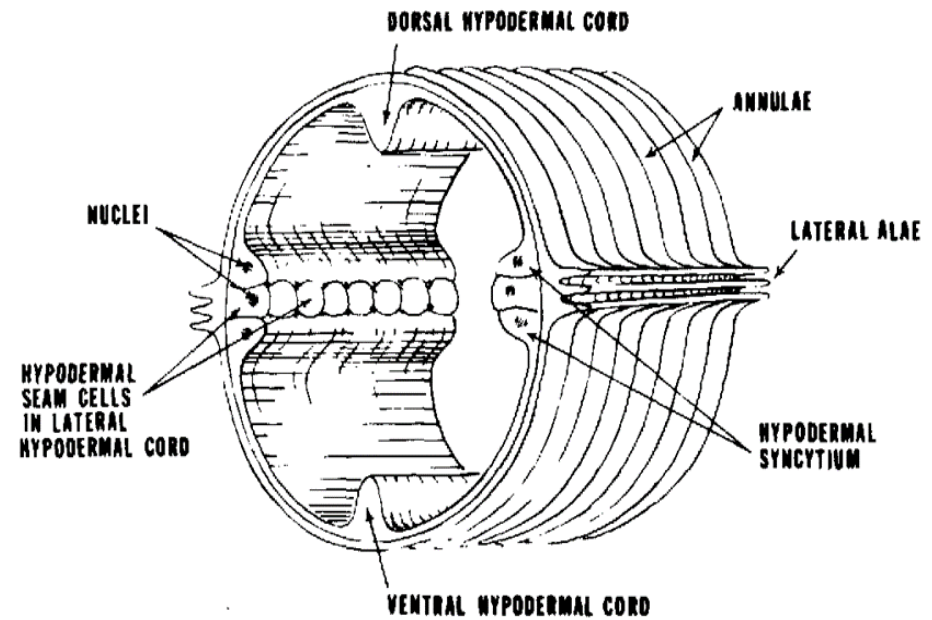


A

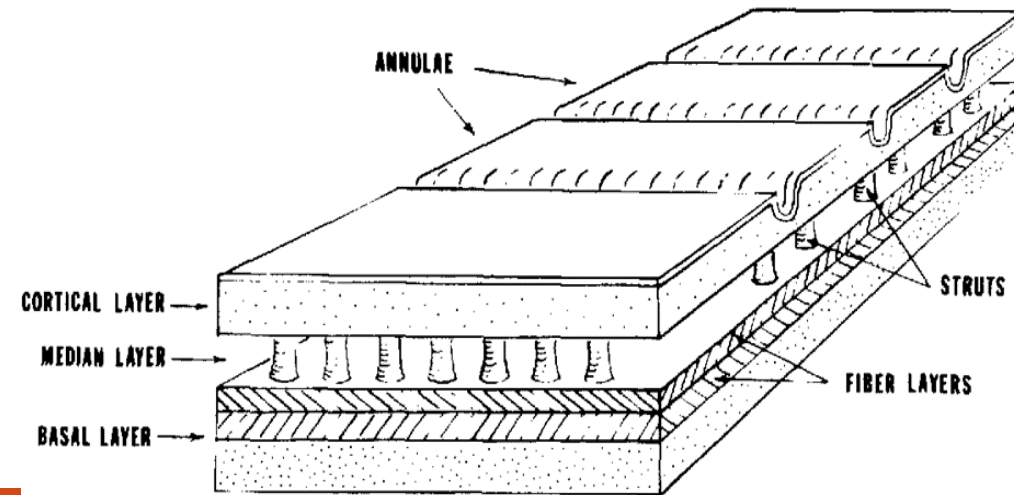


B

- There are two basic kinds of cuticular structures:
- **i. Ornamentation** (which can function in movement and positioning).
 - **i. Punctuation**
 - **ii. Transverse marking or striations**
 - **iii Longitudinal markings.**
- **ii Sensory Organs** (which function in detecting of environment).
- **iii Spines, Setae and Papillae** (may be sensory)



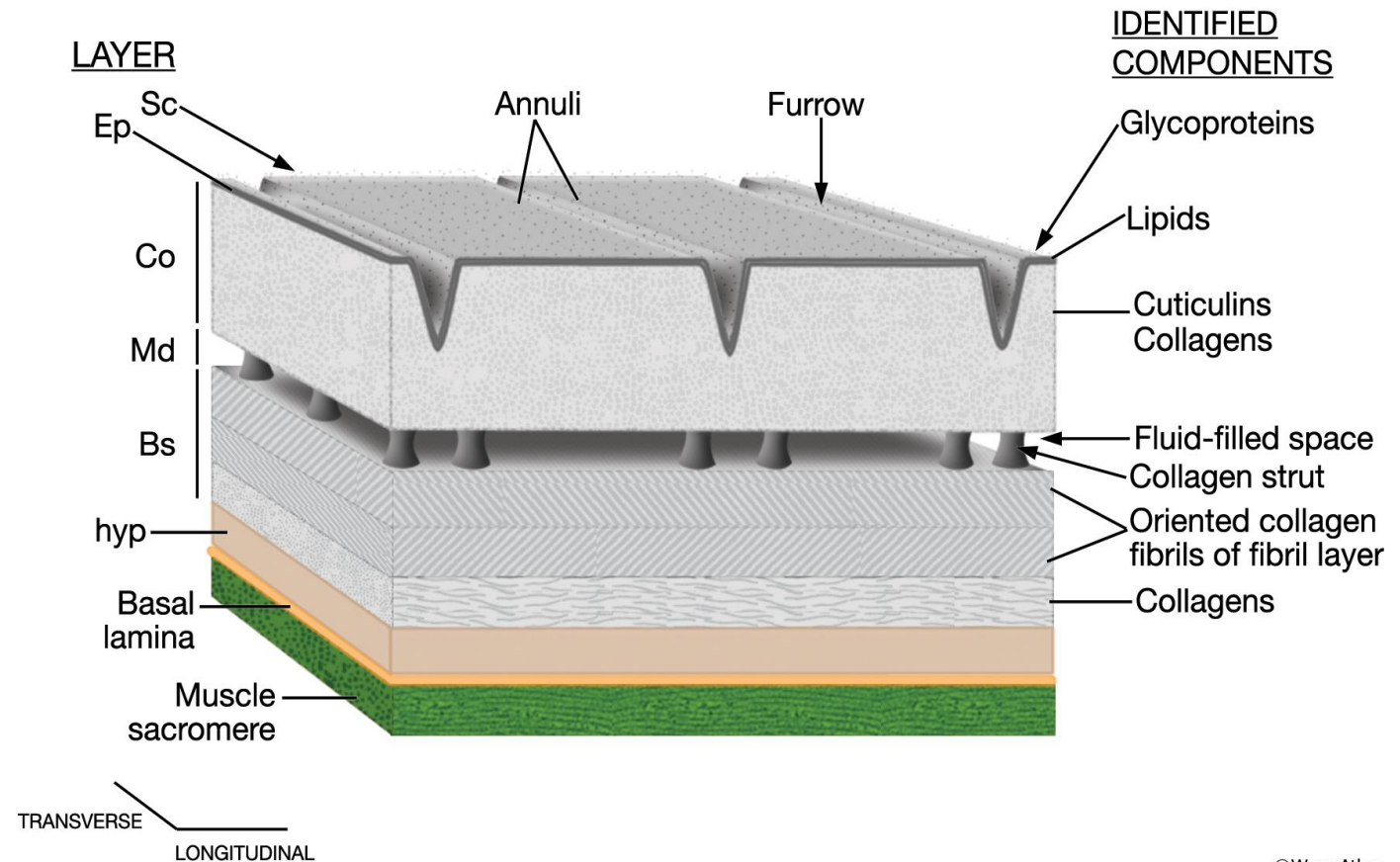
A

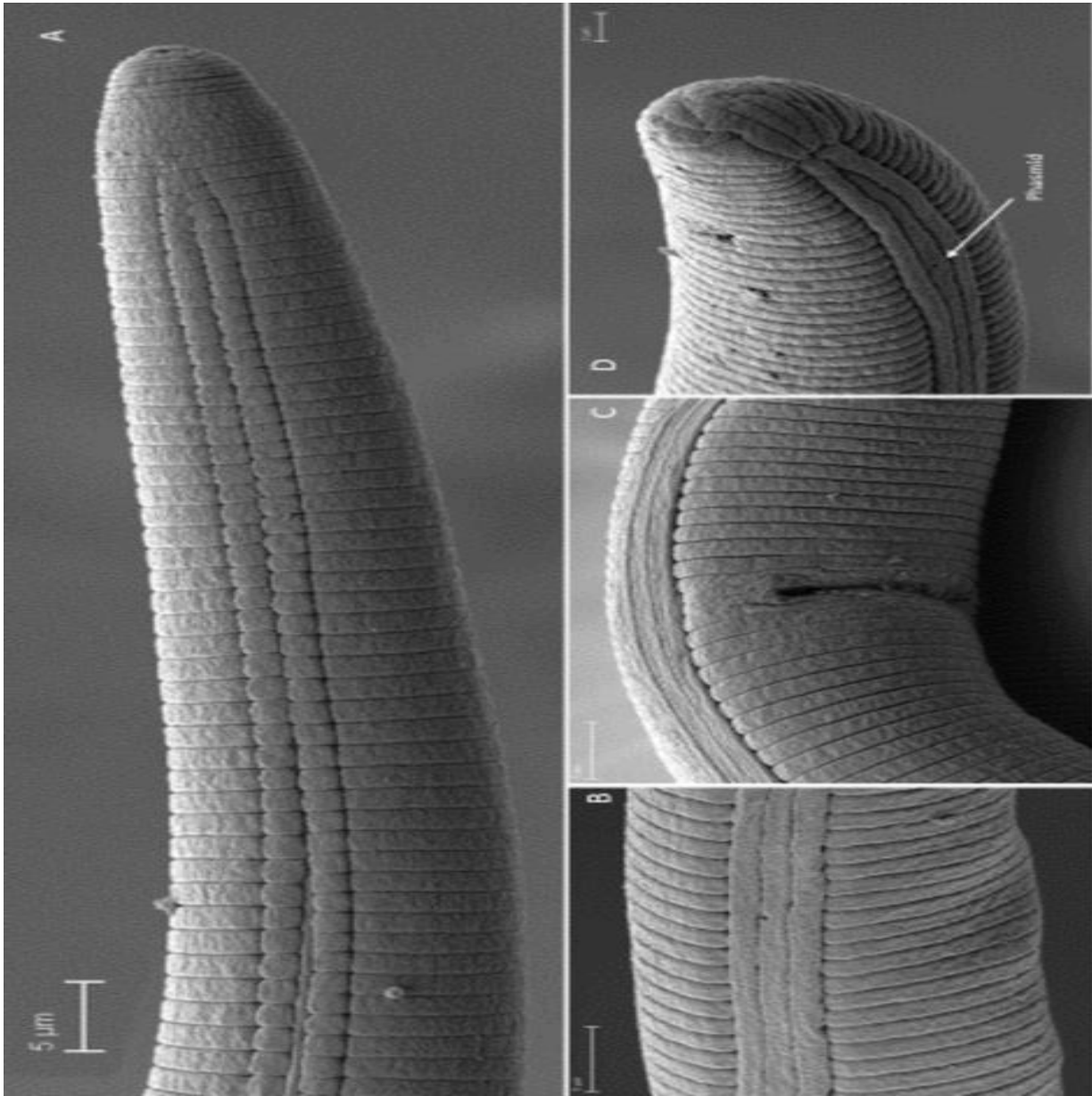


B

CUTICLE

- The cuticle is beset with various types of cuticular markings.
- It may be smooth or marked with transverse grooves (striation) known as striae.
- The raised area in between the two striae is known as interstitial region.
- These grooves form rings around the body but are superficial (restricted to outer layers of cuticle) only.

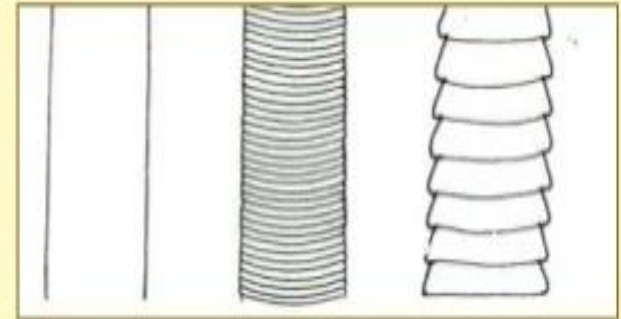




Cuticular markings

10

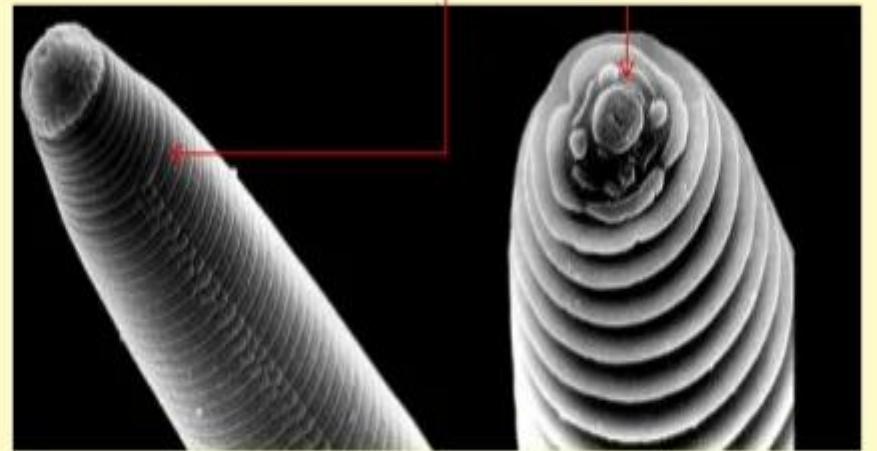
A. Transverse



Smooth

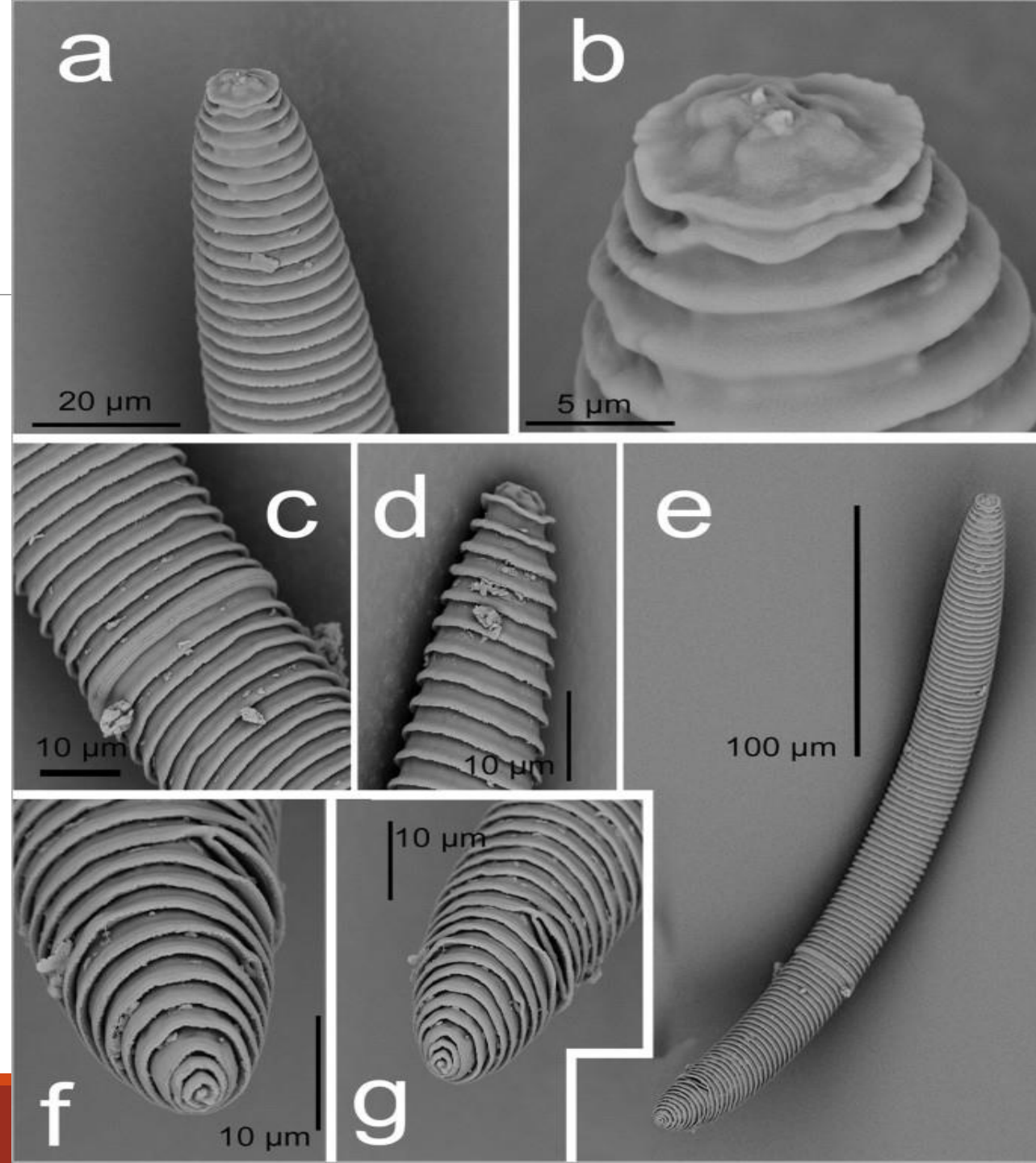
Striated

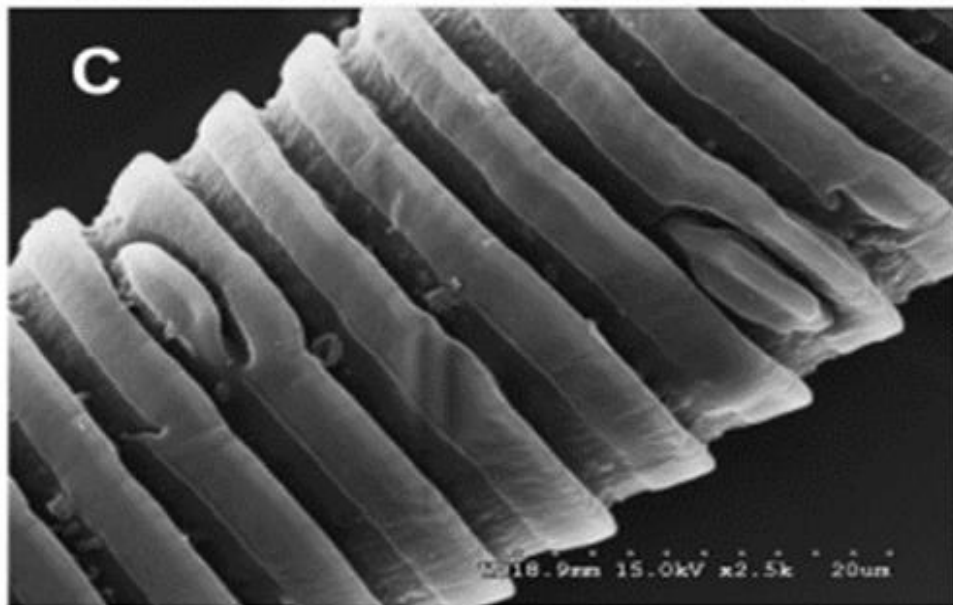
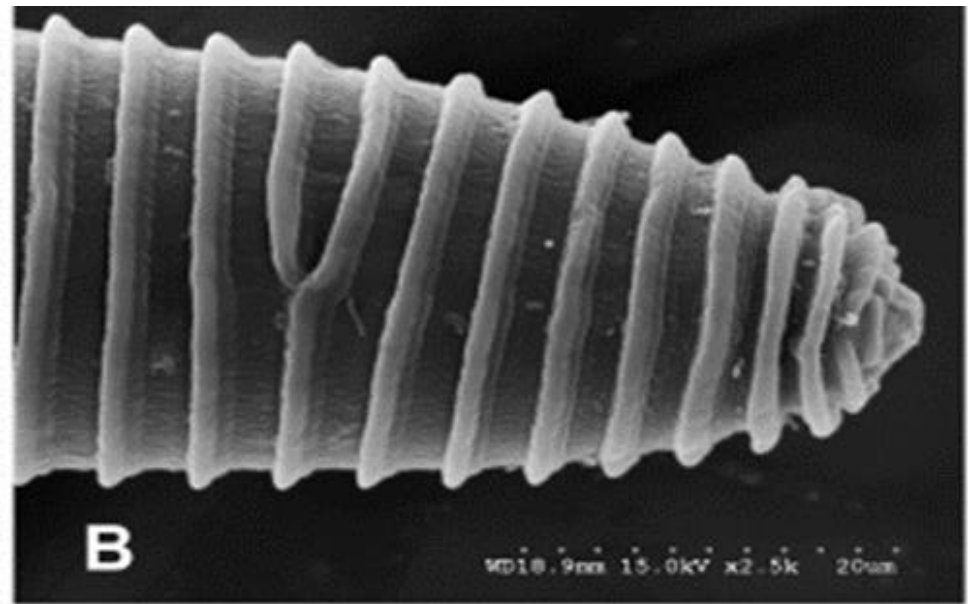
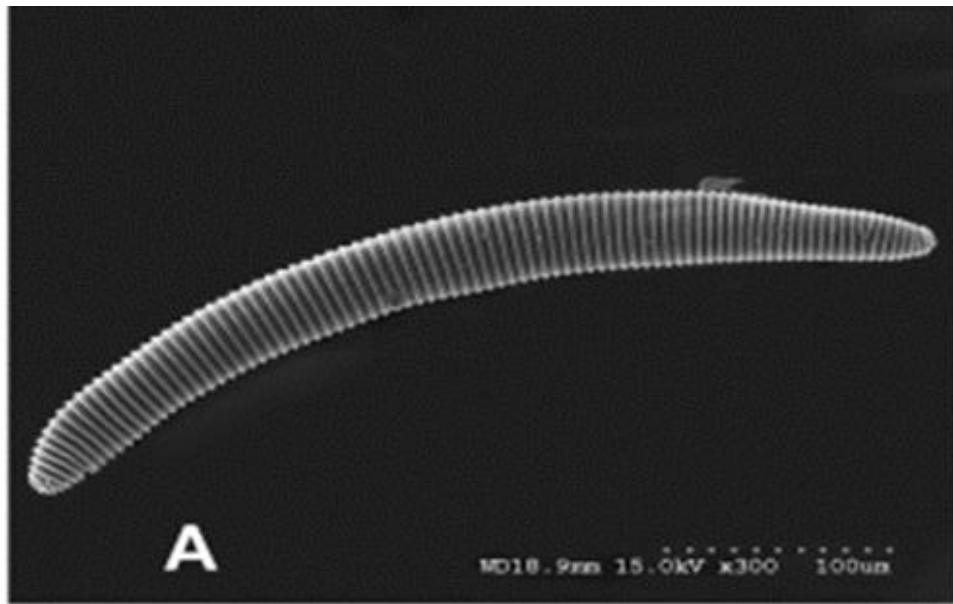
Annulated



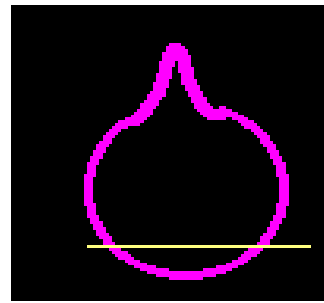
CUTICLE

- In certain plant parasitic nematodes (**criconematids**) the striae are very deep with wide interstitial zone (**annulation**), dividing the body into superficial segmentation (**annuli**).
- The posterior margins of these annuli may possess spines, scales etc. arranged in definite patterns.
- This is called **Cuticular ornamentation**.





i. Punctuations



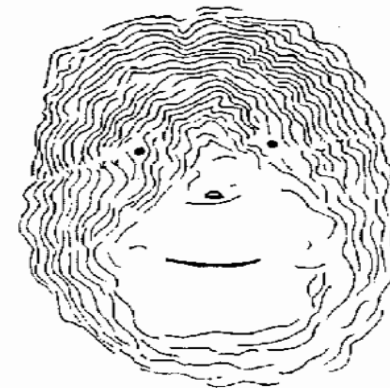
- These are minute, round dots arranged in a pattern.
- They act as structures for strengthening the cuticle rather than as pore canals through which cuticular proteins may be transported.
- In the perineal pattern of *Meloidogyne hapla* these punctuations can be seen



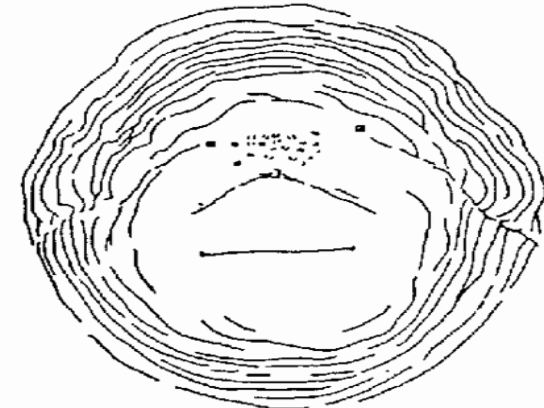
M. javanica



M. arenaria



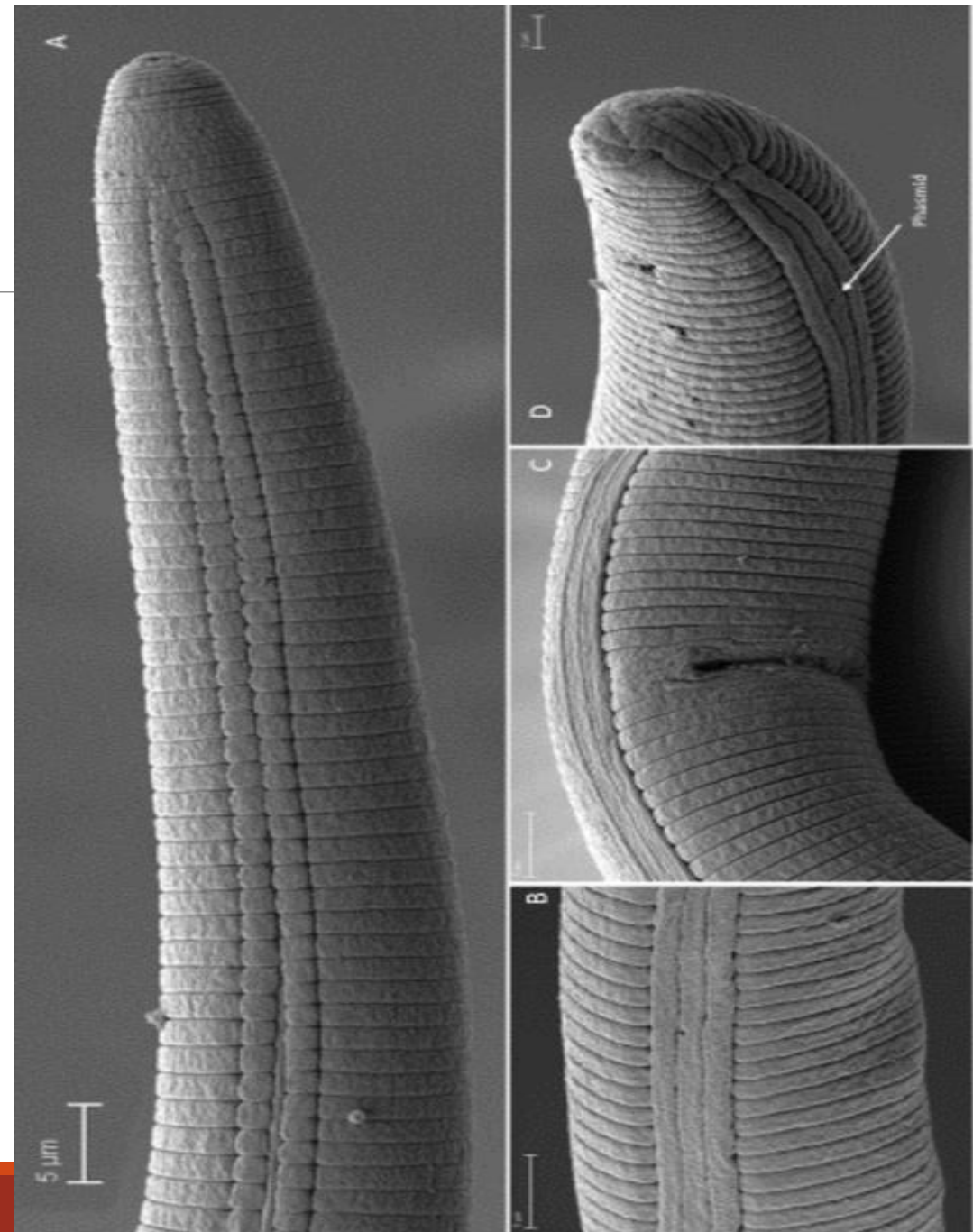
M. incognita



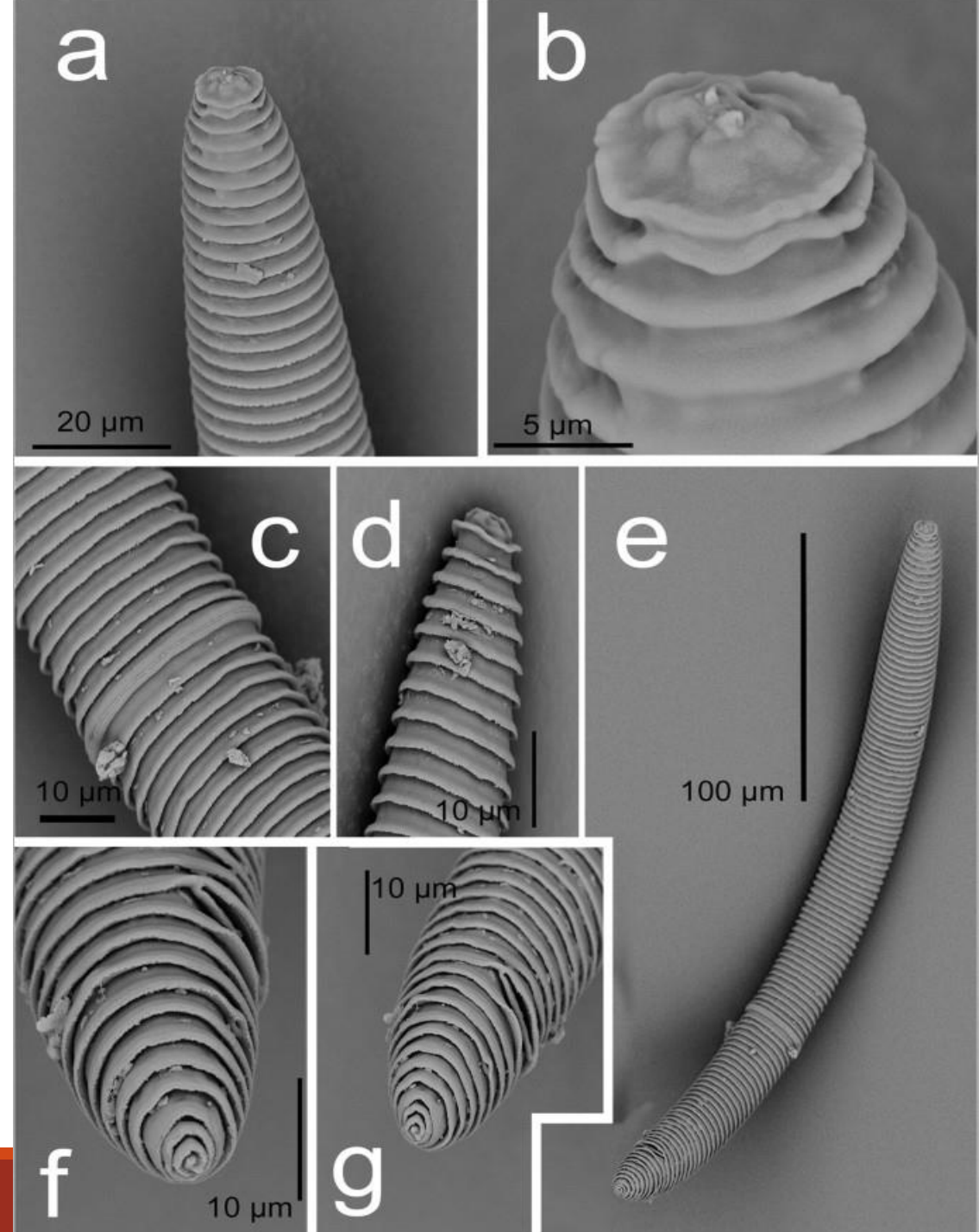
M. hapla

ii. Transverse marking or Striations

- There are transverse lines present on the surface of the cuticle.
- These markings exhibit distinct variations among nematodes and often used by the taxonomists for identification.
- The transverse markings gives the false appearance as if the nematode is segmented.

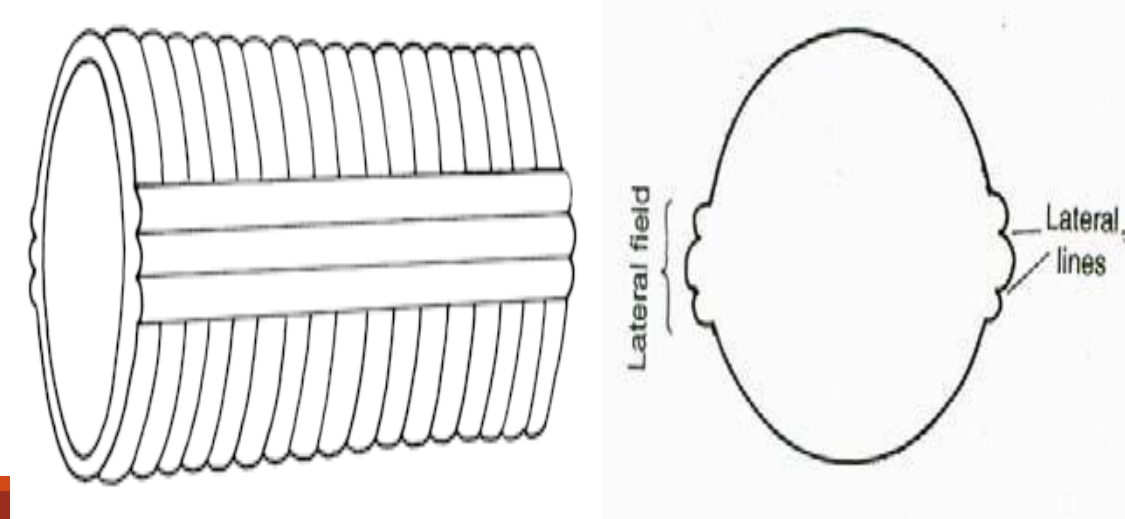
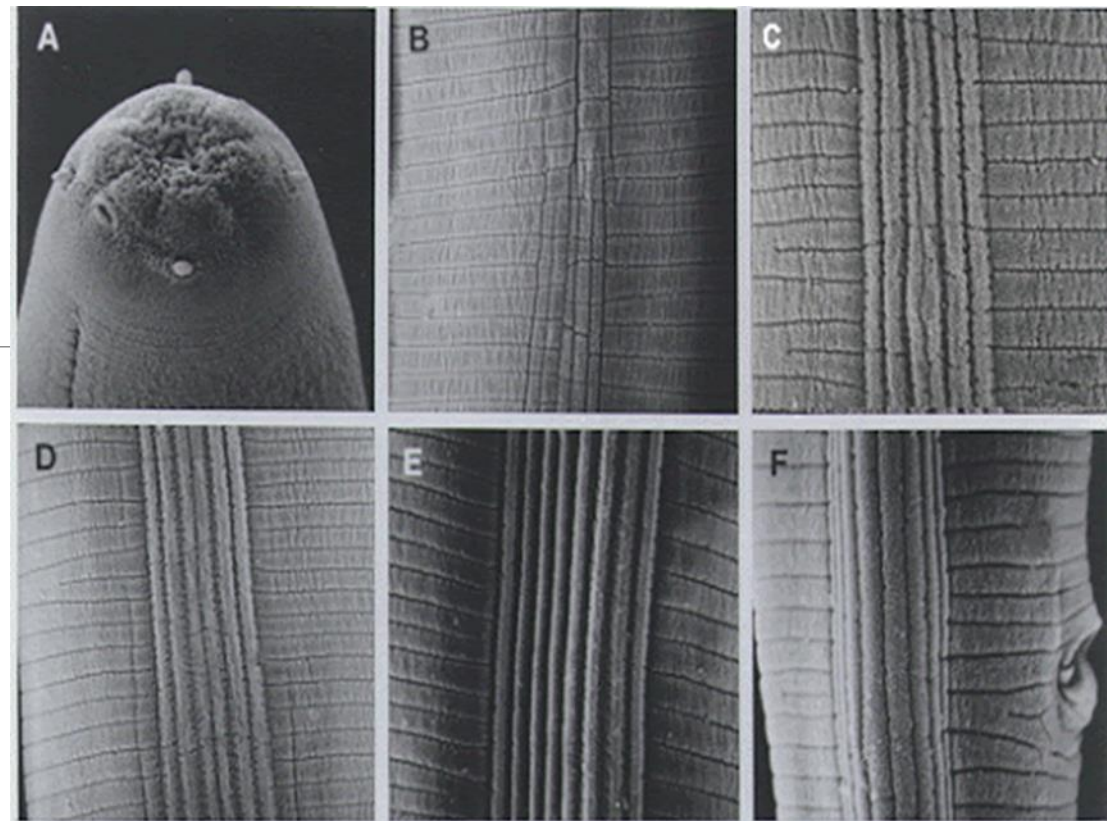


- These markings are well pronounced in some families such as Criconematidae, Tylenchidae and Heteroderidae.
- In Criconematids, the annulations are clearly visible and known as scales and spines.
- The perineal pattern in the posterior body region of *Meloidogyne* females, as well as rugose wall pattern of *Heterodera* cysts, are considered to be the modifications of transverse markings.



CUTICLE

- Generally, among plant parasitic nematodes, the striation becomes discontinuous on the two lateral sides.
- Instead, these areas are usually provided with slightly raised longitudinal cuticular structures, known as the **lateral alae** (alum = wing), running nearly the entire length of the body.
- Each lateral alum constitutes a **lateral field (seam)** and is further marked by grooves (**lateral lines or incisures**) running in the longitudinal direction.
- The number of lateral lines may vary from 0 to 16 and is specific for a nematode species



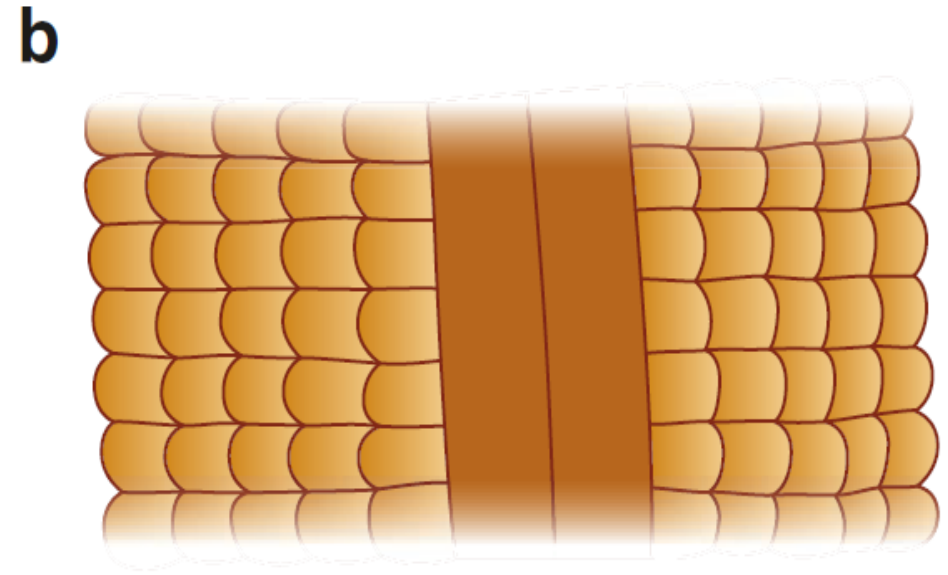
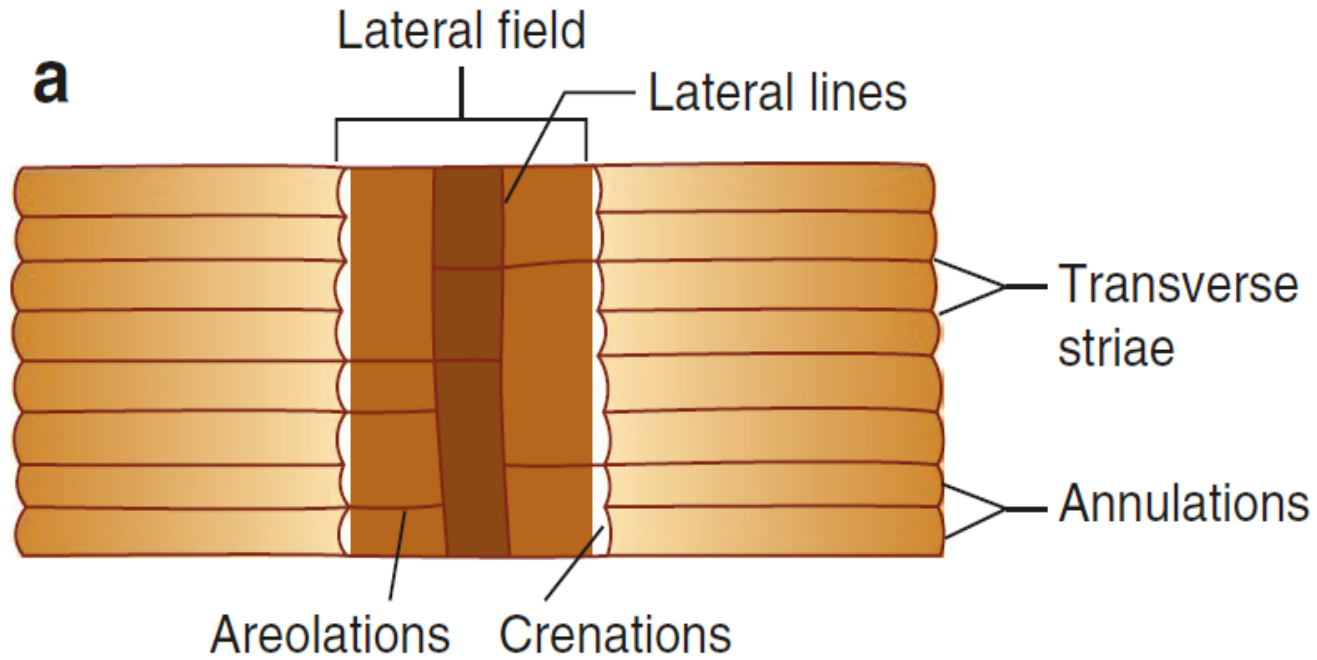
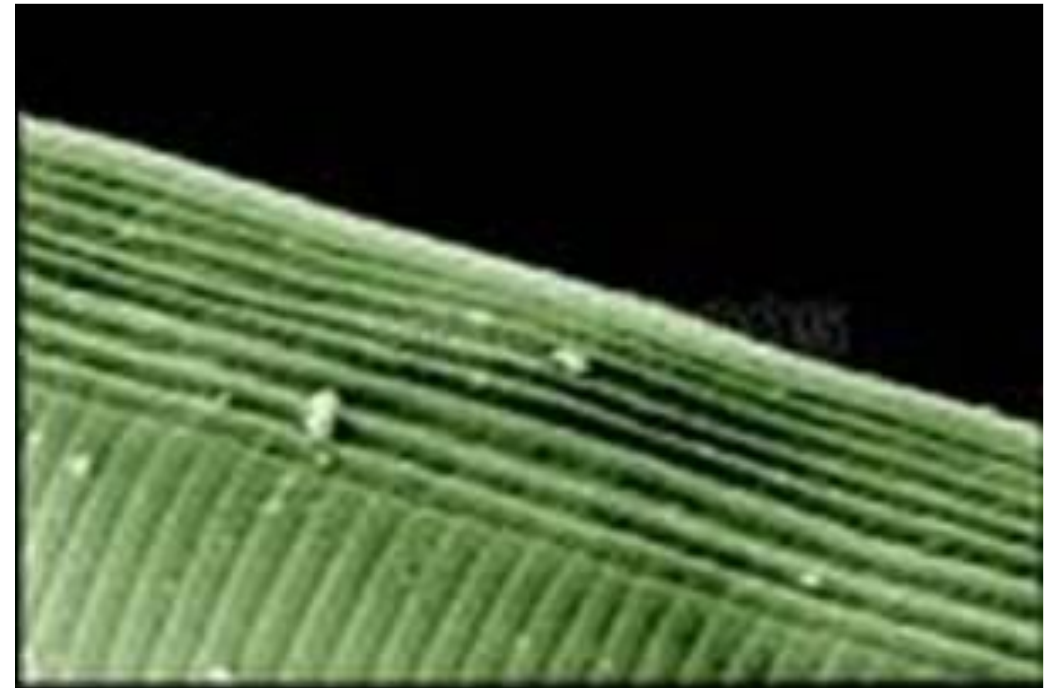


Fig. 3.4 Cuticular ornamentation with striae, lateral lines as well as areolations and crenations (a). Cuticular ornamentation of *Stegellesta* with the longitudinal lines along the whole length of the body either as involutions or ridges (b) (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

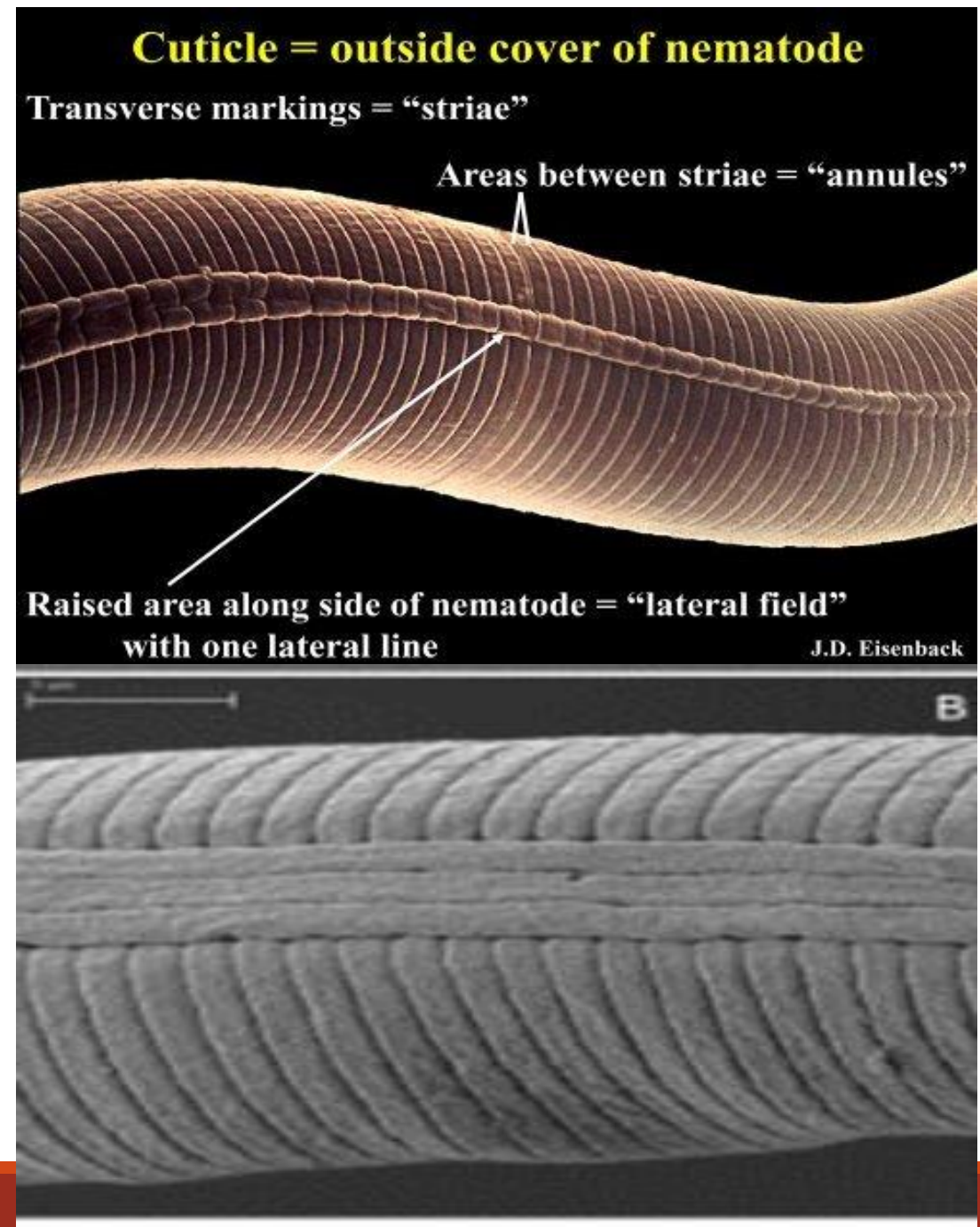
iii. Longitudinal markings

- **These markings are the lines on the cuticle, which runs longitudinally throughout the length of the nematode body.**
- **These markings are divided into**
 - **a) lateral lines or incisures**
 - **b) longitudinal ridges.**



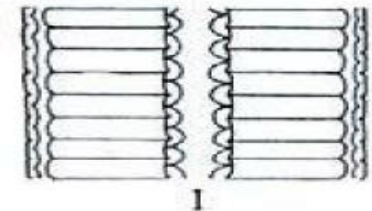
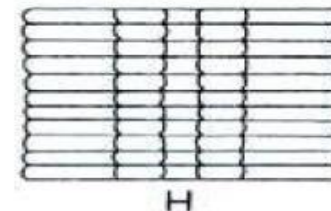
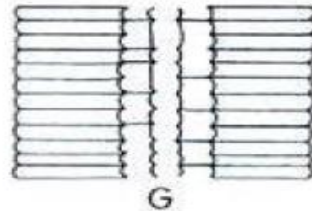
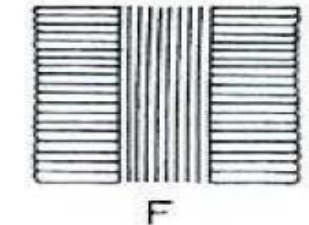
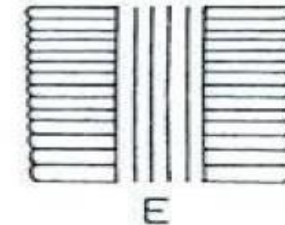
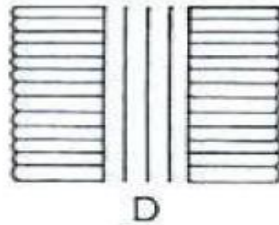
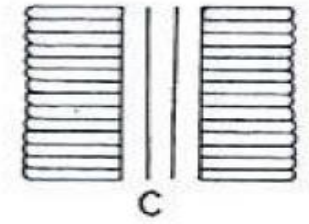
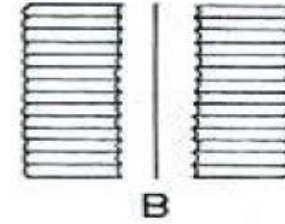
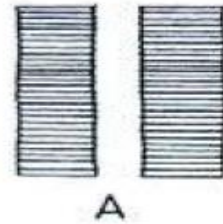
a) Lateral lines or Incisures

- These are lines running longitudinal to the body axis of nematode but they are confined to the lateral field in area just on top of **lateral hypodermal chords on either side of the nematode body running throughout the length.**
- The number of lateral lines or incisures is an important taxonomic character as it shows stability within the genus.



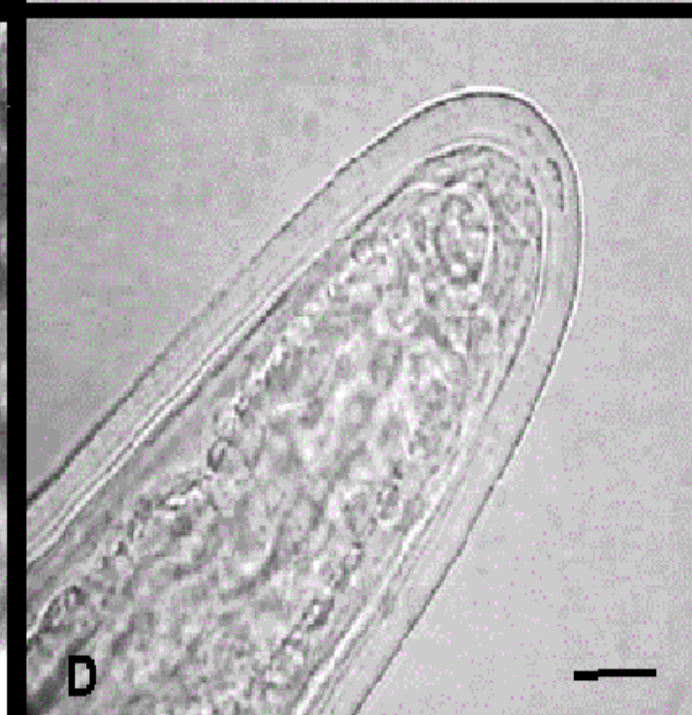
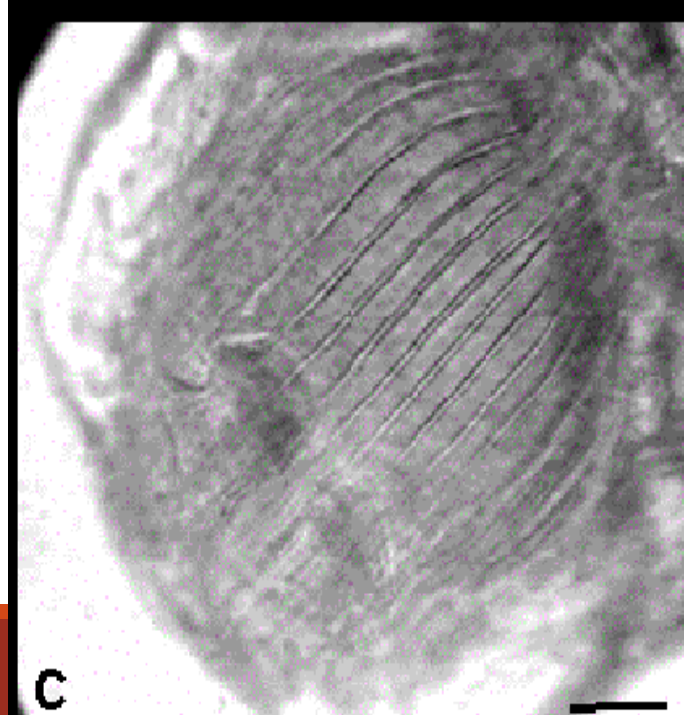
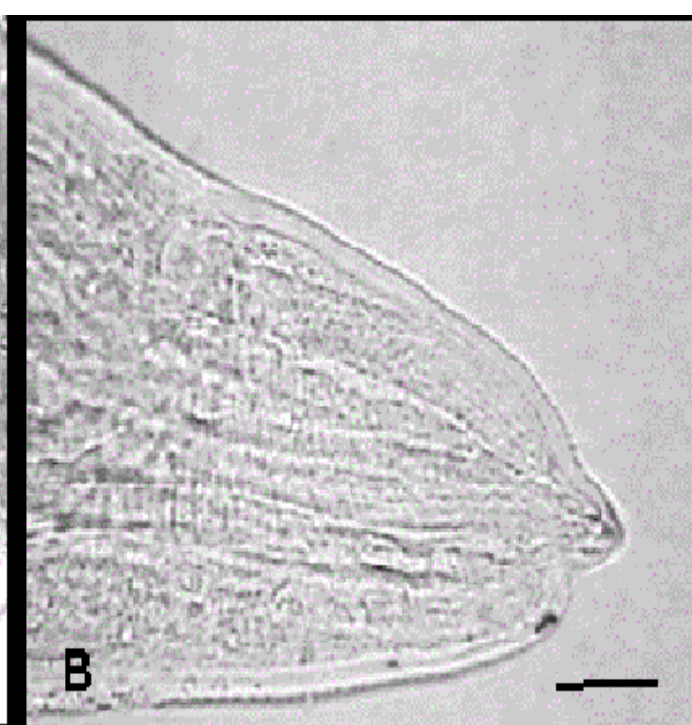
Variation in number of lateral lines

- **areolae** - areas of cuticle delineated by the intersection of longitudinal and transverse incisures



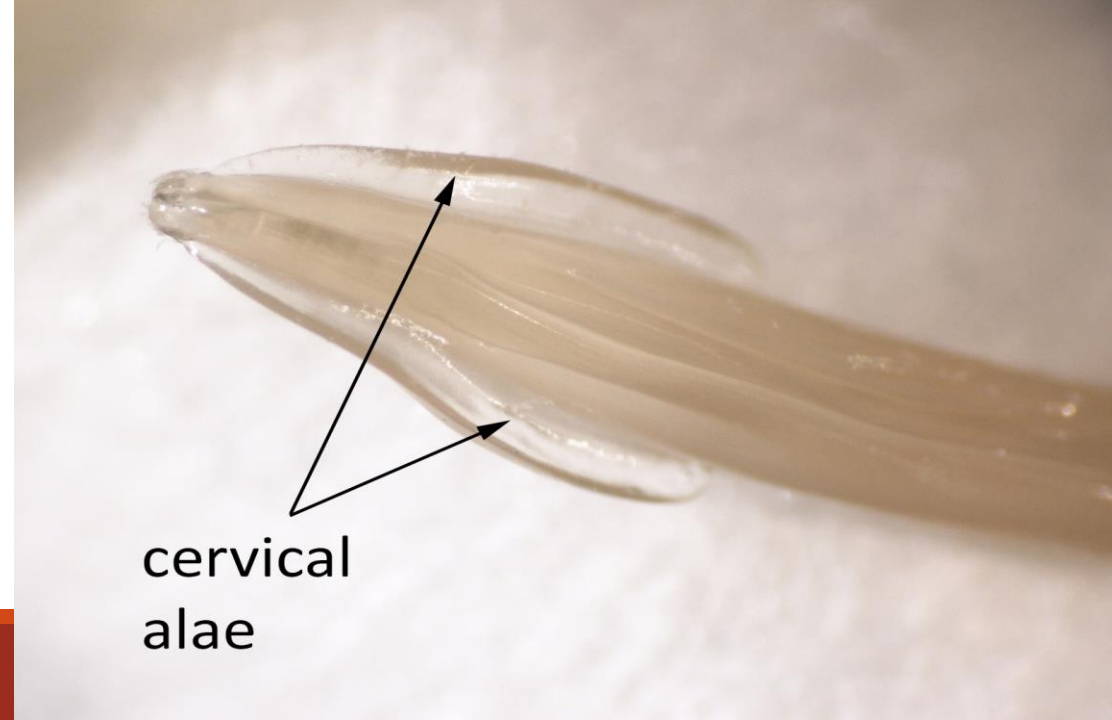
b) Longitudinal ridges

- Longitudinal ridges are raised lines present on cuticle running longitudinal to nematode body axis **but are confined in the area other than lateral field.**
- The number of these ridges is used by taxonomists for species identification.



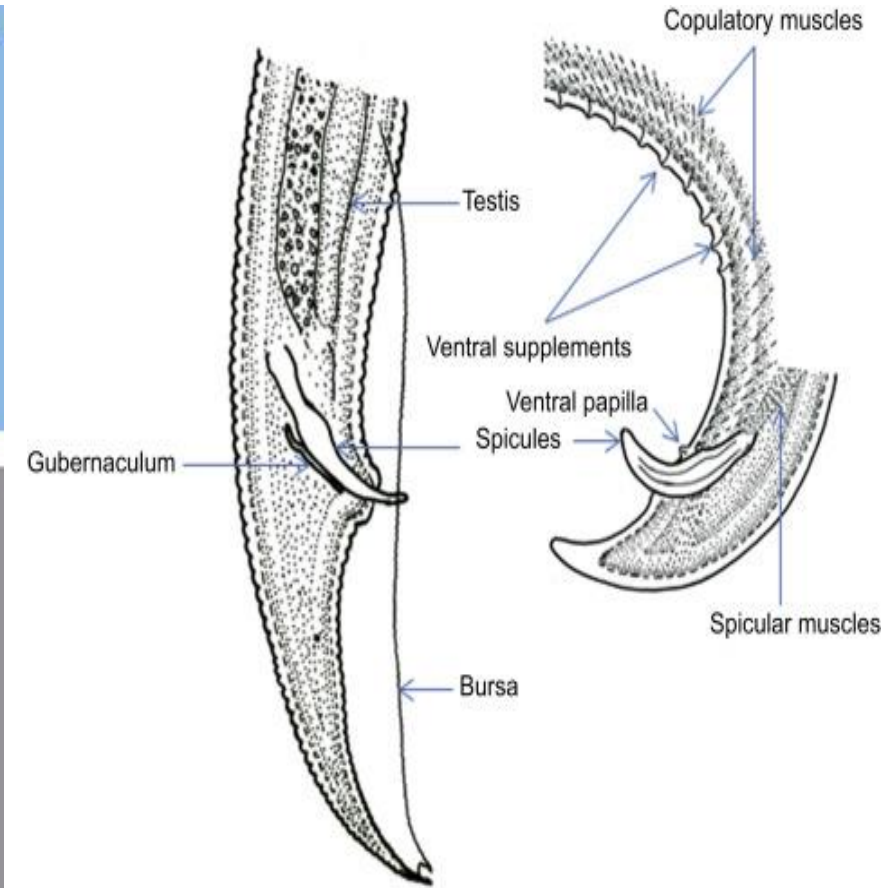
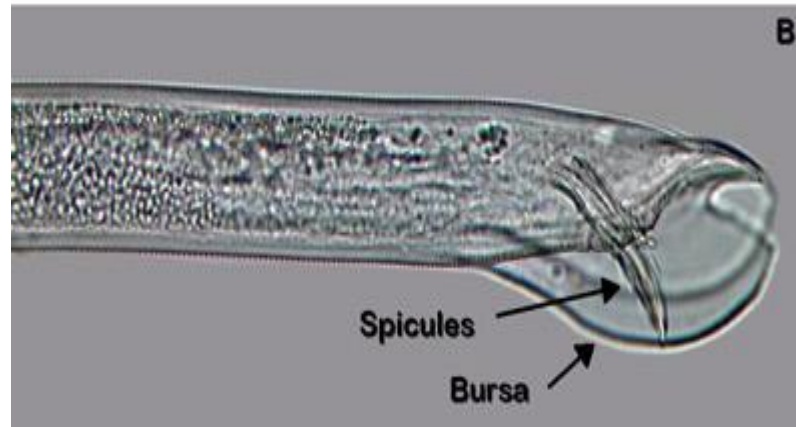
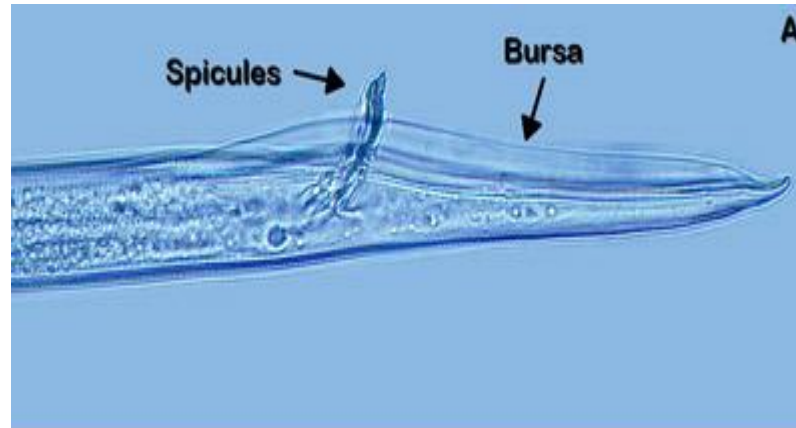
ALAE

- They are thickening or projections of the cuticle which occur in the lateral or sublateral region.
- There are 3 types of alae.
- **I. Caudal alae/ Bursa**
- **ii. Cervical alae and**
- **iii. Longitudinal alae.**



CUTICLE

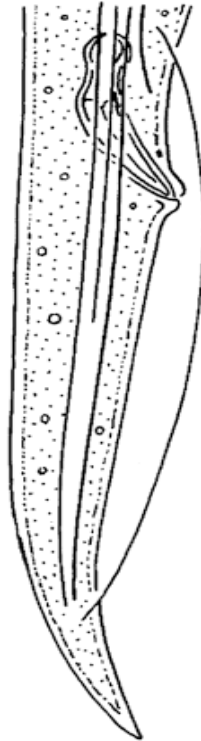
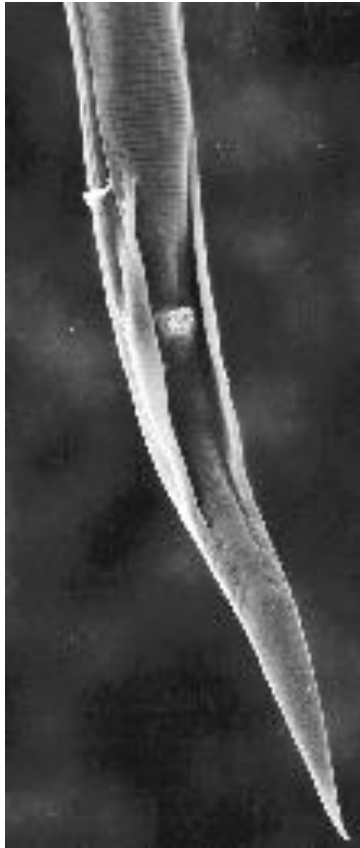
- In males of most of the plant nematodes, the cuticle extends laterally on both the sides in a wing-like manner in the tail region.
- These structures are called **caudal ale** or **bursa**, which may or may not cover the entire tail.



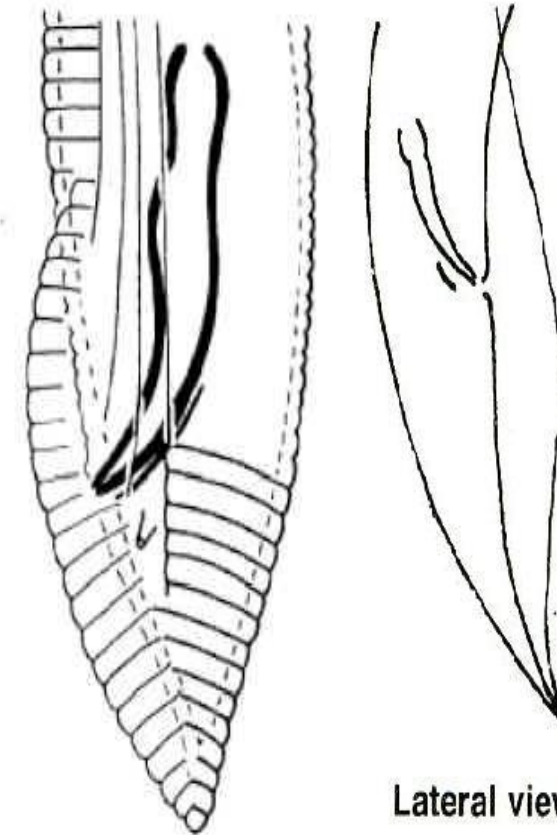
TYPES OF BURSA

Leptoderan (anterior to tail tip)

Hirschmanniella pomponiensis



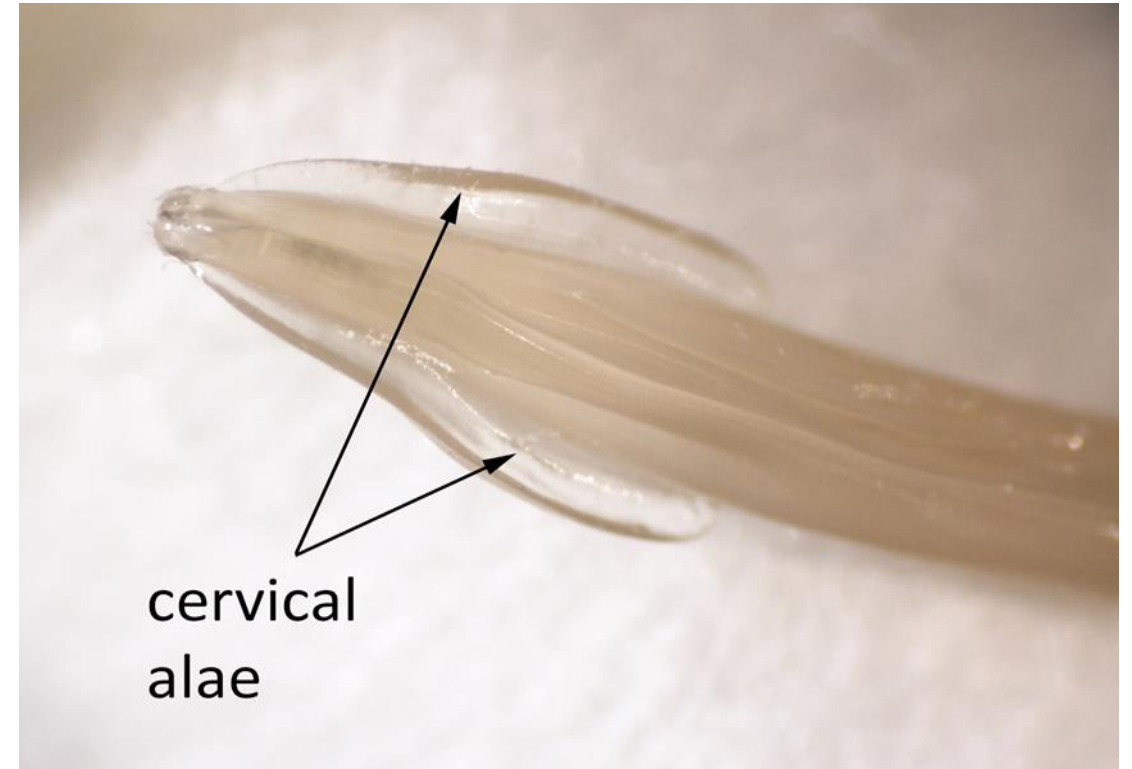
Peloderan (extending to tail tip)



Lateral view

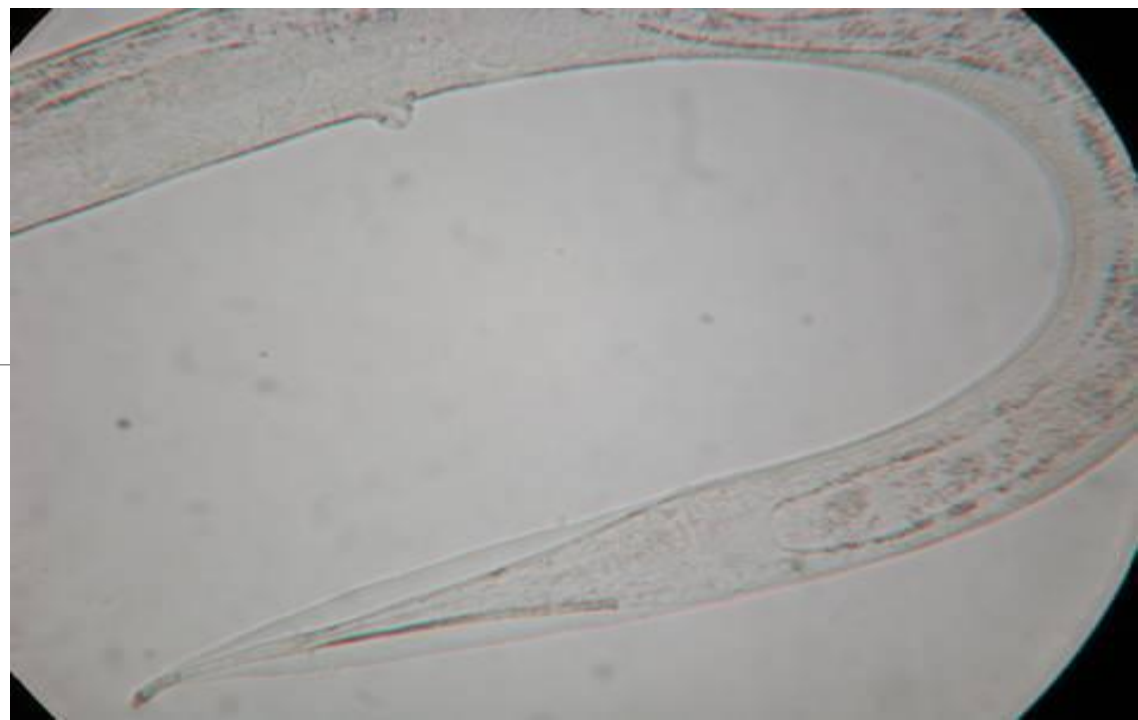
ii. Cervical alae

- **These are confined to the anterior part of the nematode body.**
- **Cervical alae are found in some species of marine nematodes.**
- **Present in strongilids, ascarids and spirulids**
- ***Eg. Toxcara***



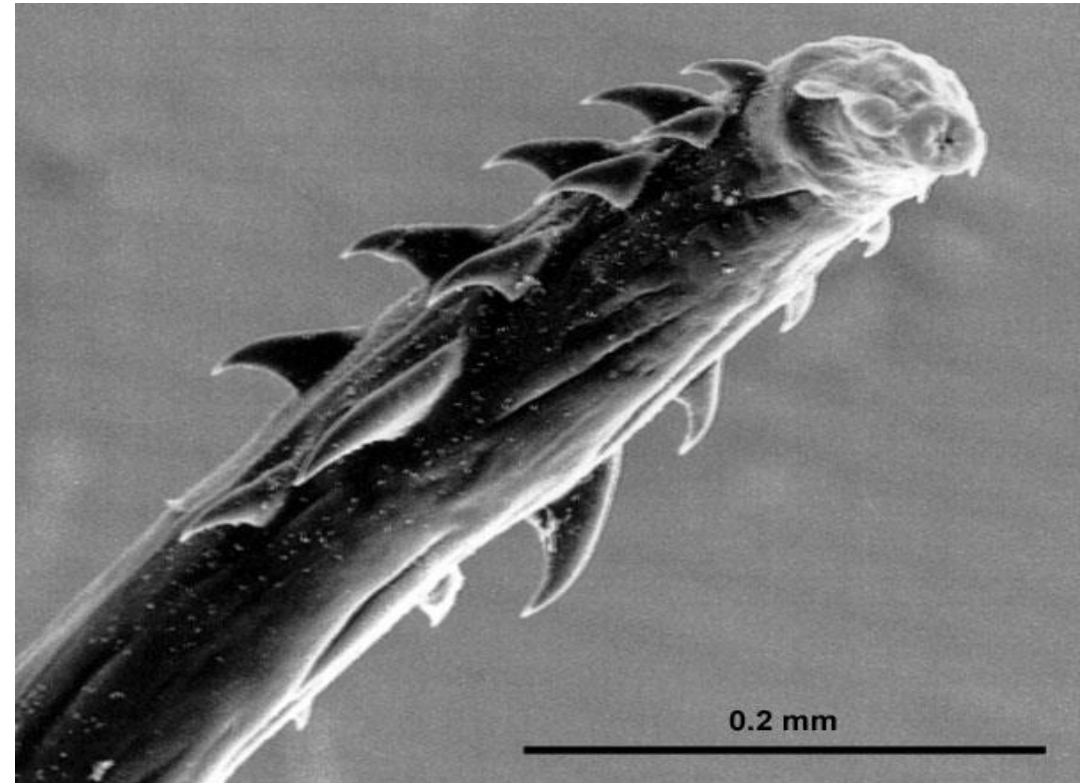
iii. Longitudinal alae

- **The longitudinal alae delimit the lateral fields and are known as lateral alae.**
- **Their form varies in different species.**
- **They are transversed by striations or furrows varying in number from 1 to 12.**
- **Functionally, they probably assist in locomotion and may permit slight changes in the width of nematodes.**
- **Eg: Tripyla**



Spines

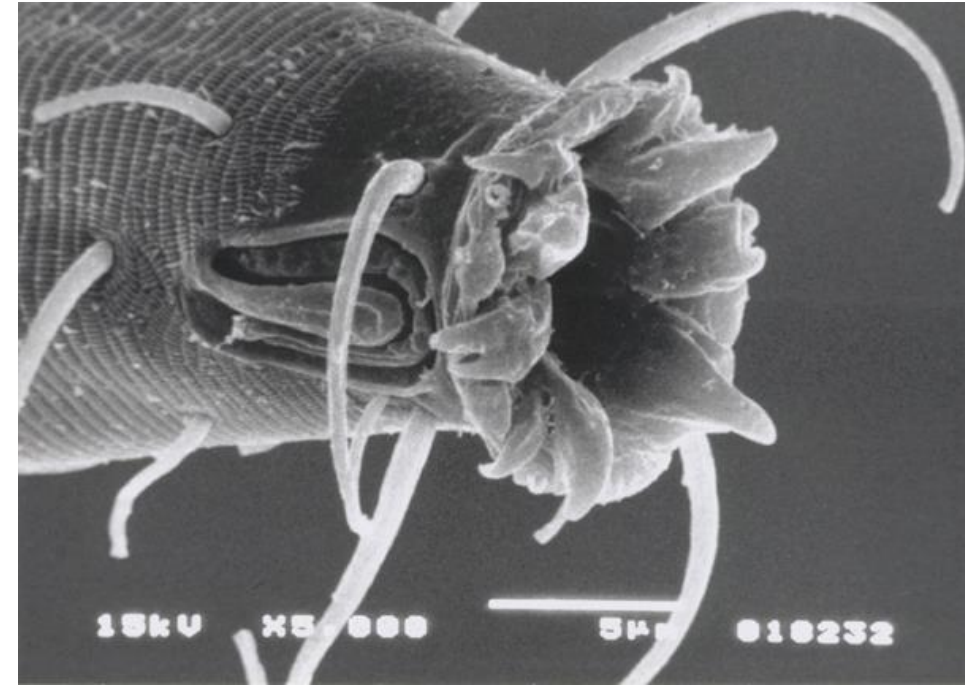
- Long, sharp, pointed cuticular extensions/protrusions without muscle or nervous connections (are usually not sensory).
- Spines are commonly seen in Secernentea, sometimes among Chromadoria and very rarely in Enoplia.
- Scales are similar to spine and distinguished by their bluntness.



Pneumonema tiliquae (Rhabdiasidae)

Setae

- Setae and their derivatives are tactile (touch) sensory structures (mechanoreceptor), generally **shorter than spines**.
- These sensilla are associated with three cells: the tormogen cell that forms the socket, the trichogen cell that forms the seta and a sensory neuron.
- Sometimes glands are associated with hollow setae and in some instances (*Draconema*) these hollow tubes are long and used in locomotion; these are called **ambulatory setae**

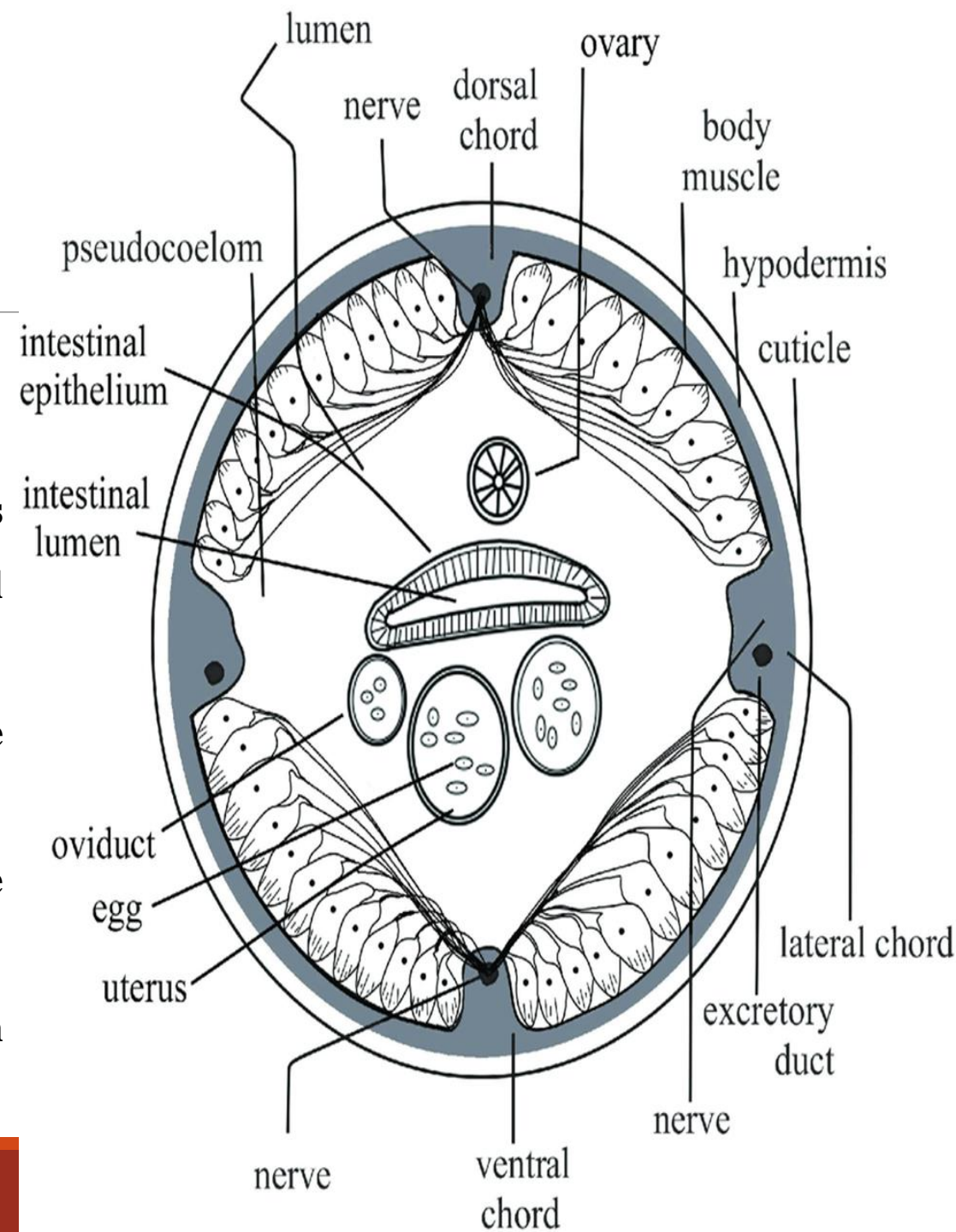


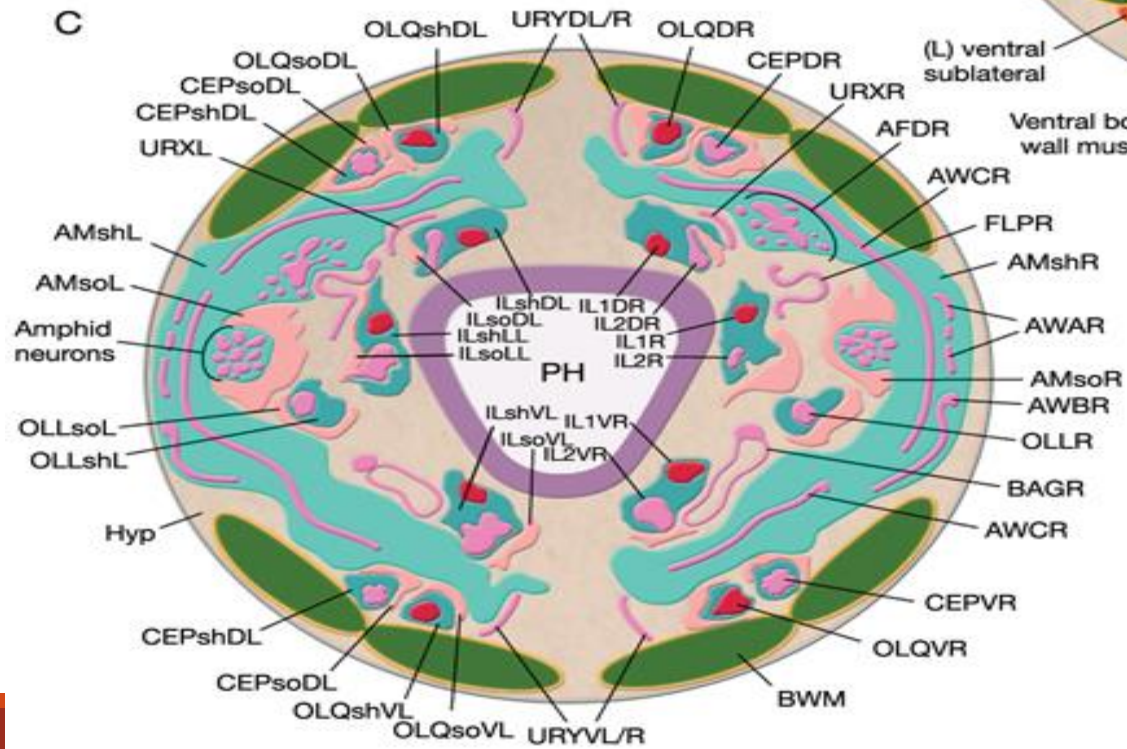
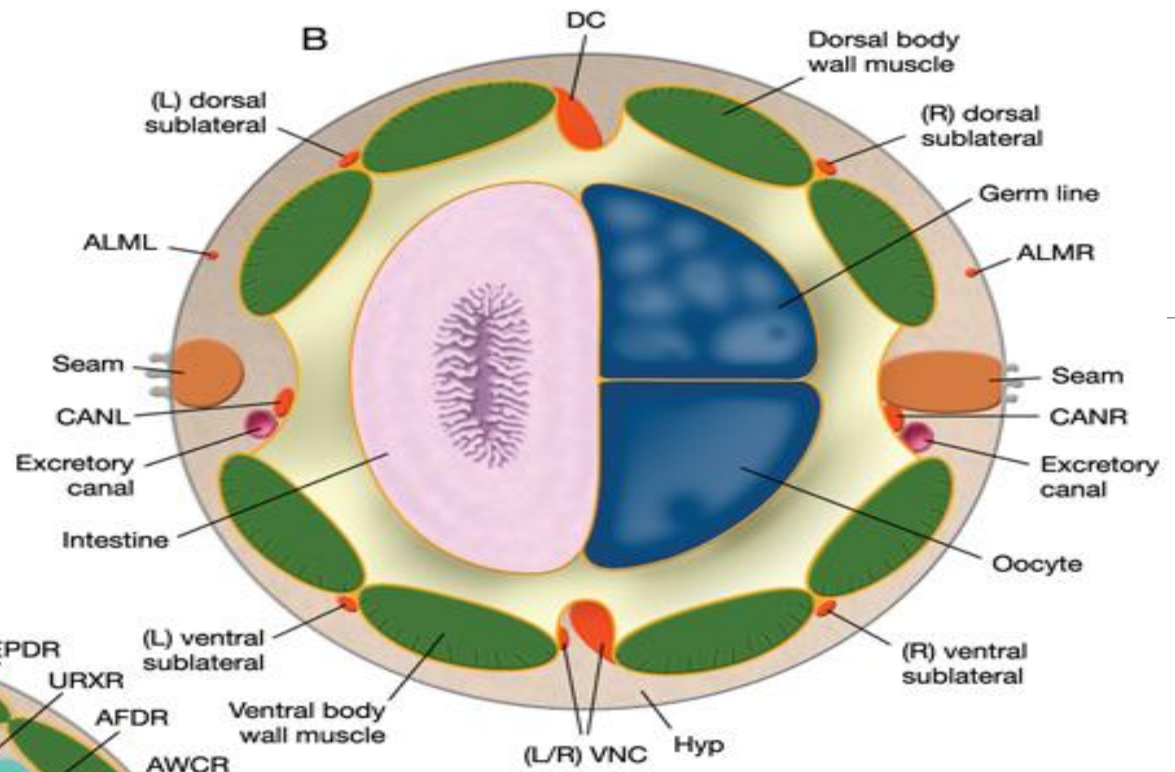
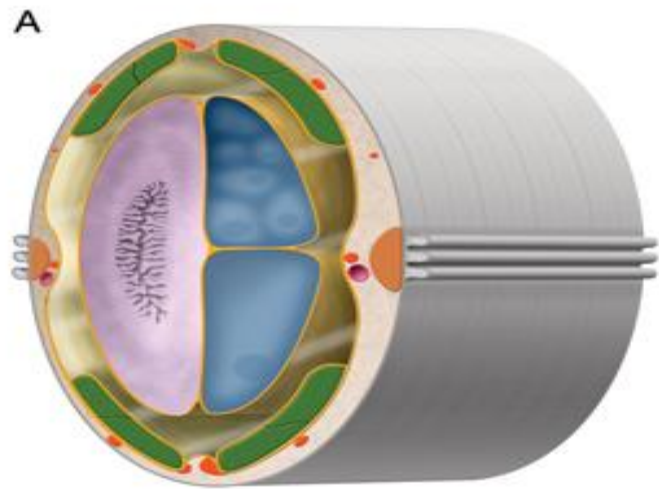
The functions of cuticle

- **Cuticle gives definite shape and size to the body, acts as an exoskeleton.**
- **Helps in movement.**
- **Being semipermeable, it regulates permeability**
- **Provides important taxonomic characters for identification of nematodes.**
- **There are four molts of the cuticle in most nematodes; there is an apparent reduction of one juvenile stage in some taxa.**
- **In Adenophorea all layers are molted, in Secernentea epicuticle is molted and exocuticle is dissolved.**

HYPODERMIS

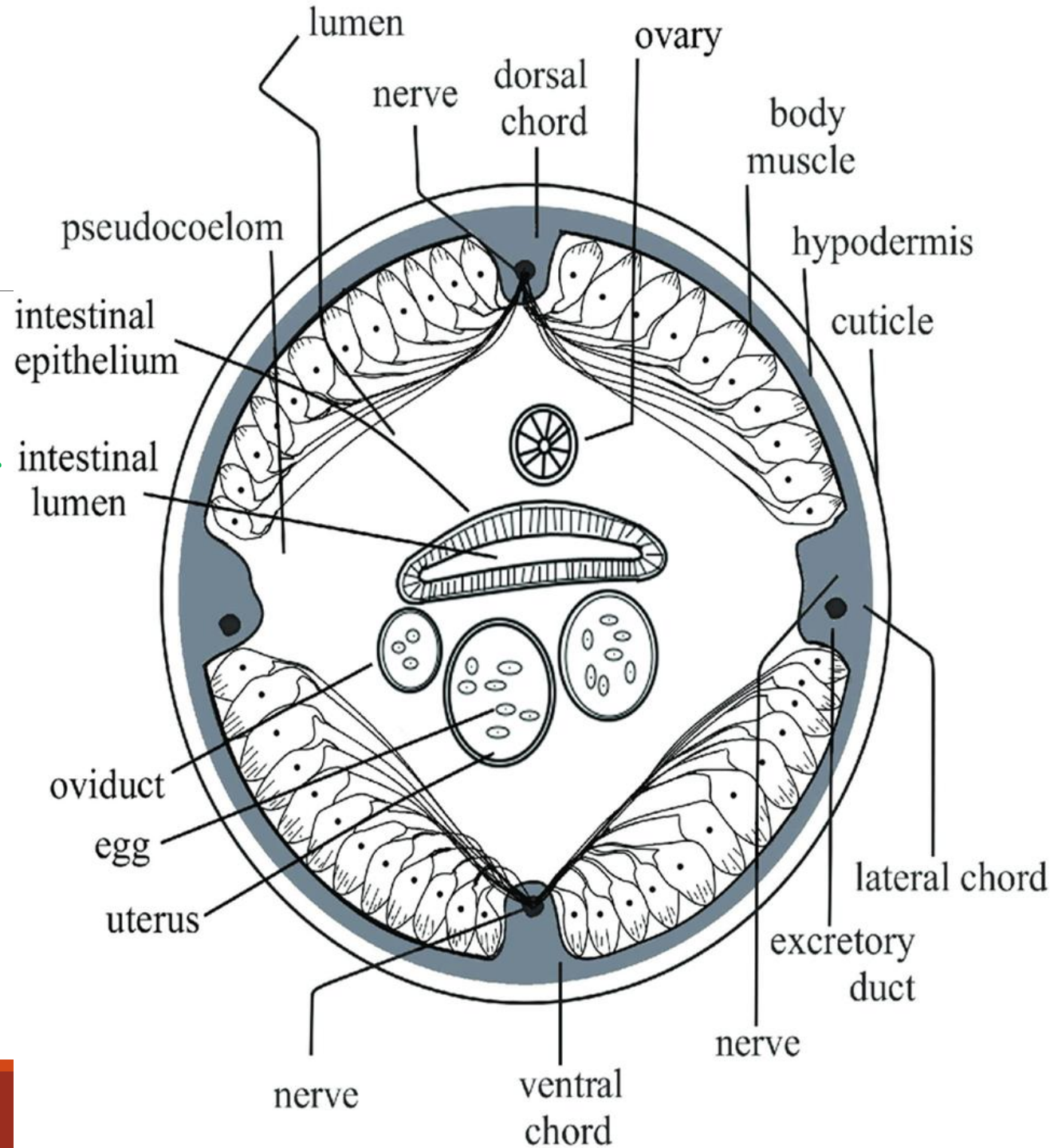
- **Underlying the cuticle is the hypodermal layer.**
- **It may be syncytial or made up of a single layer of cells.**
- **Although hypodermis is a continuous layer but it is generally thickened in the dorsal, ventral and lateral sides to form 4 hypodermal chords.**
- **The two lateral hypodermal chords are more conspicuous.**
- **The main nerve chords and excretory canals are generally located in the hypodermal chords.**
- **The major function of the hypodermis is the secretion of cuticle.**





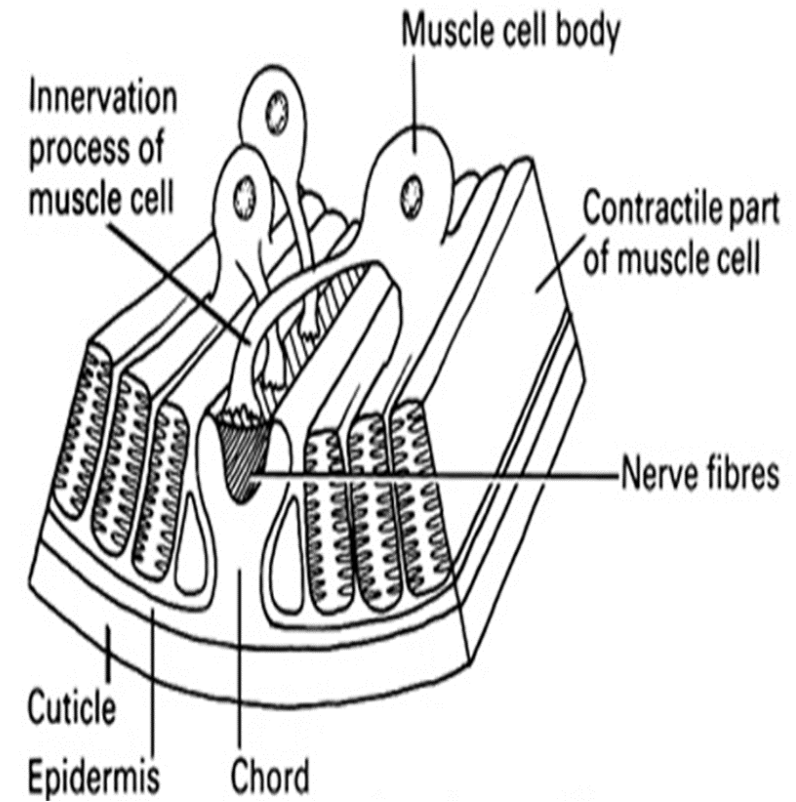
MUSCLE LAYER

- There are 2 types of muscles in the nematode body i.e., **somatic and specialized muscles**.
- **Somatic muscles constitute a single layer of spindle-shaped cells attached to the hypodermis in the 4 inter-chordal zones**
- These are responsible for the nematode locomotion, besides acting as the major reservoir of the stored food material.
- The specialized muscles are attached to specific organs (stylet, spicules etc.) and govern the movement of those organs only.



MUSCLE LAYER

- A muscle cell has 2 distinct zones: the **contractile portion (fibrillar zone)** which contains the **myofibrils**, and the **non-contractile portion (sarcoplasmic zone)** which contains **nucleus and cell cytoplasm**.
- Nematode muscles are unique in that **cytoplasmic extensions (innervation processes)**, from **non-contractile portion of muscle cells** join the **nerve chord**.
- The **innervation processes from dorsal half join the dorsal nerve chord**, and those from **ventral half join the ventral nerve chord**.
- The **muscle cells of dorsal half work in unison**, as the **muscles of ventral half**, thus regulating the **bending of nematode body in a dorso-ventral plane while moving**.

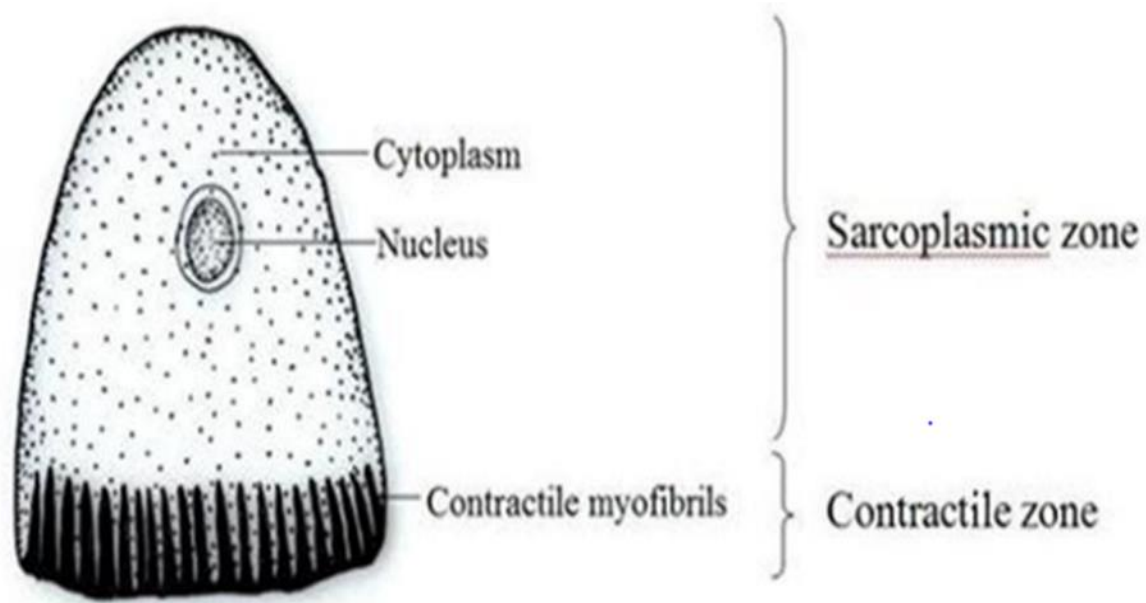


MUSCLE LAYER

- Based on the shape of cells and arrangement of contractile elements (**myofibrils**), the muscle cells are classified into 3 types, i.e.
- **Platymyarian:** contractile elements restricted to wide base of cell touching the hypodermis.
- **Coelomyarian:** contractile elements extending up the sides of the cells which have a narrow base.
- **Circomyarian:** contractile elements present on whole of the cell circumference, enclosing the sarcoplasm in between.

- When only **2-5** muscle cells are present in each inter-chordal zone, the arrangement is known as **Meromyarian**.
- If they are more than 5, it is called **Polymyarian**.
- Usually **Platymyarian cells are Meromyarian** and **Coelomyarian cells are Polymyarian**

MUSCLE LAYER



Platymyarian muscle



Coelomyarian muscle

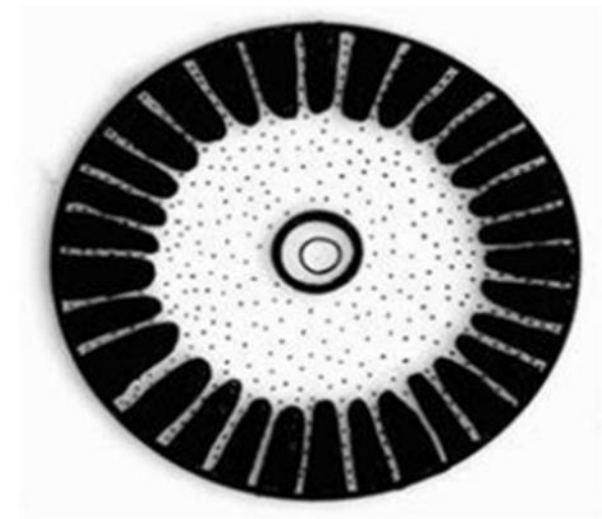
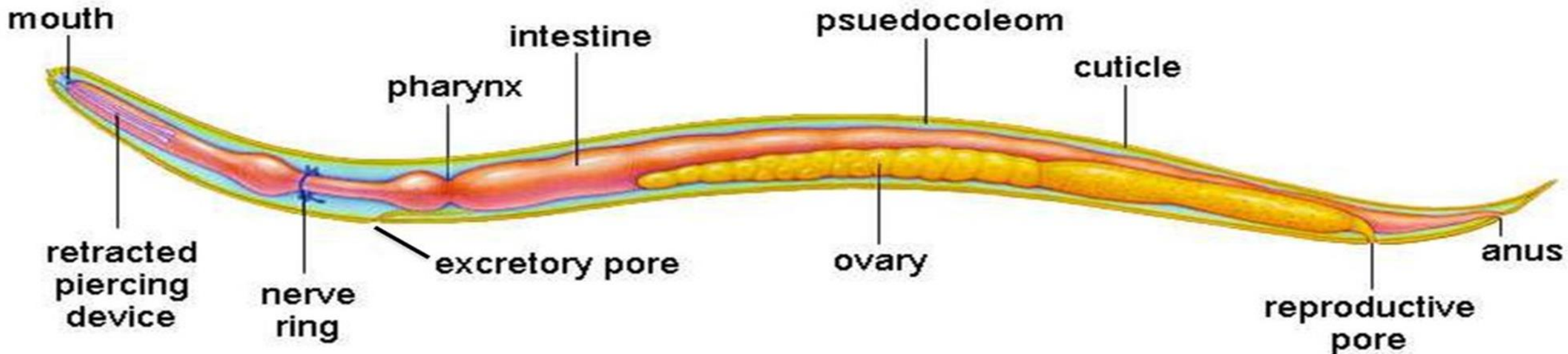
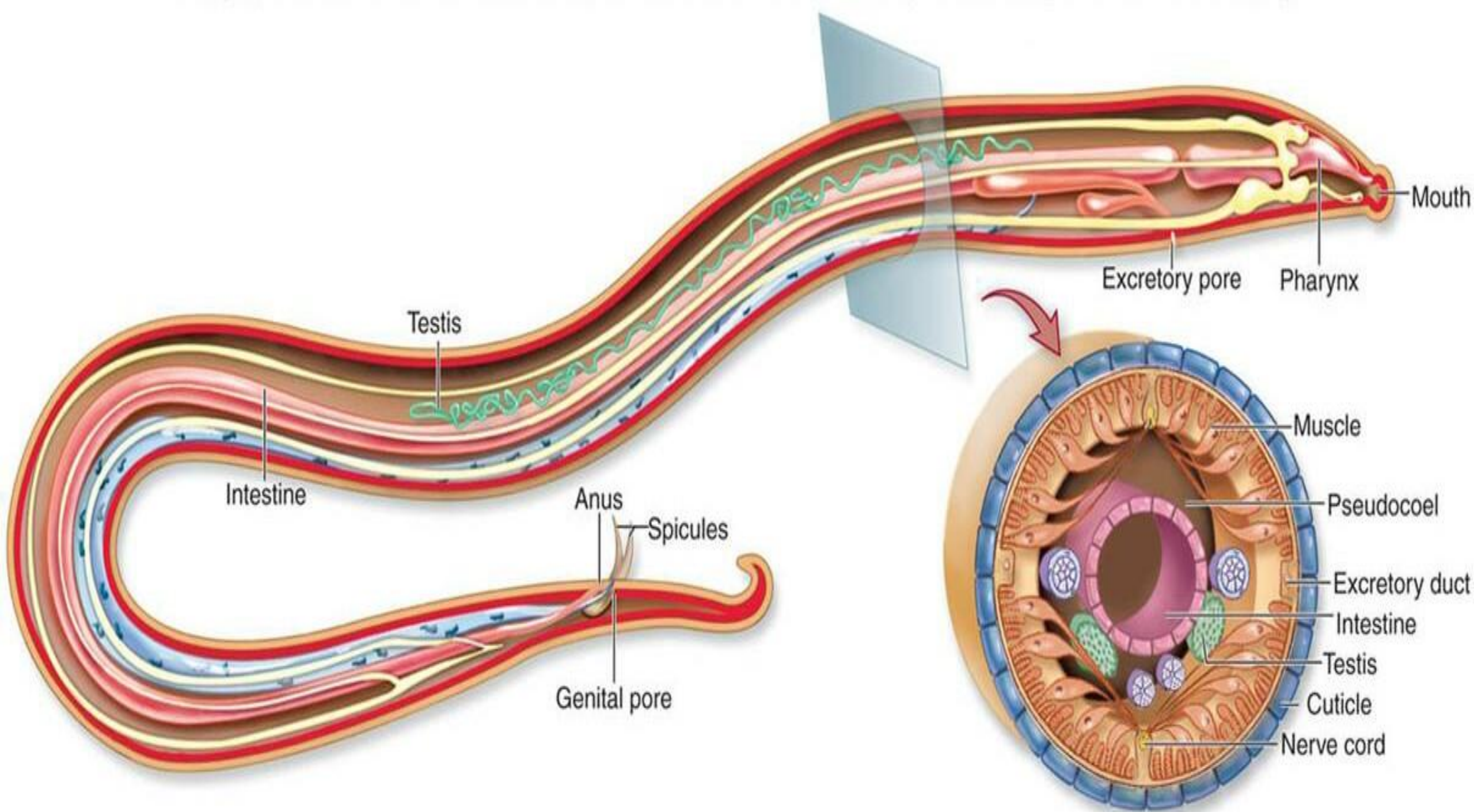


Figure 5.2 Types of muscles in nematodes

THE INNER BODY TUBE (ALIMENTARY CANAL)

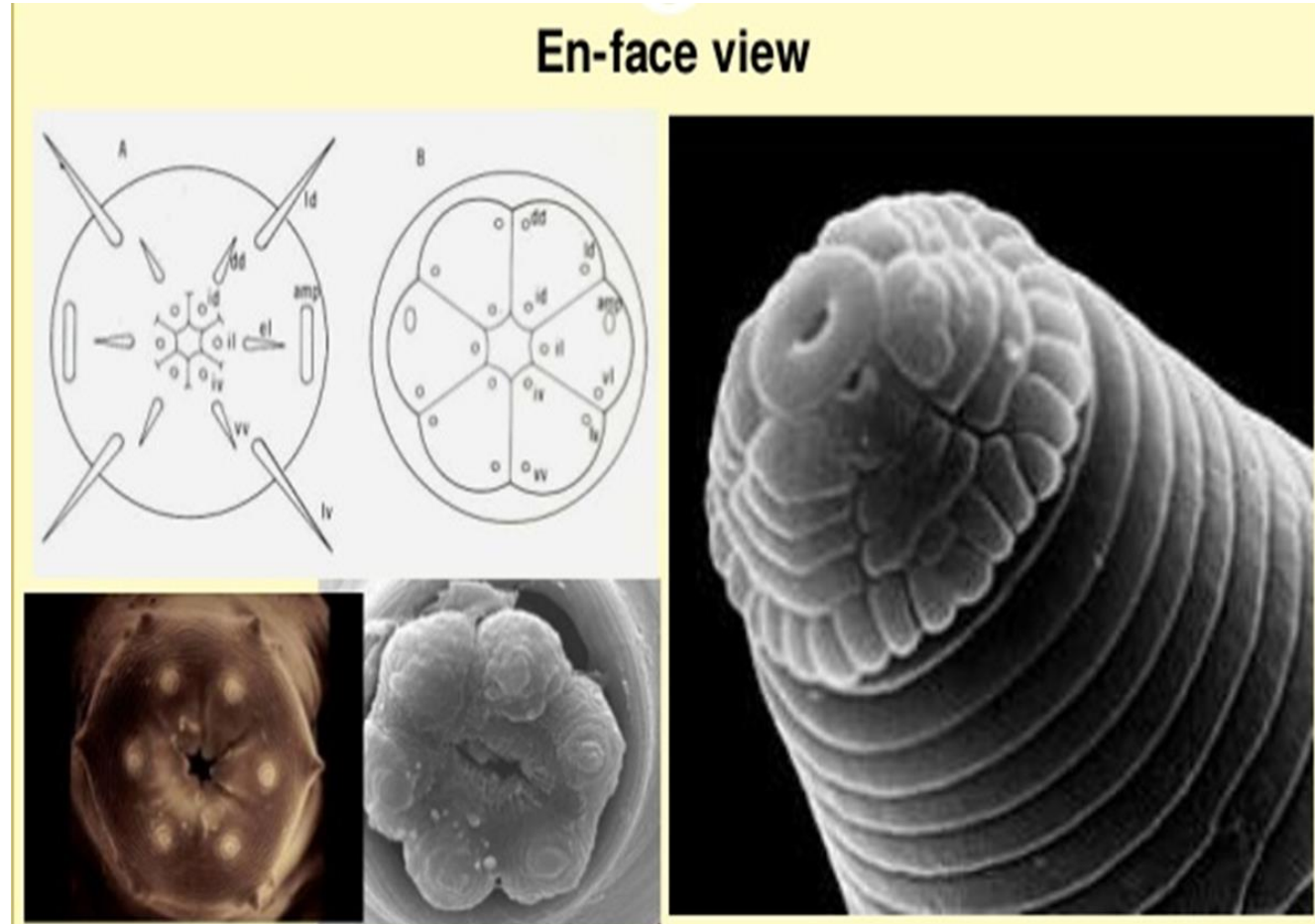
- The inner body tube forms the alimentary canal or the gut, and it can be distinguished into 3 zones
- **Stomodaeum (fore gut):** constitute stoma, oesophagus, cardia
- **Mesenteron (mid-gut):** constitute intestine
- **Proctodaeum (hind-gut):** constitute rectum and anal opening
- Stomodaeum and proctodaeum are lined with cuticle internally.





Stomodaeum

- It starts at the **oral aperture** or the mouth which is located terminally.
- The oral aperture is basically surrounded by **6 lips** (2 sub-dorsal, 2 sub-ventral and 2 lateral in position).
- **Reduced to 3 in Ascarids, 2 in spirurida.**
- The oral aperture leads internally into a cavity known as **stoma or buccal cavity**.
- The walls of the stoma are modified differently in nematodes with different feeding habits.



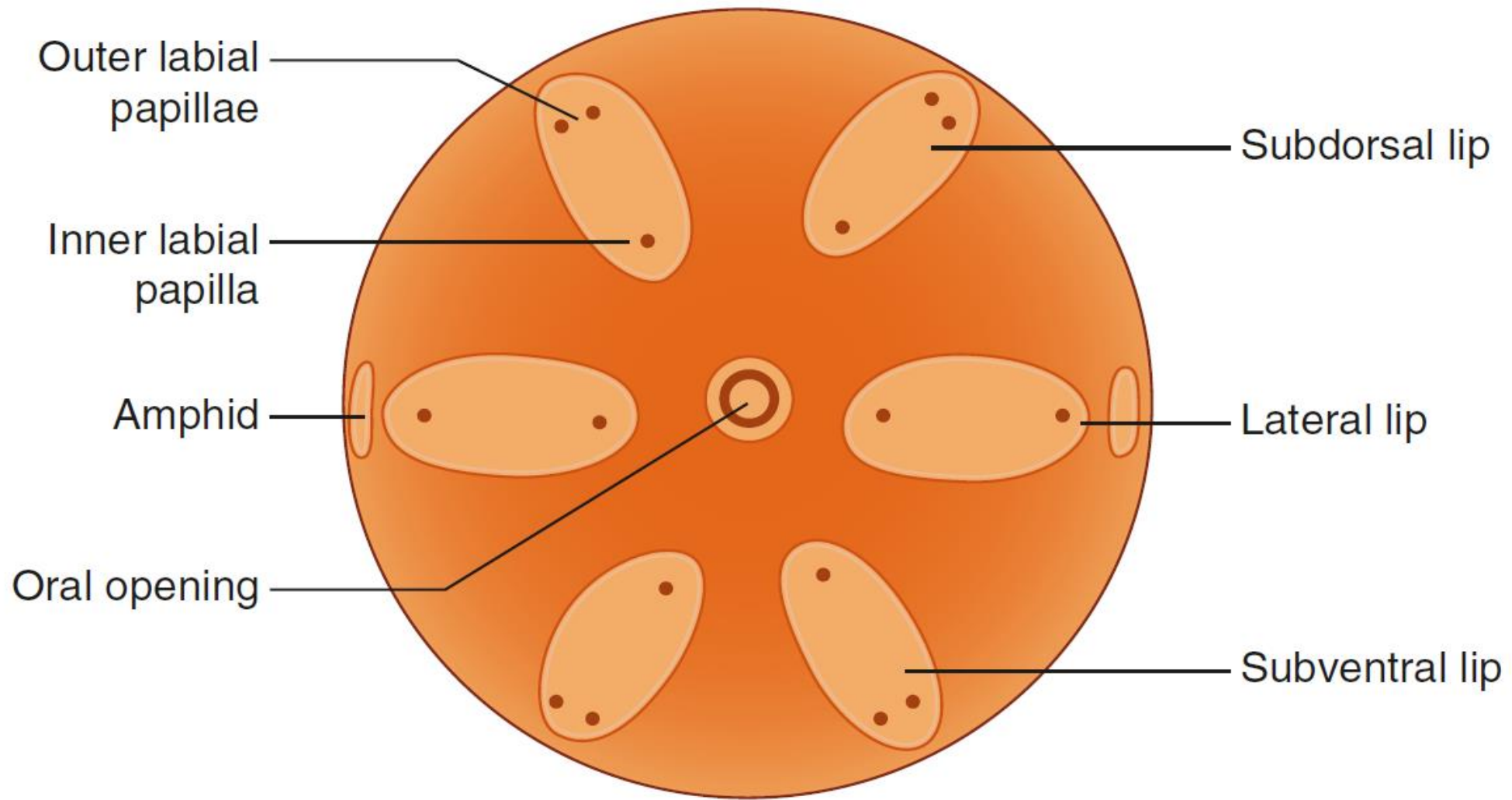
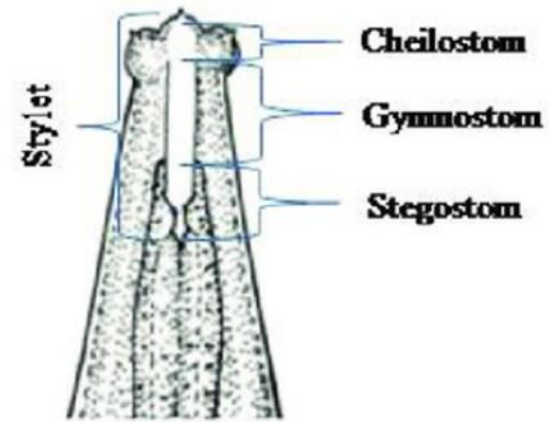


Fig. 3.9 *En face* view of a nematode lip region that usually consists of six sectors, or lips, of which two each are situated subdorsally, laterally and subventrally (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

Stomodaeum

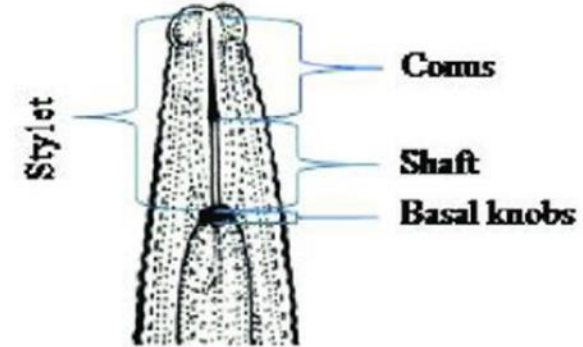
- Bacterial and fungal feeders have tubular or funnel-shaped or barrel-shaped stoma whereas plant-parasitic tylenchids and aphelenchids have a protractible, hypodermic needle-like stylet/spear.
- The predators, on the other hand, have wide and spacious stoma which may or may not be provided with tooth, teeth or denticles.
- In case of mononchids, it is simply called buccal/stomal cavity. The buccal cavity in mononchids is generally provided with dorsal tooth, a pair of subventral teeth, denticles,



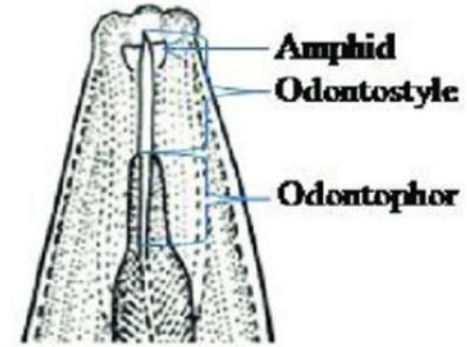
A



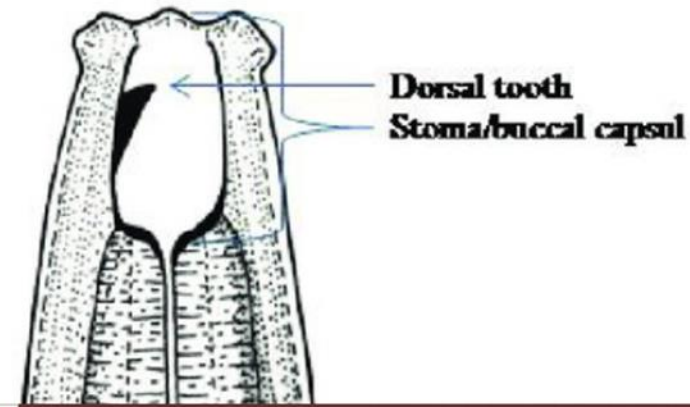
B

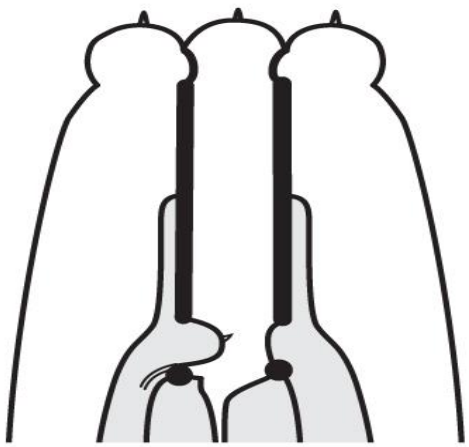


C



D

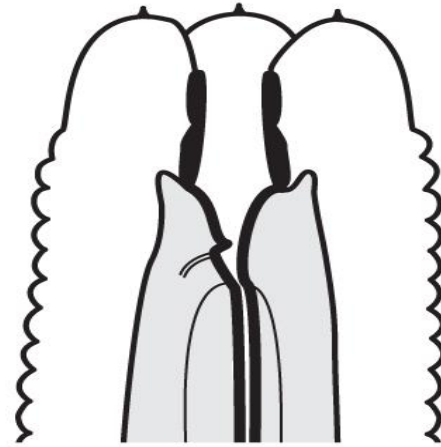




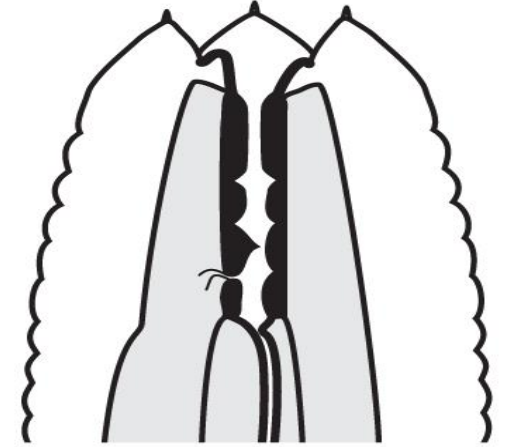
rhabditids



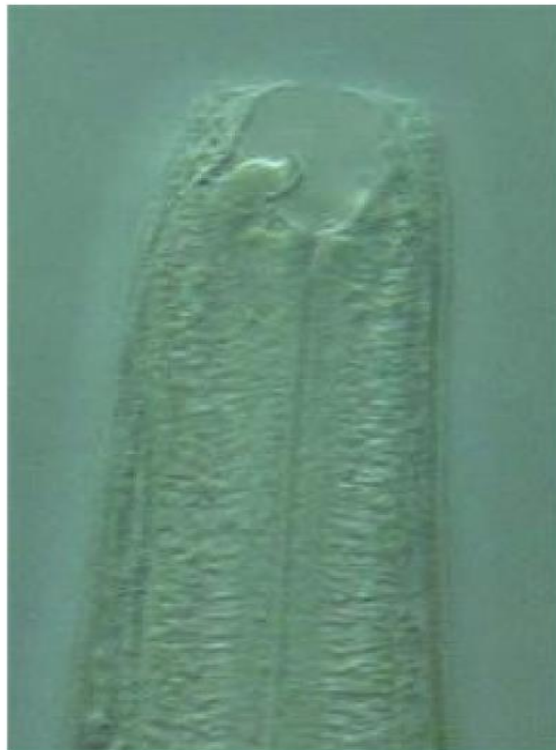
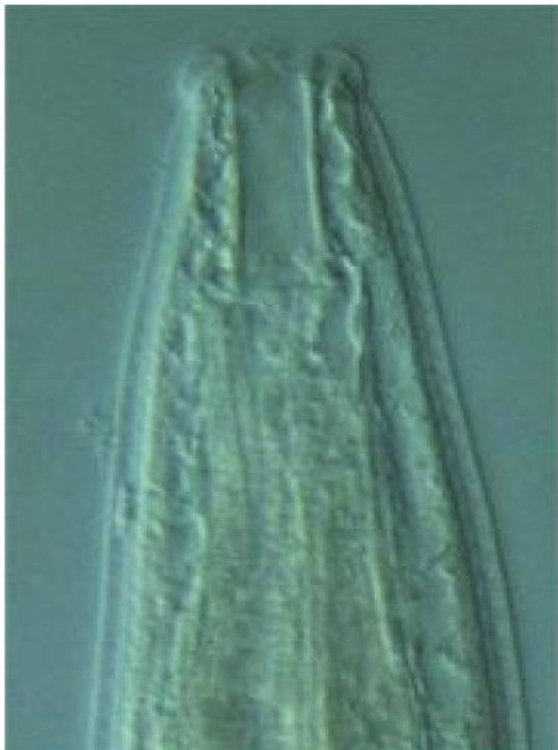
diplogastrids



panagrolaimids



cephalobs



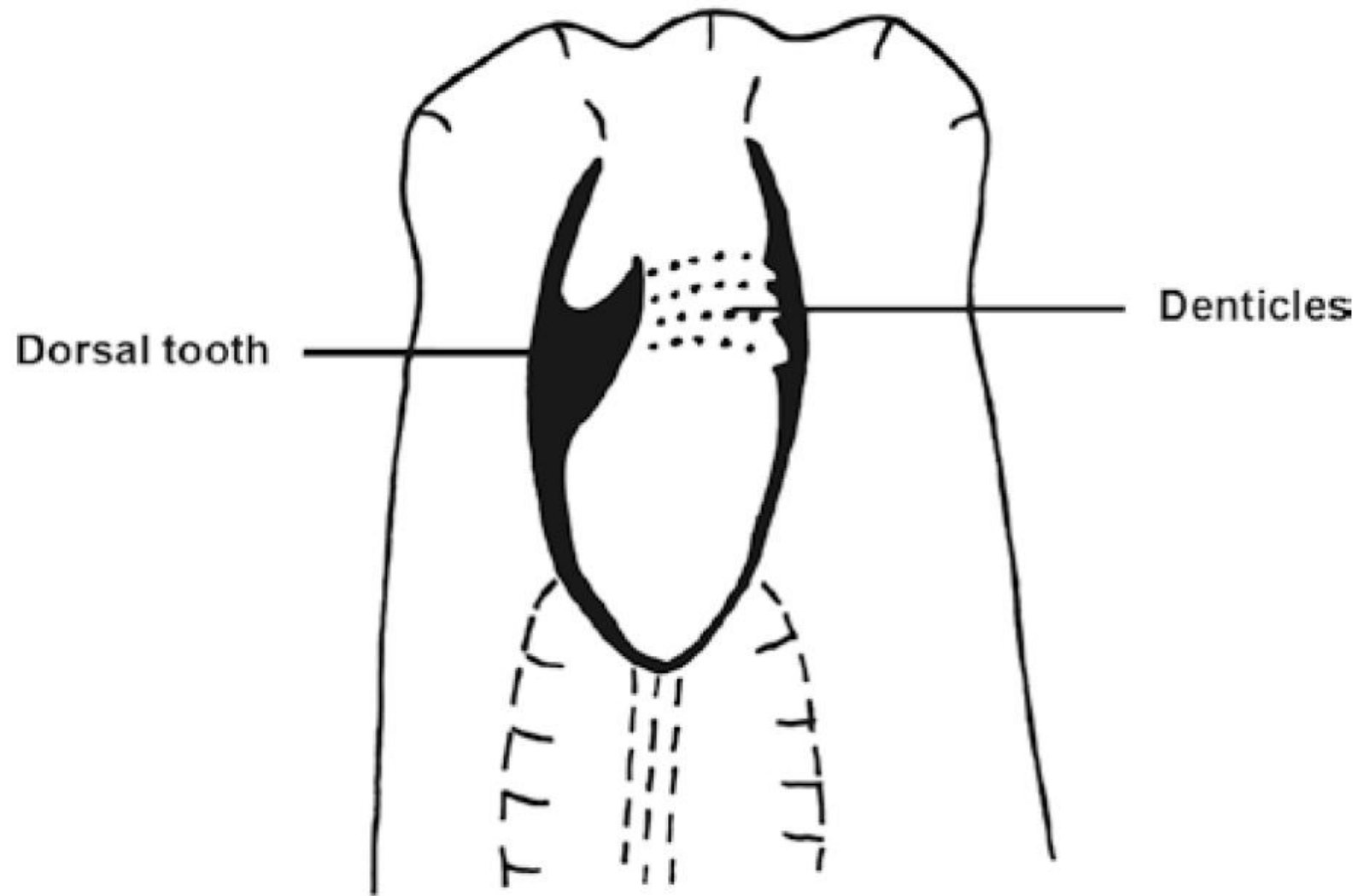
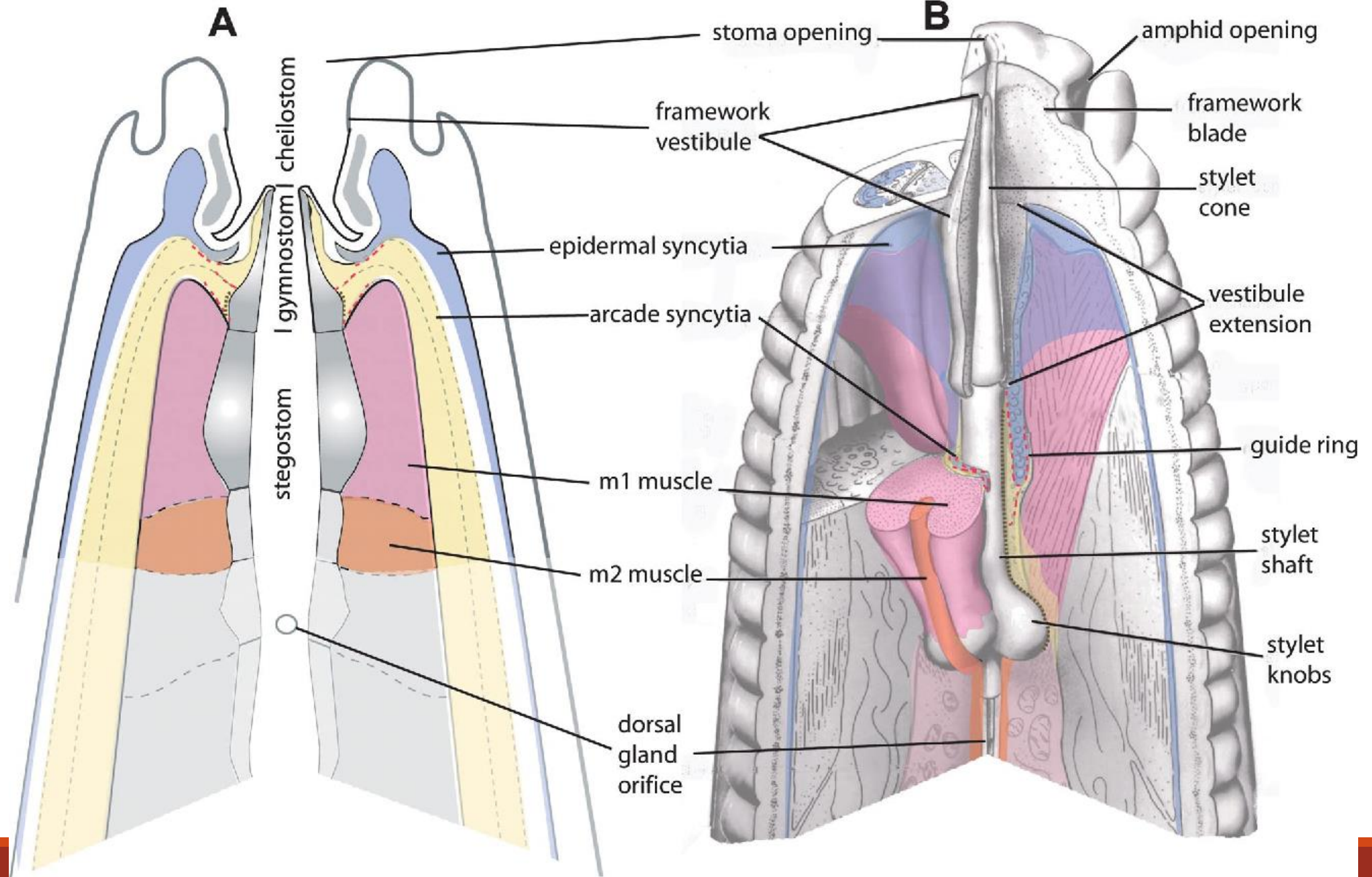


Fig. 3.12 Stoma of a predacious nematode (*Mylonchulus* sp.) illustrating the dorsally situated mural tooth with denticles in the wall of the stoma (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

Stomodaeum

- **Among plant parasitic nematodes**, the stomal walls fuse together and form a hypodermic needle-like structure called stylet or **stomatostylet** or **spear** having a **fine lumen (less than 1 um)**.
- **The stomatostylet consists of 3 parts-** **the anterior conus, the middle shaft, and 3 posterior stylet knobs (1 dorsal and 2 sub-ventral in direction)**.
- **The stylet is a protrusible organ and when pushed inside the plant cell, helps in ingestion of cell cytoplasm through the lumen.**
- **The movement of the stylet is regulated by stylet protractor muscles and is guided by a hardened basket like structure located in head region known as cephalic sclerotization.**





Stomodaeum

- In Adenophorea, the stylet is thought to be derived from a tooth and, therefore, it is called as **odontostylet**.
- The flanges that serve as points of attachment for the stylet protractor muscles.

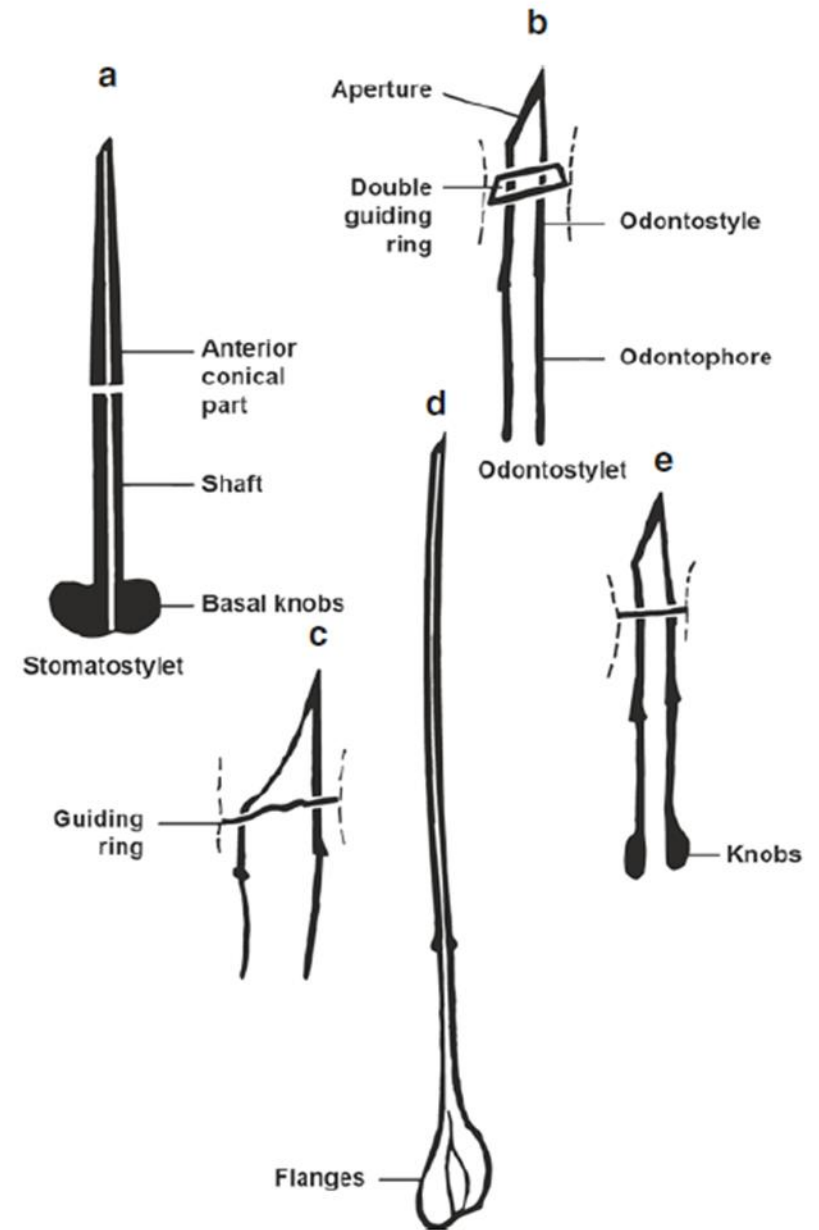
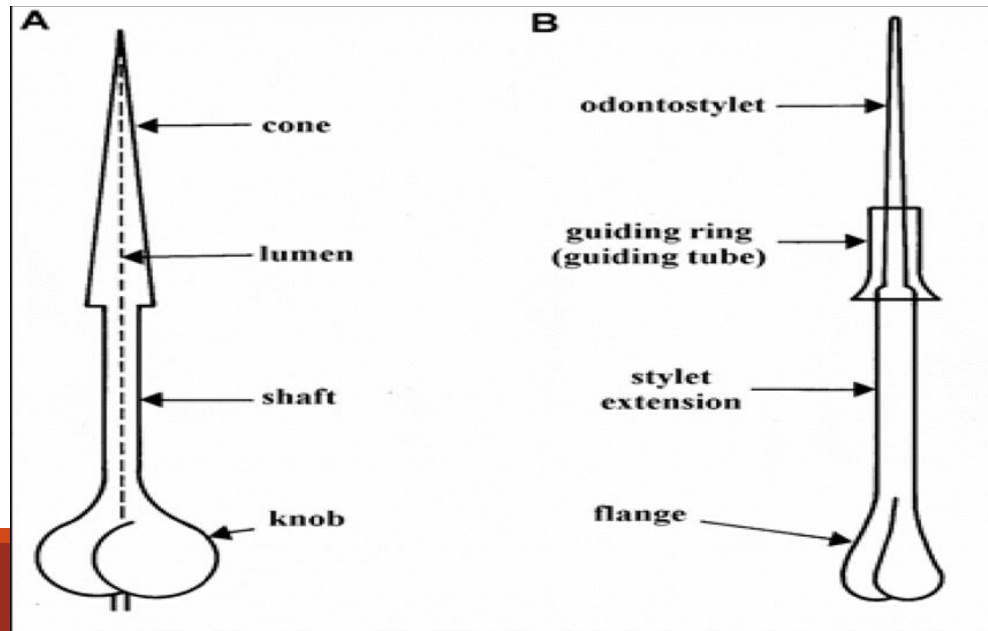
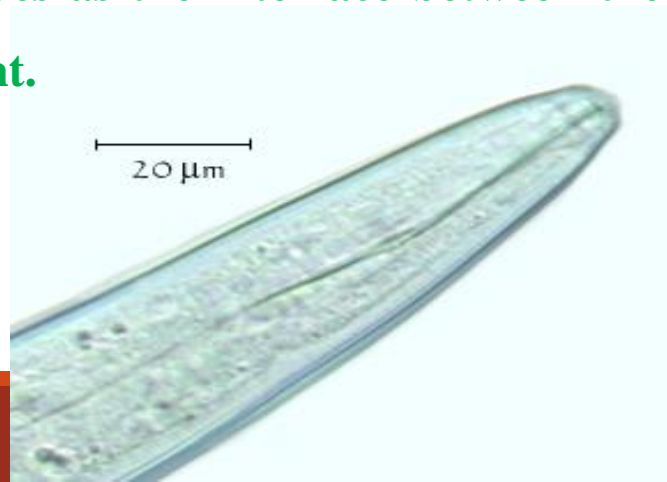


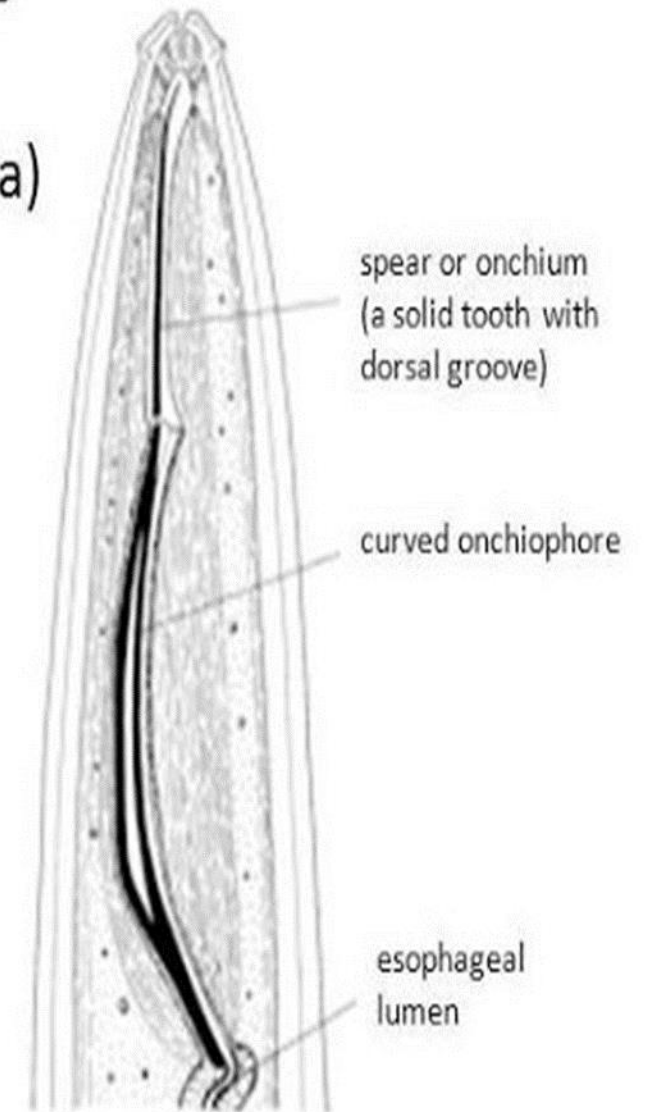
Fig. 3.11 Typical appearance of a stomatostylet in the Tylenchida (a) and an odontostylet in the Dorylamida as well as some free-living nematodes (b-e) (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council-Plant Protection Research, Pretoria, South Africa)

Stomodaeum

- In some plant parasitic nematodes like *Trichodorus* and *Paratrichodorus* the odontostylet is distinctly curved ventrally, lacks flanges and it is not hallow.
- In functions to pierce the cell wall of the root. The nematode secrets a hallow tube out of its stoma that connect it with the plant.
- This feeding tube serves as the interface between the nematode and the plant.

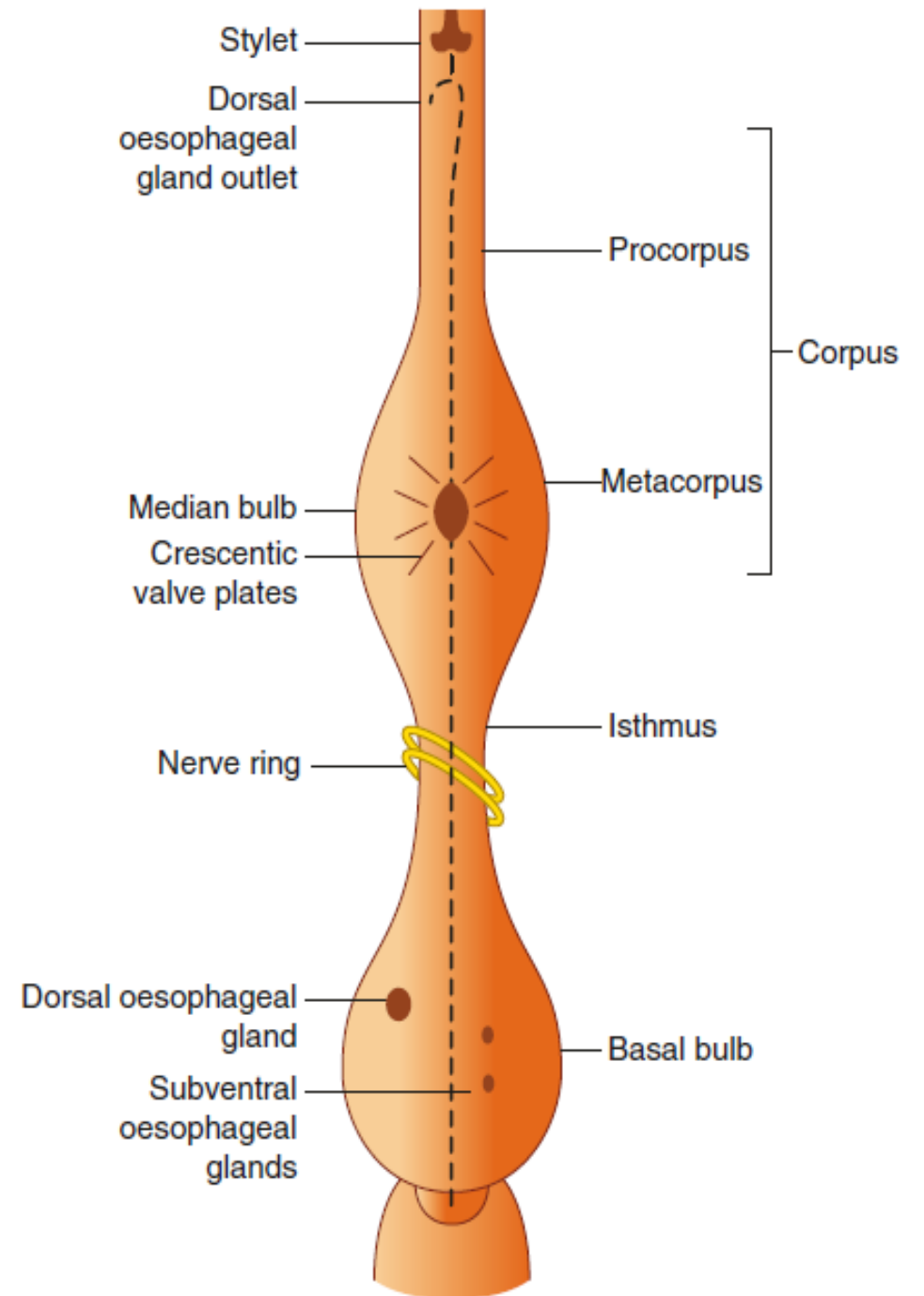


Onchiostyle
(Order
Triplonchida)



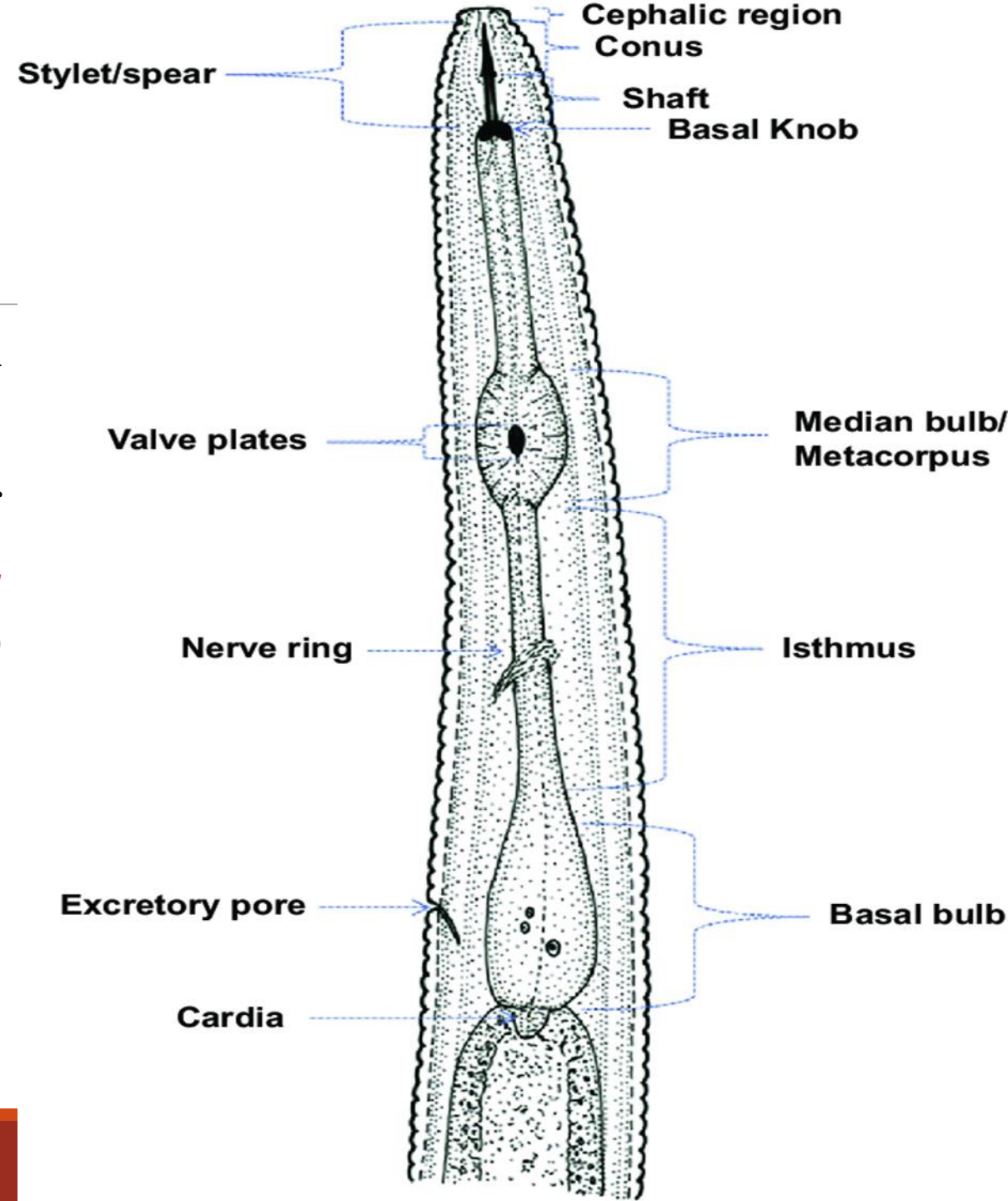
Stomodaeum

- The lumen of the stylet is continuous with that of the **oesophagus** or pharynx.
- **Oesophagus** is basically a pumping organ which sucks in and pushes the ingested food material into the intestine.



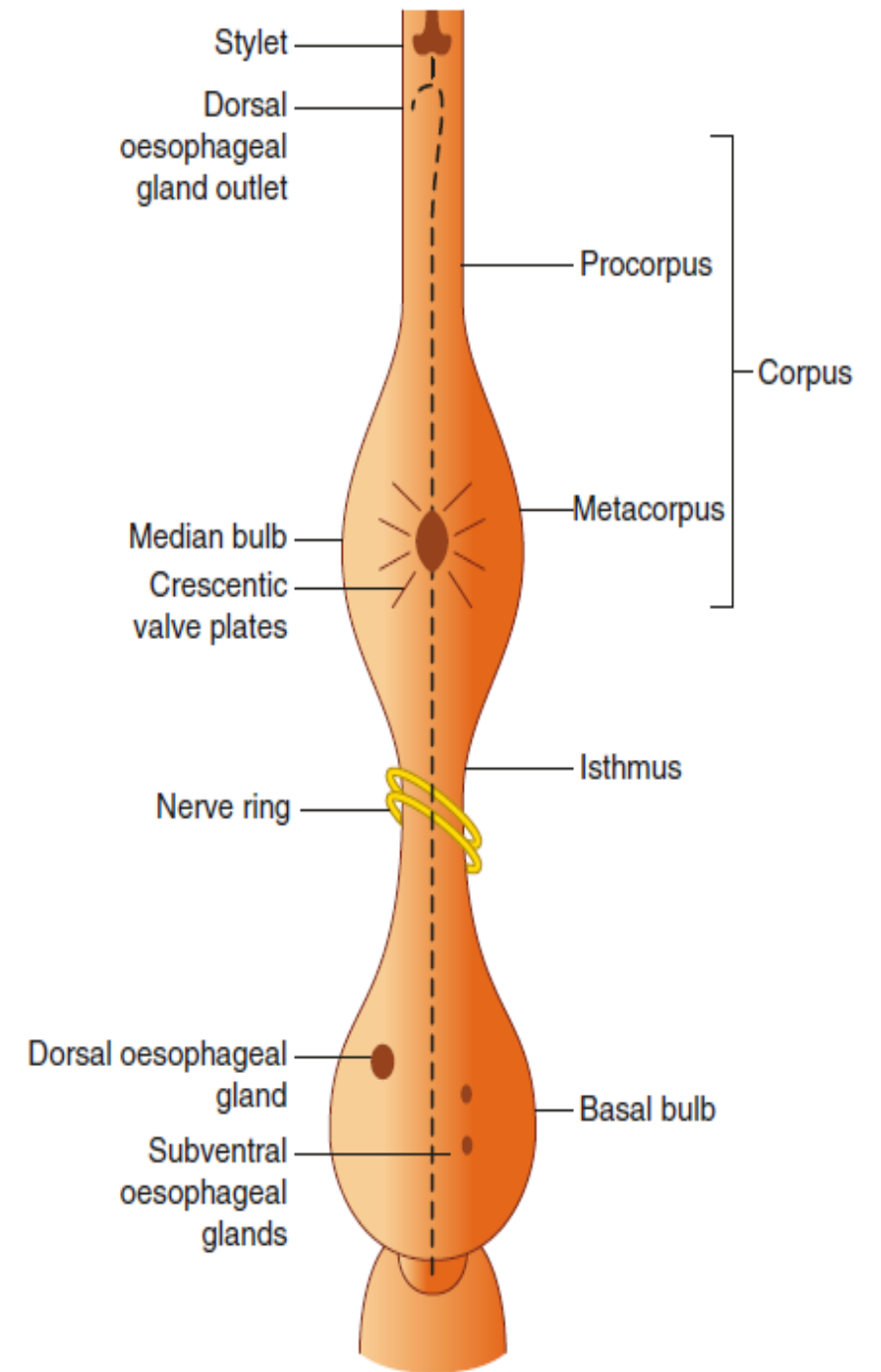
Stomodaeum

- The structure of the esophagus is also variable in nematodes of different feeding habits.
- It may be **cylindrical throughout (1part)**, or **narrow anteriorly and broader posteriorly (2 part)**, or it may have **2 bulbous structures (3 part)** as in case of most plant parasitic nematodes.



Oesophagus

- **The various parts of a 3-part oesophagus are-corpus (further divided into procorpus and metacarpus or median bulb), isthmus and basal bulb.**
- **Further variations within 3-part esophagus are discernible among different groups of plant parasitic nematodes.**
- **Procorpus is a narrow anterior portion which enlarges to form a muscular median bulb (metacarpus), the latter is armed with valves.**
- **The pulsation of median bulb helps in the ingestion of cell cytoplasm through the stylet into the oesophagus, and further pushing the ingested food material into the intestine.**



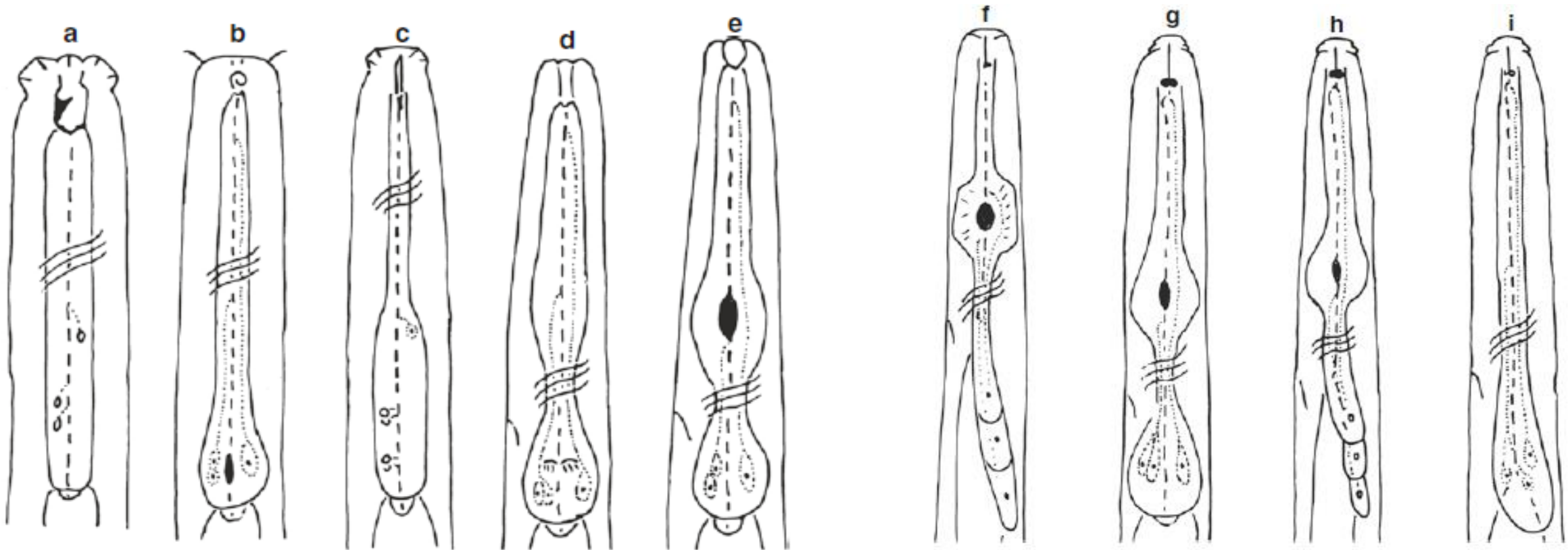
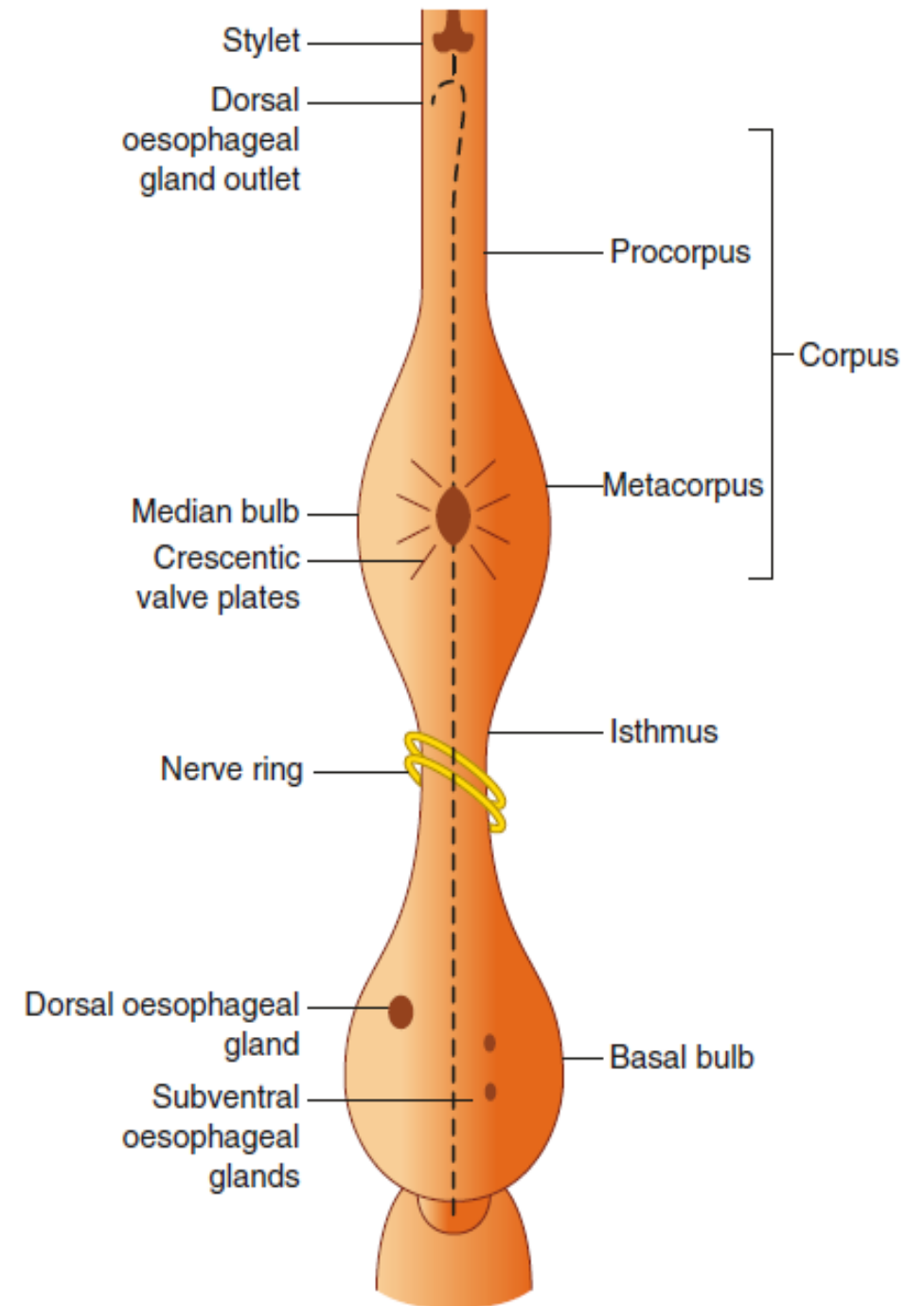


Fig. 3.14 Oesophagus types: (a) a cylindrical or cylindroid type (Mononchida), (b) a bulboid type with a slender, cylindroid anterior part and an ovoid basal bulb, (c) a dorylaimid type, (d) a rhabditoid type, (e) a diplogasteroid type, (f) an aphelenchid type: the dorsal gland opening (DGO) opens at the level of the median bulb, (g–i) tylenchid types: the DGO opens at the level of the base of the stylet. In Tylenchida, the oesophageal glands may either be contained within the basal bulb (g) or they may be lobe-like and overlap the intestine, dorsally, ventrally or laterally (h). In some nematode groups the oesophagus does not contain a valved median bulb (i) (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

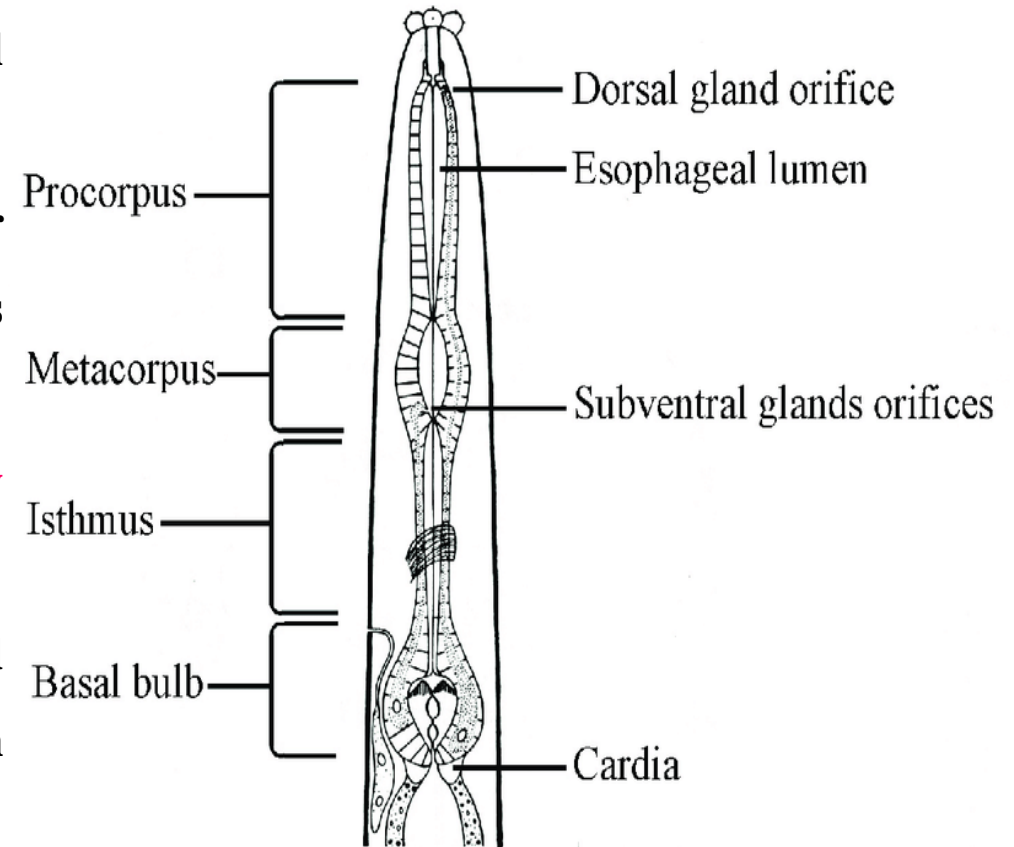
Oesophagus

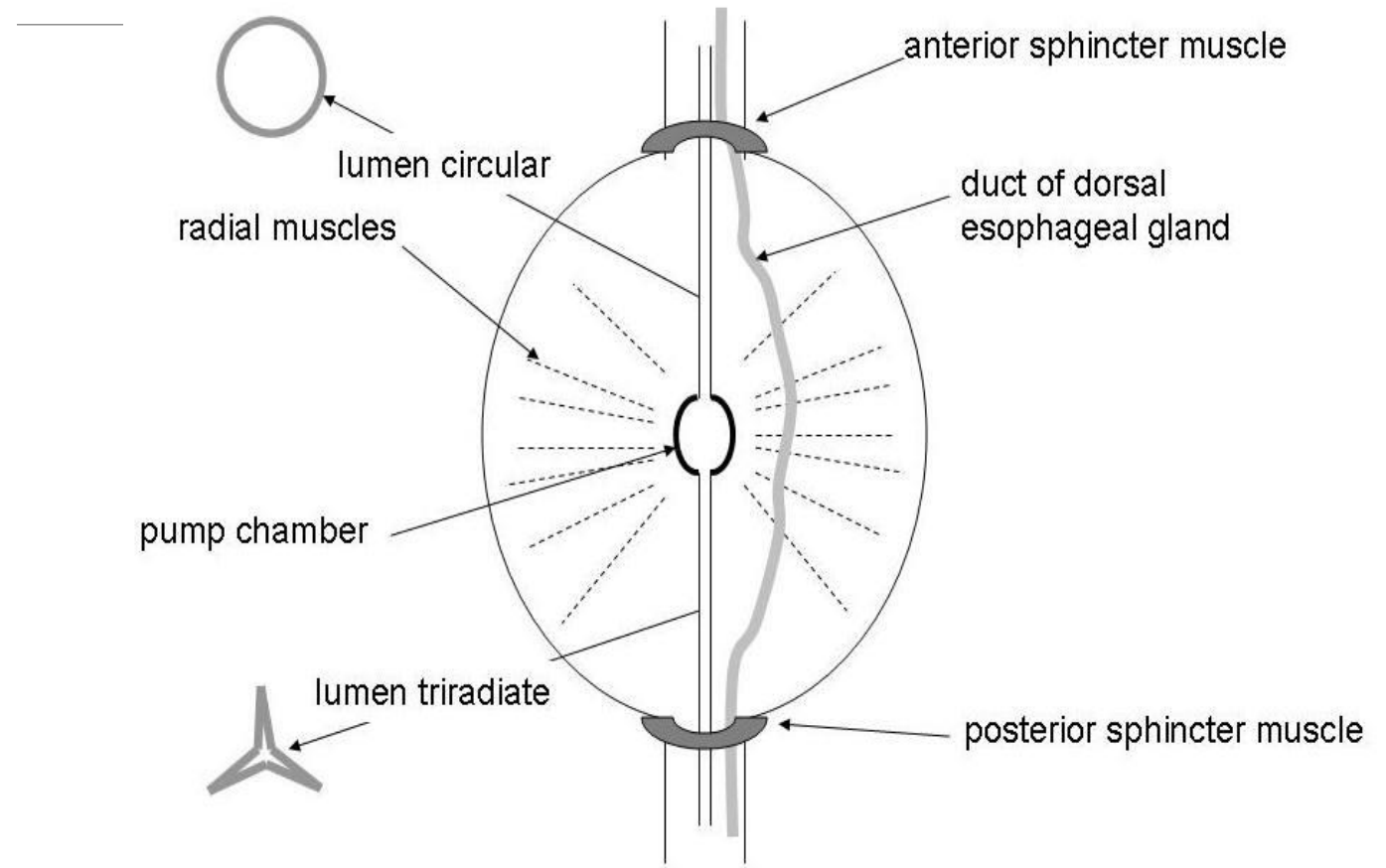
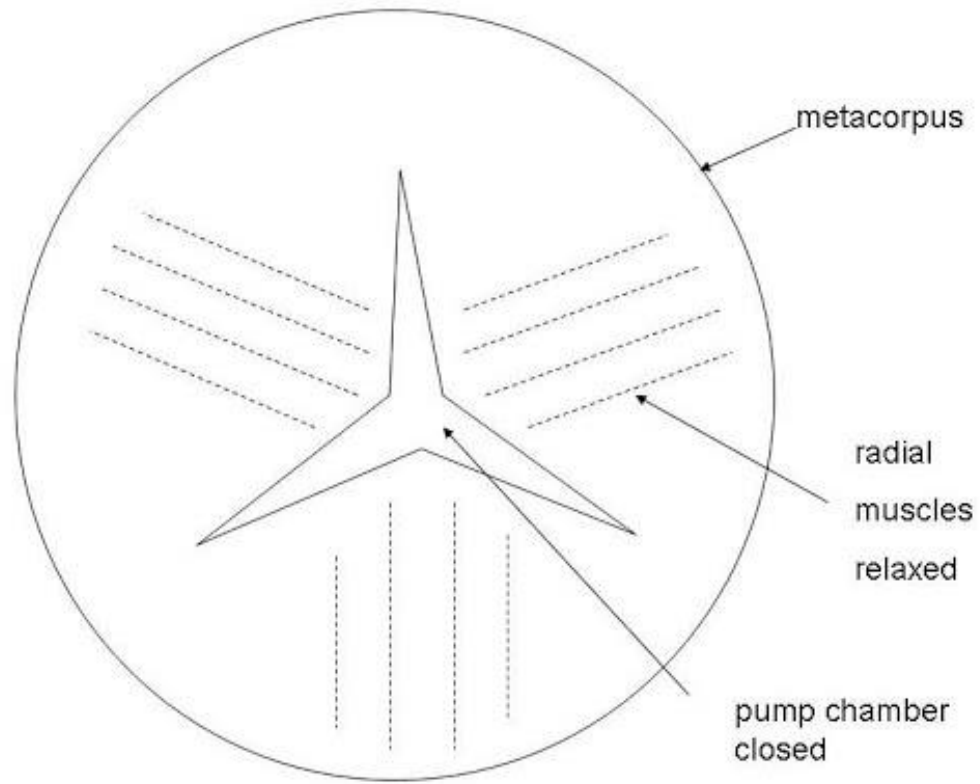
- Following this is a narrow zone, the isthmus which is linked to the basal bulb or the end bulb in which the oesophageal glands are located.
- The esophageal glands are 3 (1 dorsal and 2 sub-ventrals) and open into the esophageal lumen through ducts running in the oesophageal walls.
- In plant parasitic tylenchids, the dorsal gland opens near the base of stylet, whereas the ducts of the 2 sub-ventral glands join the esophageal lumen in the median bulb.
- The glands secrete the 'saliva' for the digestion of food.



Oesophagus

- In certain nematodes the esophageal glands are more developed and cannot be accommodated within the basal bulb.
- In such cases these extend (overlap) over the anterior part of the intestine to some distance on various sides (dorsal ventral, lateral).
- The oesophageal lumen is triradiate and is lined by cuticle.
- The junction of oesophagus with the intestine is guarded by a valve, the cardia or oesophago-intestinal valve which regulates the unidirectional flow of food.





ESOPHAGUS



CYLINDRICAL



STICHOSOME

TWO PART

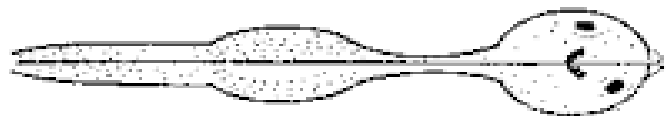


DORYLAIMOID

THREE PART



RHABDITOID



RHABDITOID



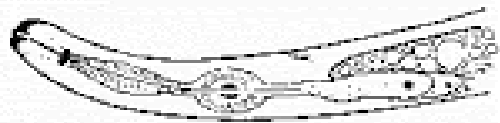
TYLENCHOID



TYLENCHOID



APHELENCHOID (WITH VENTRALLY OVERLAPPING GLANDS)

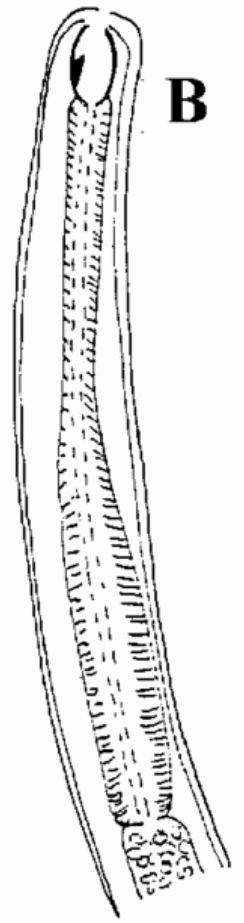


TYLENCHOID WITH DORSALLY OVERLAPPING GLANDS

ESOPHAGEAL-INTESTINAL VALVE



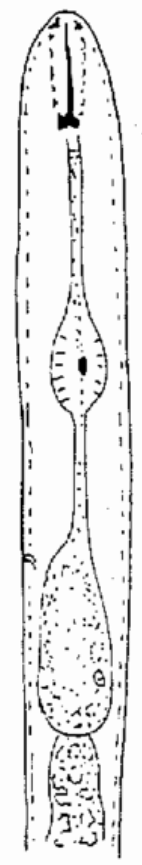
A



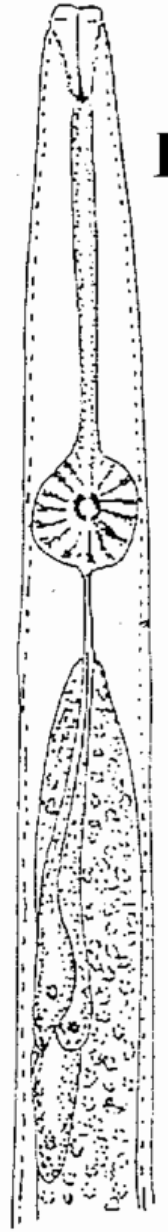
B



C



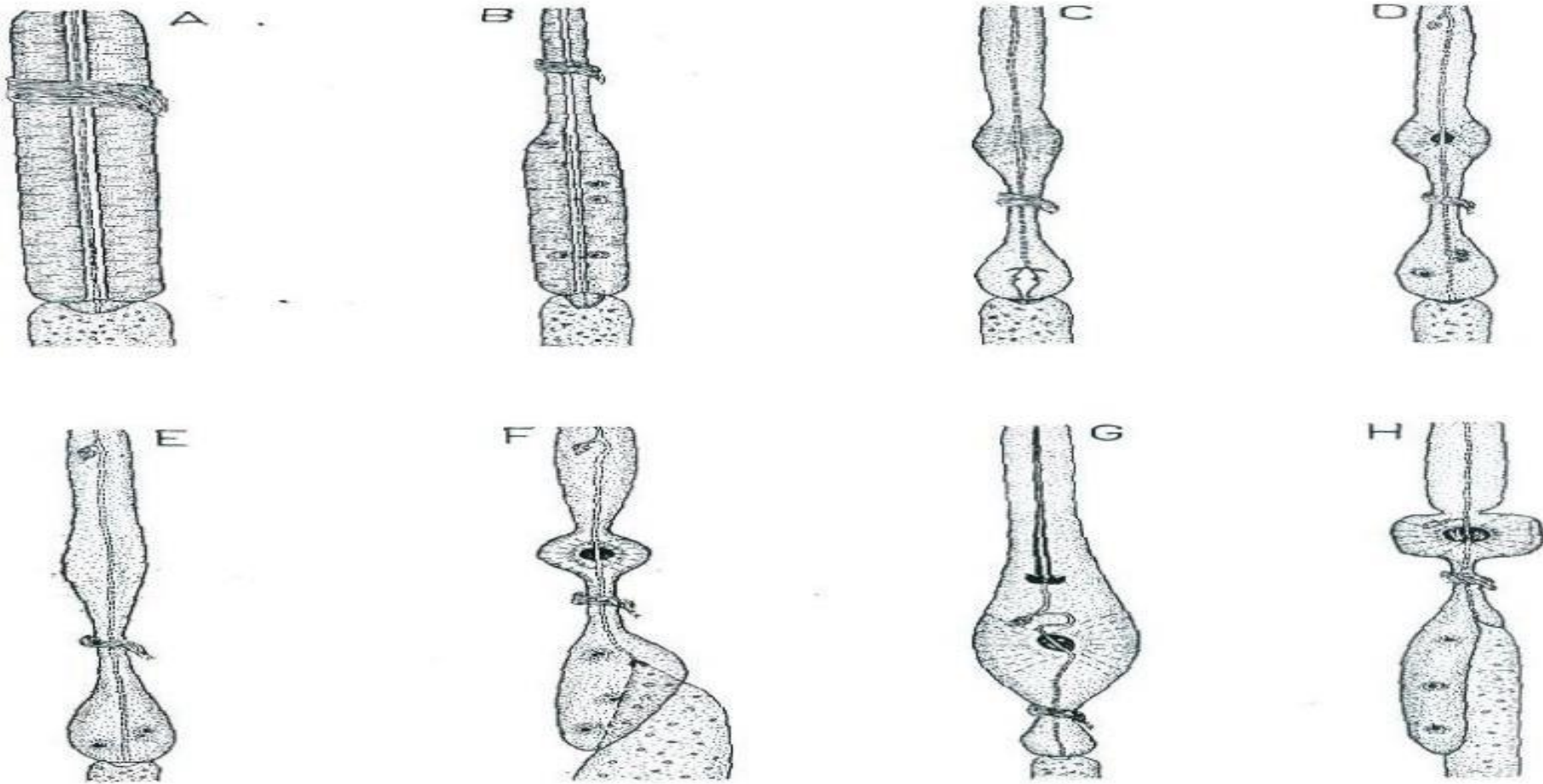
D



E

50μ

ADAPTED FROM:
<http://ianwww.unl.edu/ians/plntpat/hnematode/nemasite.htm>;
(ORIGINALLY FROM -
TARJAN, ESSER &
CHANG, 1977)



Variations in structure of oesophagi – A. Monochid, B. Dorylaimid, C. Rhabditid, D. Tylenchid, E. Neotylenchid, F. Hoplolaimid, G. Croiconematid, H. Aphlenchid

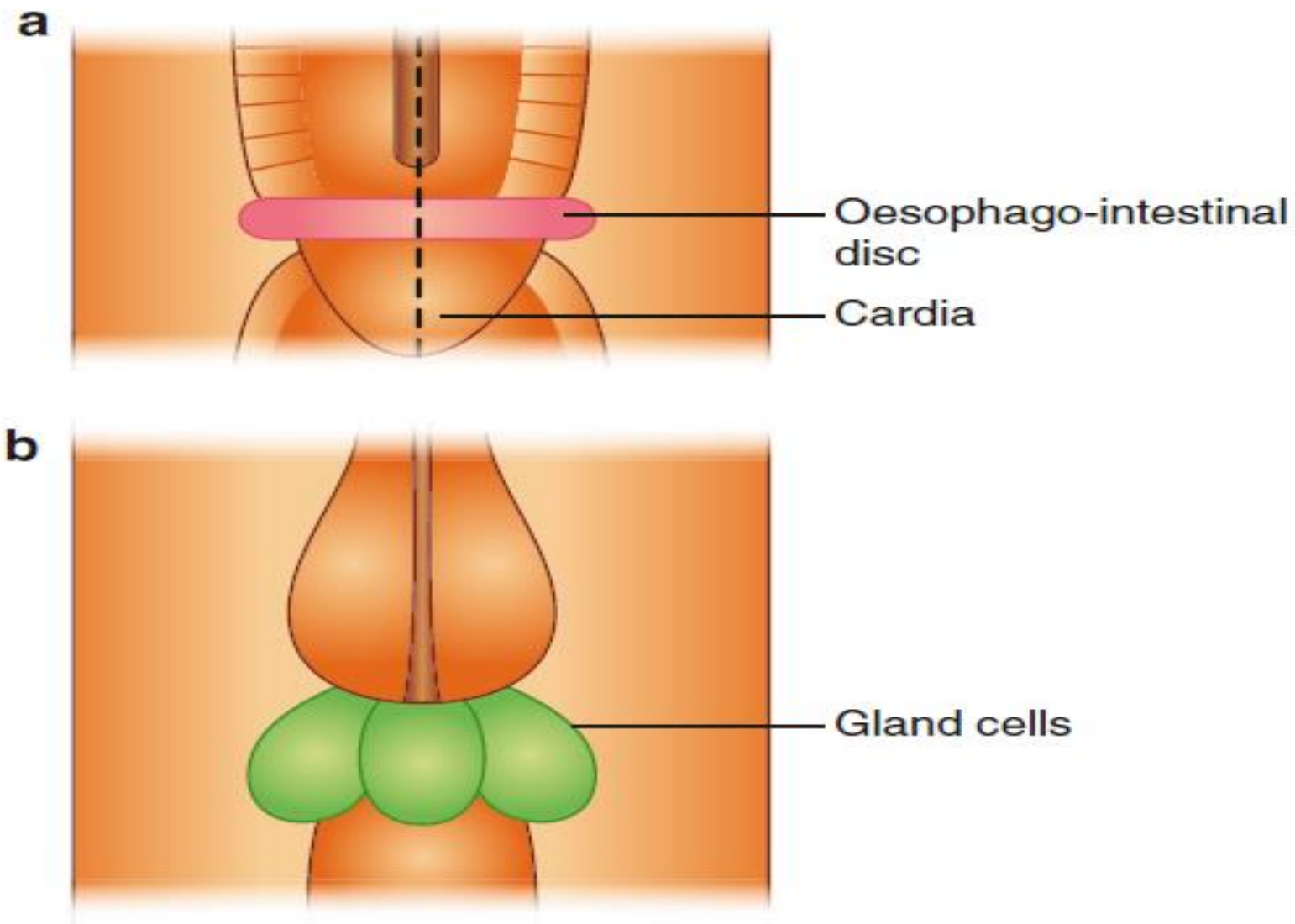
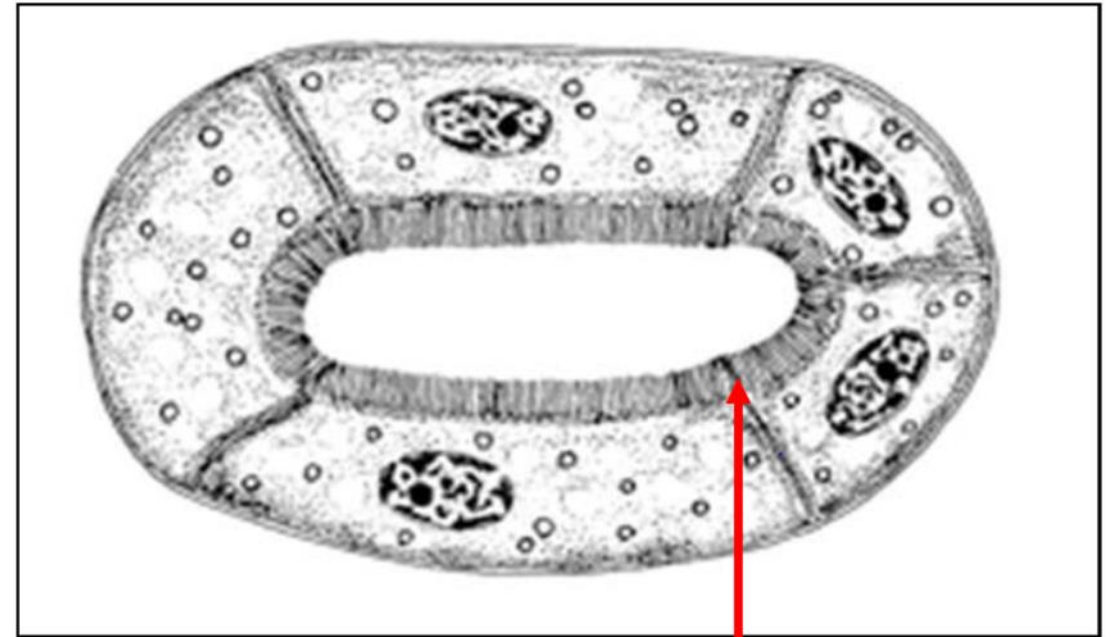


Fig. 3.15 Cardia situated as junction between the oesophagus and the intestine (a) and gland cells associated with the cardia (b) (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

Mesenteron

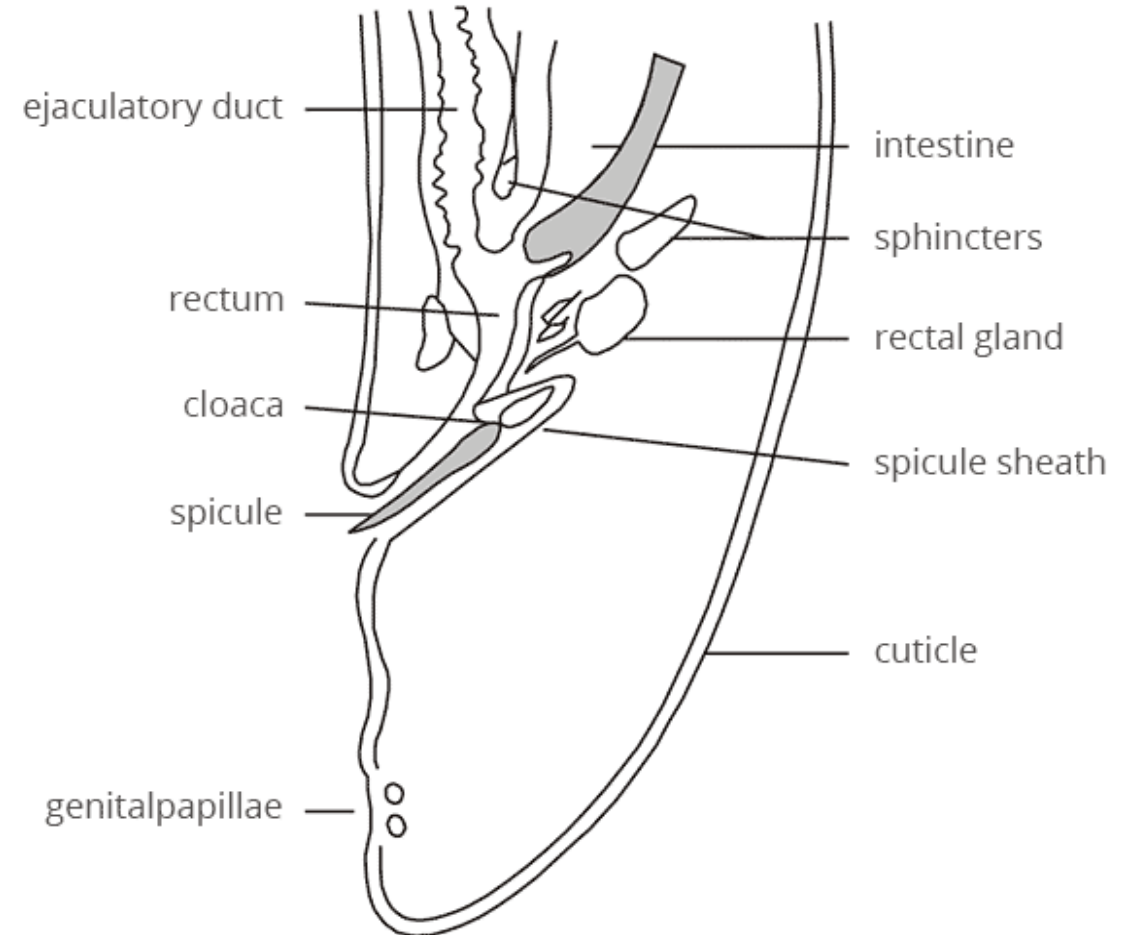
- It is constituted only by the intestine which is a simple straight tube running most of the length of the body.
- The intestine is composed of a single layer of endodermal epithelial cells.
- Internally, these cells bear a layer of finger-like projections (microvilli), which are absorptive and secretory in function



Microvilli seen on the inner lining

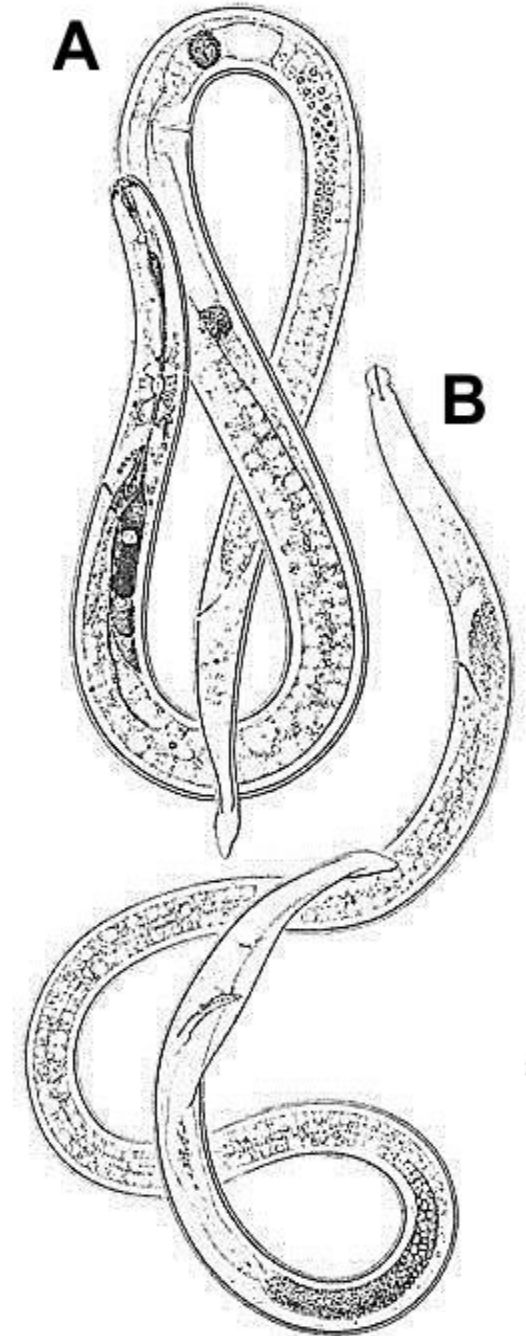
Proctodaeum

- It consists of rectum which is a short flat tube, lined internally by cuticle.
- It opens to the outside on ventral side through anus in females.
- However, in case of males, the reproductive system joins the rectum to form a common tube called cloaca, which opens to the outside through cloacal opening on the ventral side and serves as a common opening for digestive and reproductive systems



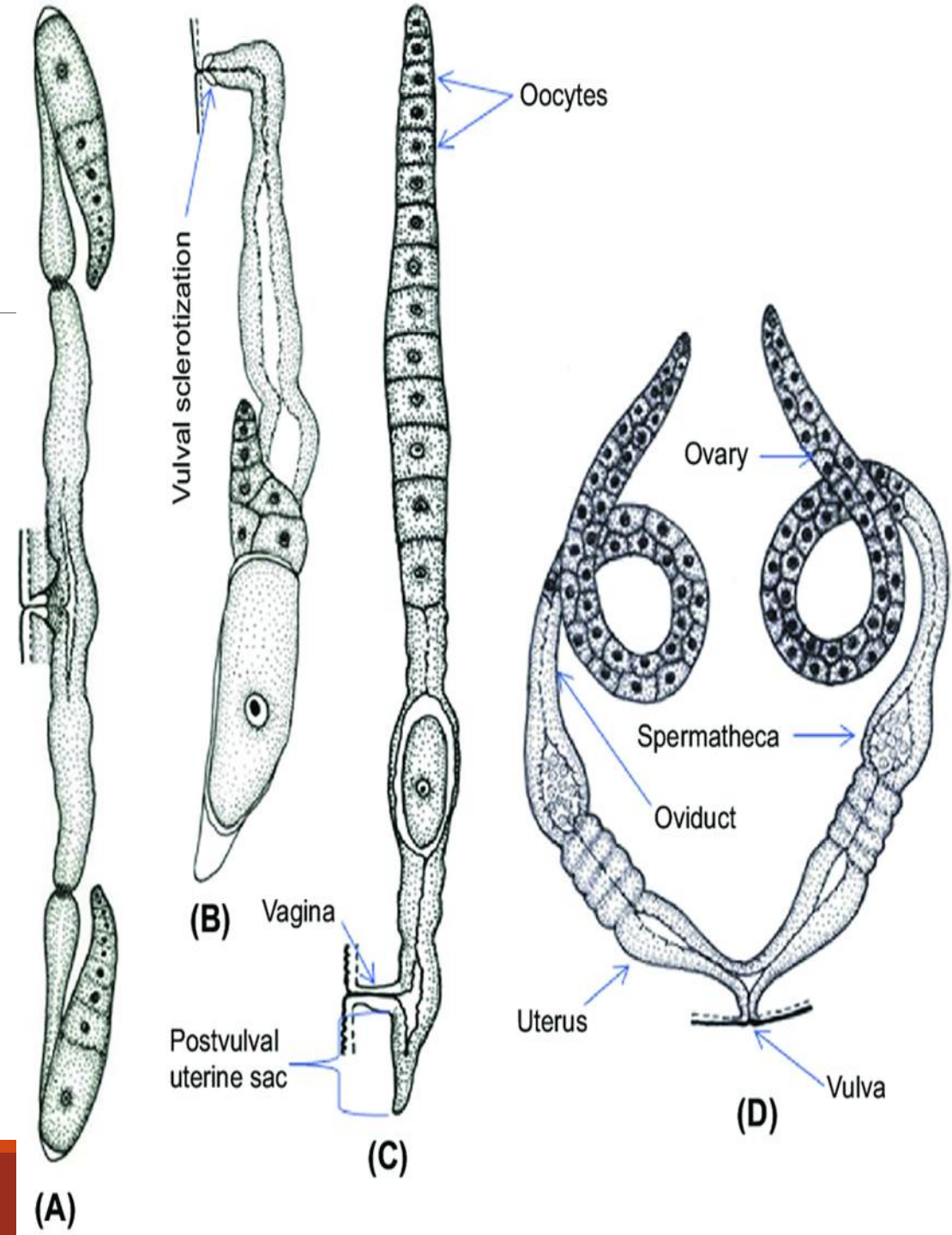
REPRODUCTIVE SYSTEM

- Nematodes are dioecious or unisexual, i.e. males and females are separate.
- In general appearance both the sexes look alike and are similar in respect of other body systems.
- However, males can be distinguished by the possession of spicules and usually bursa near the posterior end.
- **In both males and females the reproductive system is again tubular, called genital tract, which is suspended in the body cavity.**



Female Reproductive system

- The various parts of the female genital tract are **ovary (gonad), oviduct, spermatheca, uterus, vagina and vulva (gonoduct)**.
- The oocytes are formed in the ovary where they grow in size.
- They pass down to spermatheca via oviduct.
- **Spermatheca, if present stores the sperms after mating and when the oocytes pass through it, they get fertilized.**



Female Reproductive system

- Further layers on the egg (ovum) are laid while it is passing through the glandular portion (crustaformeria) of the uterus.
- Vagina helps in the expulsion of egg to the outside and opens on the ventral side through a slit-like opening, the vulva.

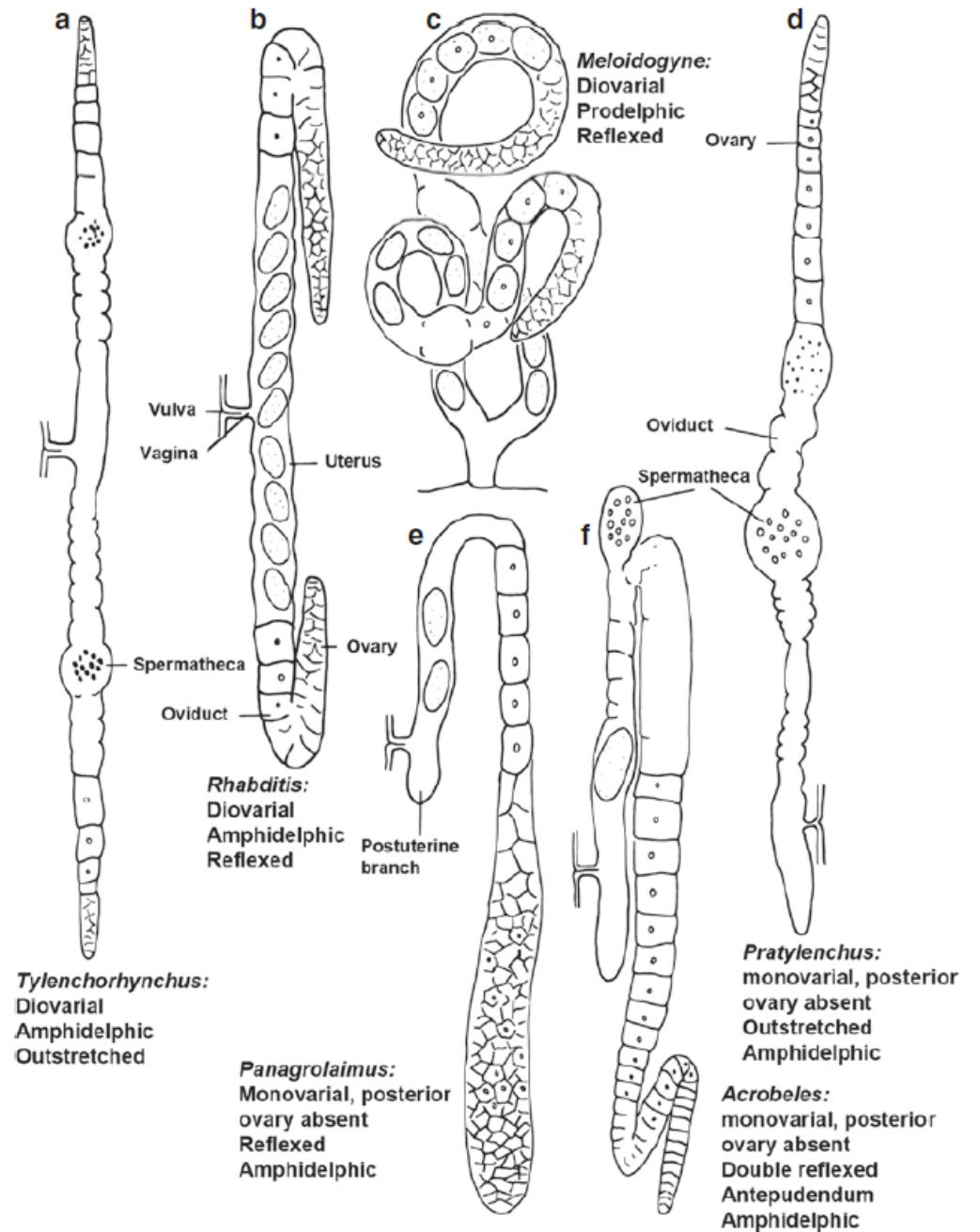


Fig. 3.16 (a–f) Female reproductive systems (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

Female Reproductive system

- Females may possess only 1 gonoduct (monodelphic) which may be directed anteriorly (prodelphic) or posteriorly (opisthodelphic).
- In those females which possess 2 gonoducts (didelphic), the uteri of two gonoducts unite to form a common vagina leading to vulva.
- In didelphic forms, one gonoduct may be directed anteriorly and the other posteriorly (amphidelphic), or both may be directed anteriorly (prodelphic), or posteriorly (opisthodelphic).

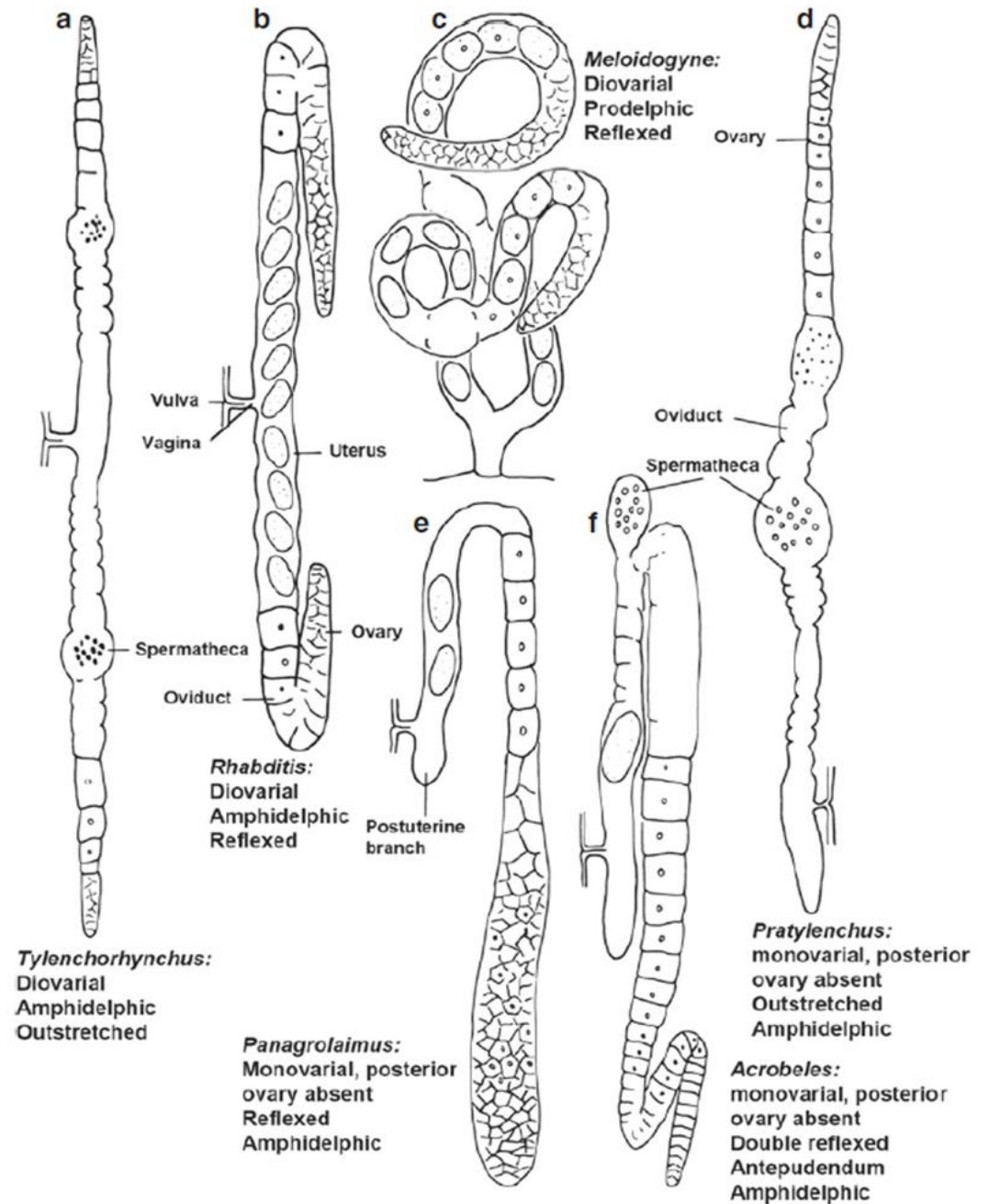


Fig. 3.16 (a–f) Female reproductive systems (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

Male Reproductive system

- Among plant parasitic nematodes, males generally have a single genital tract (monorchic), but 2 genital tracts (diorchic) may be present in other groups of nematodes.
- Various parts of male genital tract are: testis, seminal vesicle, vas deferens, cloaca and cloacal aperture.
- Sperms are formed in the testis, and may be temporarily stored in the seminal vesicle.
- Vas deferens joins posteriorly with rectum to form cloaca.
- A pair of hard curved structures, the spicules are located in a pouch of cloaca.

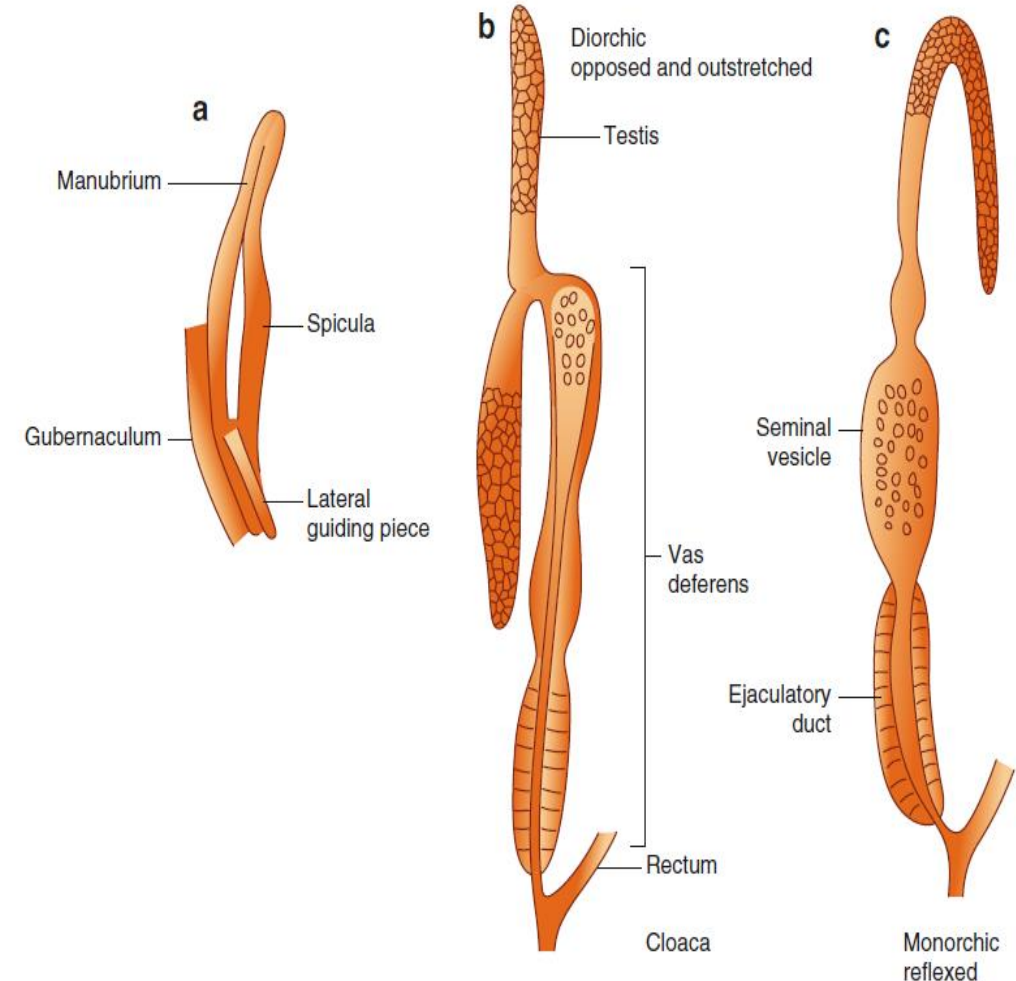


Fig. 3.17 Male reproductive systems: spicula and gubernaculum (a), and a diorchic (b) and monoichic (c) system (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

Male Reproductive system

- The spicules are protrusible and help in the insemination of females during mating.
- The movement of spicules is guided by a plate-like hard structure, the gubernaculum.
- Bursa is usually present in plant parasitic nematodes.
- It is generally reduced (leptoderan) in nematodes with filiform tails, in others it may extend up to the tail tip (peloderan).
- Bursa helps in claspng the female during mating.
- Spicules, gubernaculum and bursa constitute secondary sexual organs.

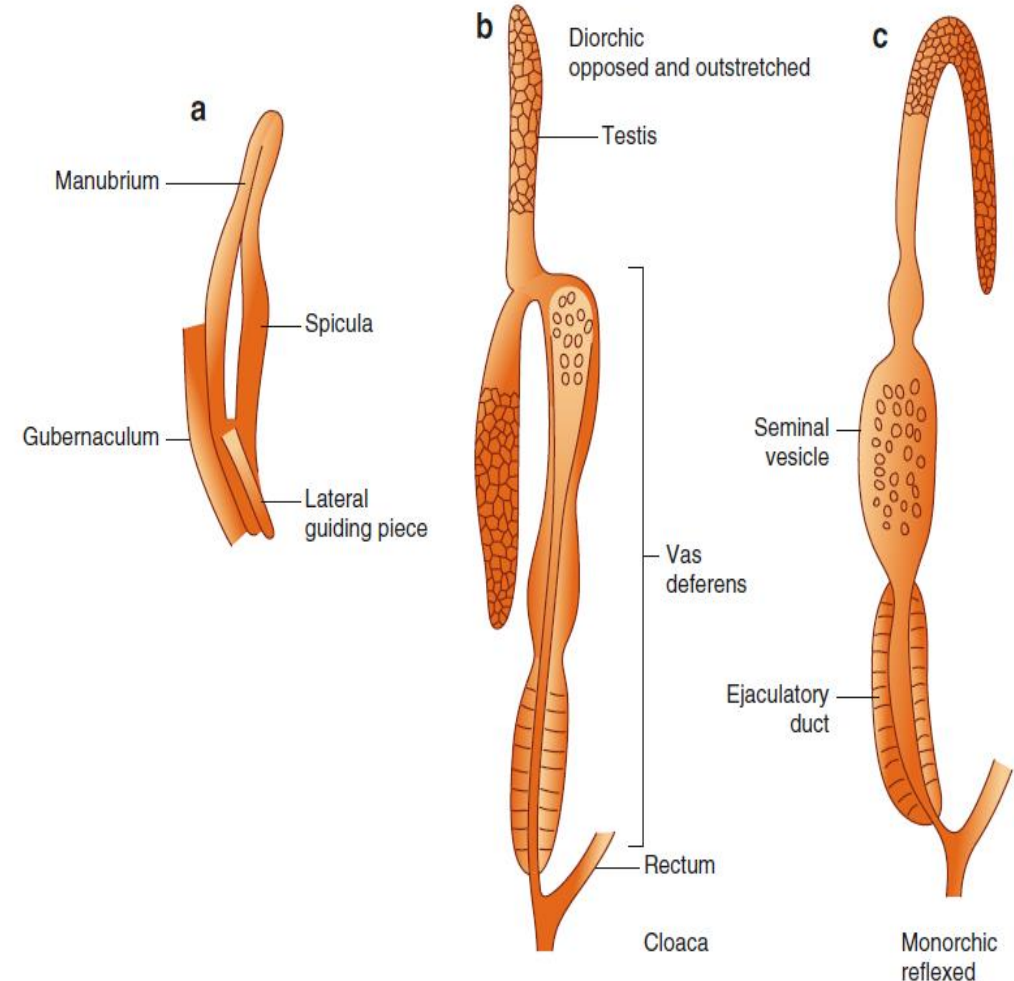
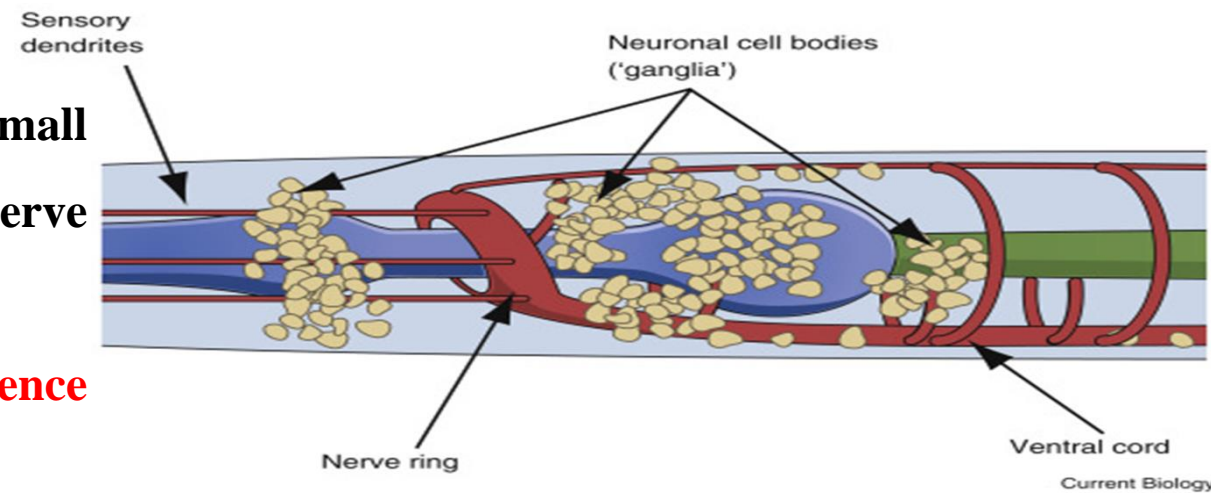


Fig. 3.17 Male reproductive systems: spicula and gubernaculum (a), and a diorchic (b) and monoorchic (c) system (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council-Plant Protection Research, Pretoria, South Africa)

NERVOUS SYSTEM

- In general, nematodes have a highly developed nervous system.
- In plant parasitic nematodes, because of their small size, the only part visible in whole mounts is the nerve ring, the so called 'brain' of the nematode.



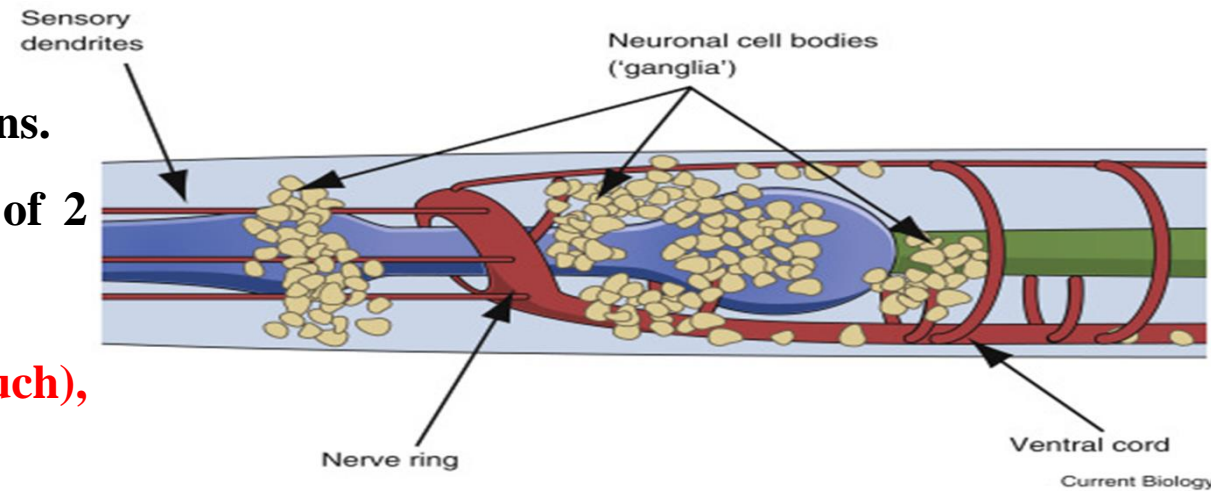
- **It encircles the esophagus, usually the isthmus, hence also called as circum-oesophageal commissure.**
- Six longitudinal nerves extend from the nerve ring anteriorly to innervate the cephalic sensory organs.
- Posteriorly, 4 main nerves- dorsal, ventral and 2 laterals arise from the nerve ring, run in the respective hypodermal chords, and innervate various parts of the body.

NERVOUS SYSTEM

- **Transverse commissures interconnect the longitudinal nerves throughout the body.**
- **Associated with the nervous system are sense organs.**
- **In plant parasitic nematodes, these are broadly of 2 types,**

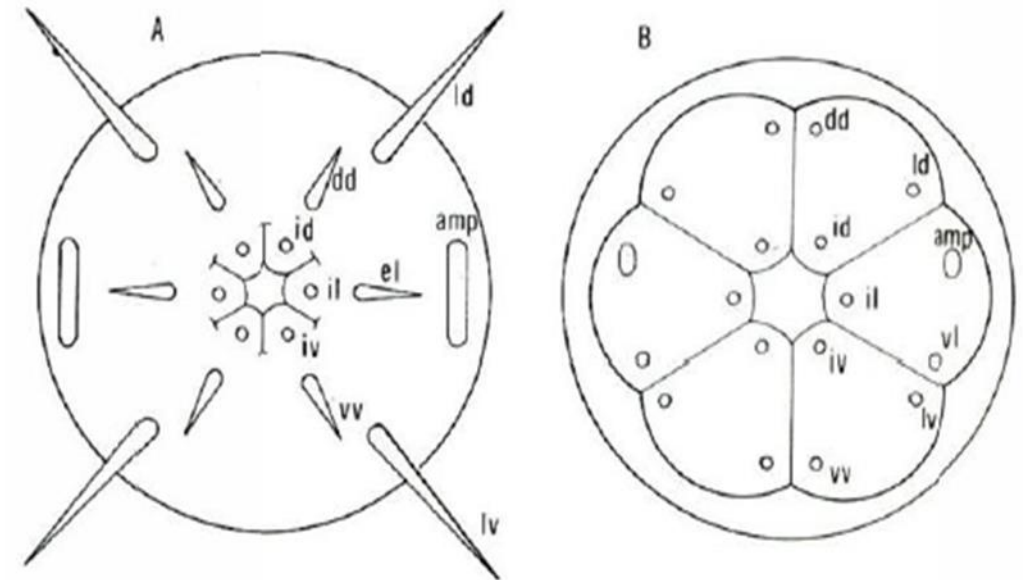
- **Tactoreceptors (which perceive the sense of touch), e.g. papillae,**

- **Chemoreceptors (believed to sense the presence of chemicals), e.g. amphids and phasmids.**



Cephalic/ labial papillae

- Cephalic/labial papillae are basically 16 in number and are arranged in 2-3 circles on the lips around the oral opening



Enface view of nematode showing arrangement of lips and cephalic setae (A) and papillae (B) in 2-3 circles

Amphids

- **Amphids are a pair of sense organs located in the head region and open on each of the 2 lateral sides through amphidial apertures.**
- **Among plant parasitic nematodes, amphids are considered to be helpful in locating the host roots by perceiving chemical stimuli secreted by the host in the rhizosphere.**

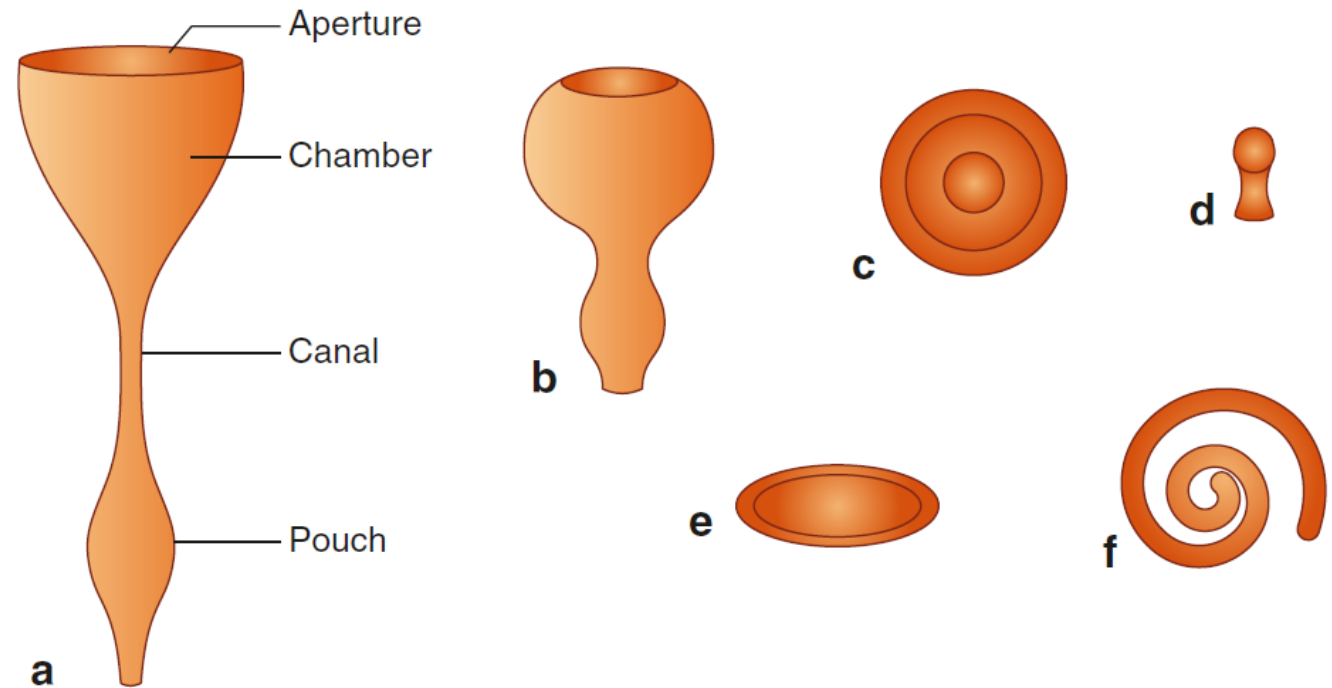
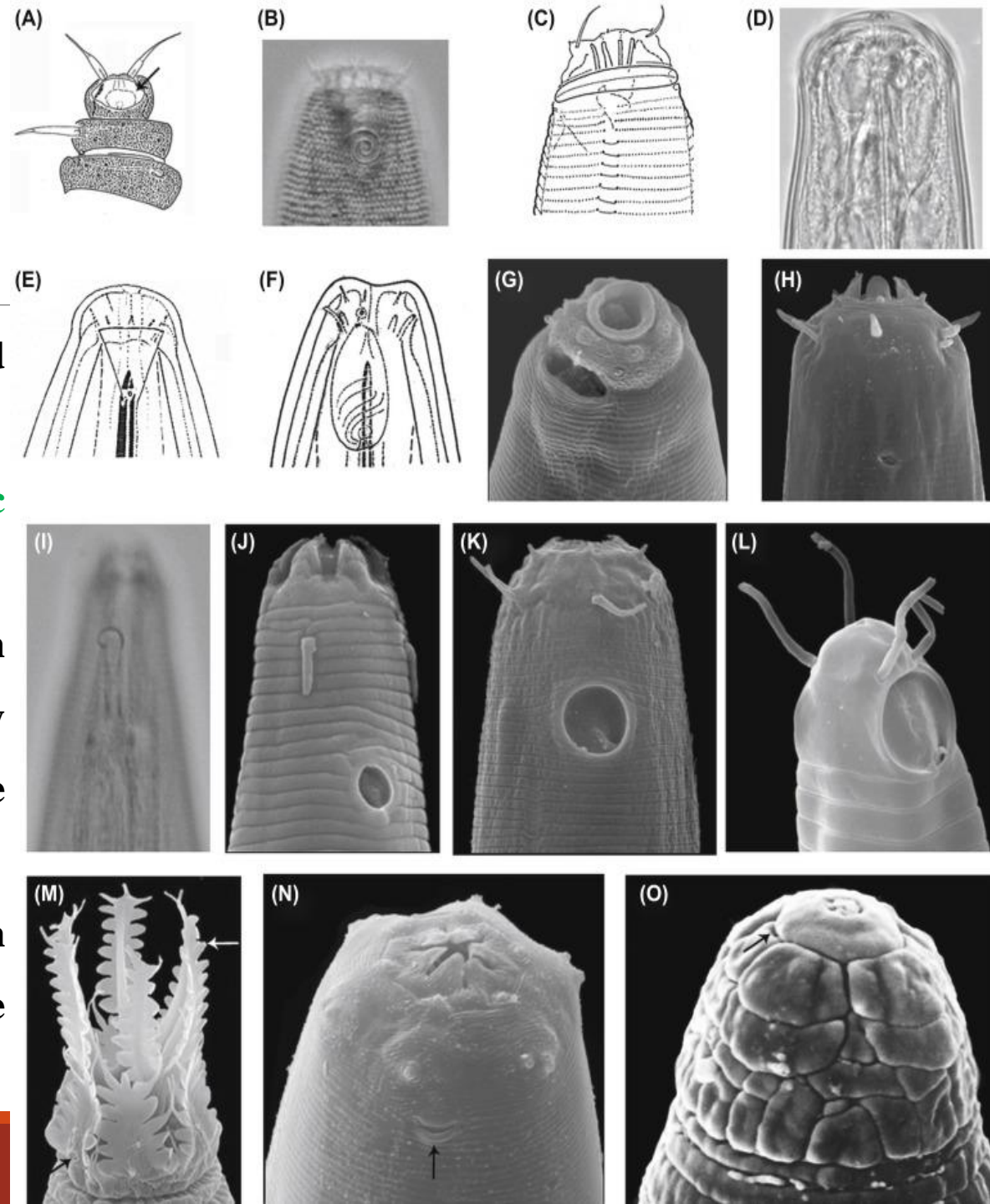


Fig. 3.5 Shape and structure of amphids: stirrup- or funnel-shaped (a), cyathiform (b), circular (c), pore-like (d), oval (e) and spiral-shaped (f) (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)

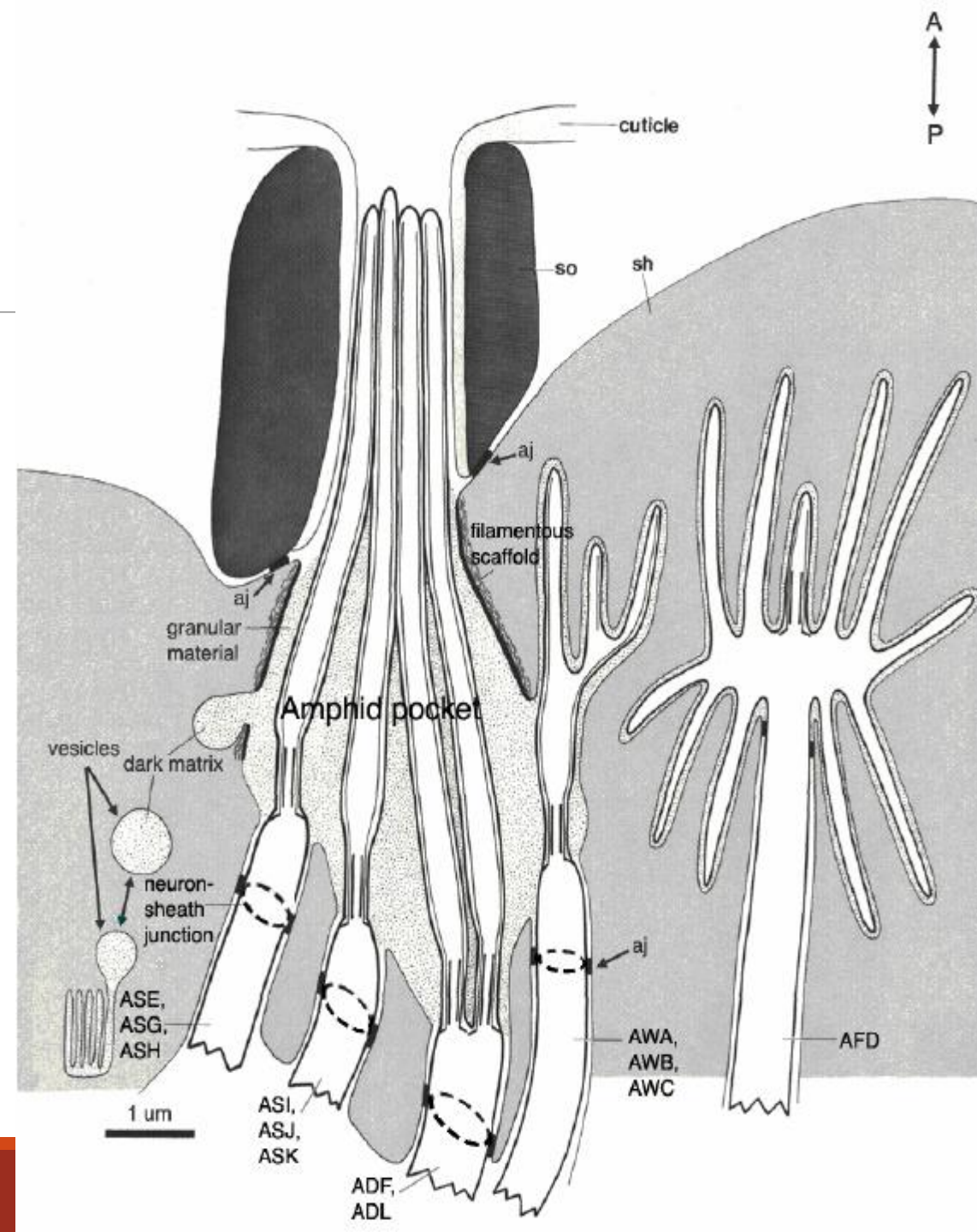
Amphid

- The amphids are found in all groups of nematodes and form an integral part of the anterior sensilla-complex.
- They are paired lateral organs located in the cephalic region of the nematode.
- The amphids occur in many shapes and sizes in different nematode groups and are generally considered to be of diagnostic value in nematode systematics within and between groups.
- The amphid has an amphid aperture situated either on the lips (labial) or post-labial and opening to the exterior.



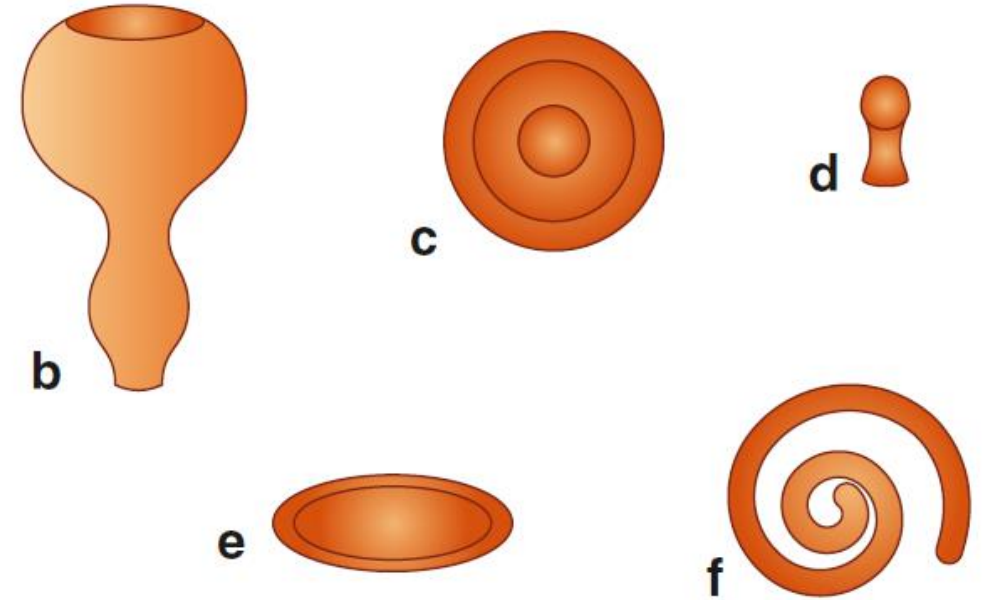
Amphid

- Internally the aperture is connected to a **pouch (fovea)** which leads to fusus or sensilla pouch through an **amphid duct or canalis amphidialis**.
- The fusus is connected to the amphidial nerve through the nerve process.
- The fovea, duct and anterior most part of the sensilla pouch are lined with cuticle.
- In different nematode groups the amphid aperture exhibit shapes- pore like, circular, hooked, stirrup shaped, spiral etc. The size and nature of fovea is also variable.



amphids

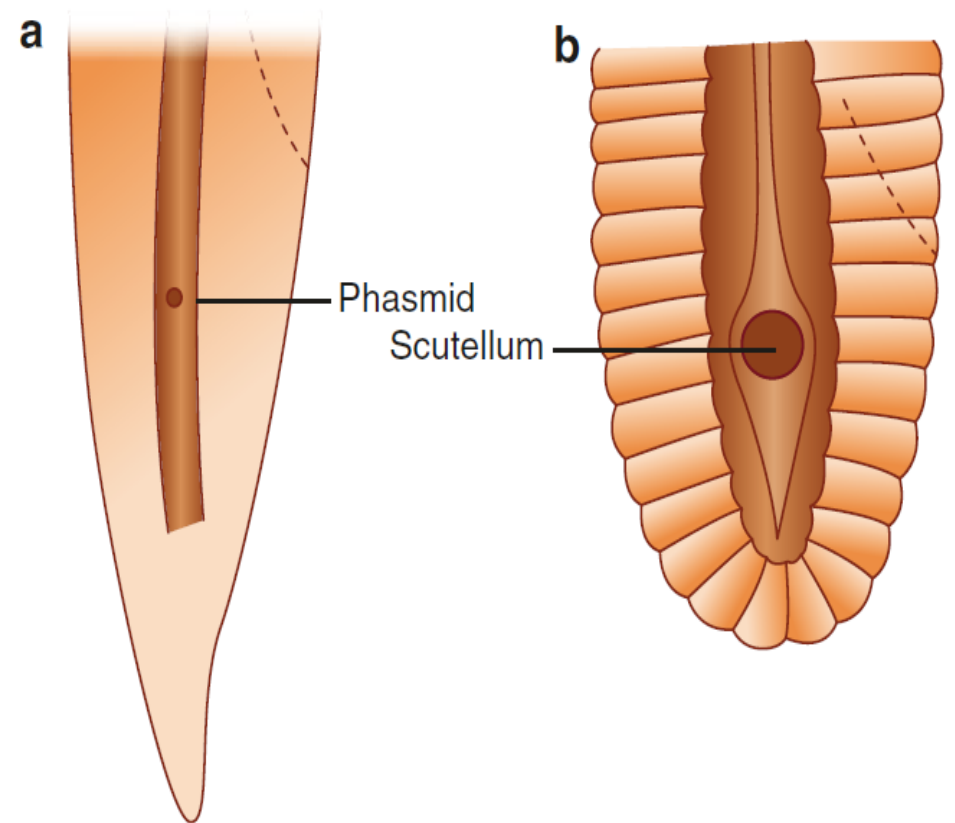
- The amphids open to the exterior and since long have been considered as chemoreceptor organs responsible for detecting changes in the outside environment of the nematode.
- However, it is quite likely that apart from being chemoreceptory, they may also perform secretory or some sort of photoreceptive function.
- Electrophysiological evidence to determine the exact mechanism of action of this sensilla is lacking.
- have a secretory role in producing mucus-like material near the head.



Phasmids

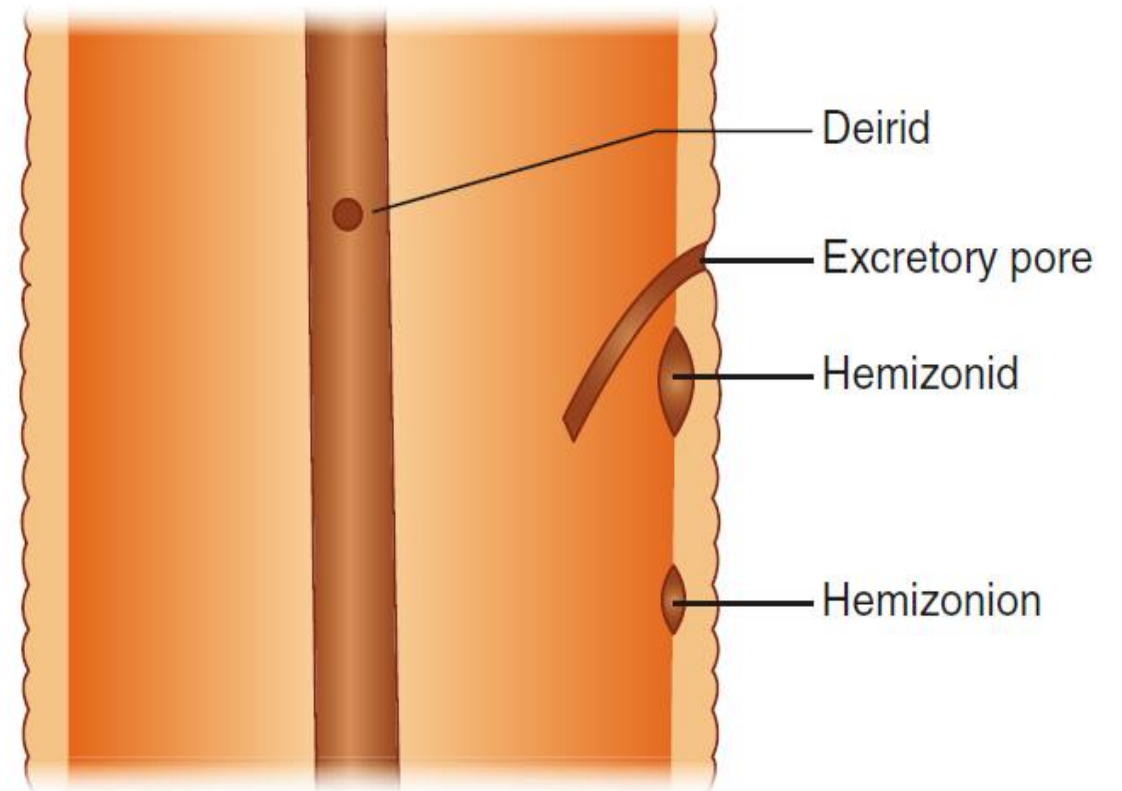
- A similar pair of chemoreceptors, the phasmids, are located in the tail region, opening through pores in the lateral fields.
- Phasmids may be enlarged in a few nematodes, and are known as scutella (*Scutellonema*)

Fig. 3.6 Phasmid situated posterior to the anus (a) and the scutellum in *Scutellonema* on the tail (b) (Redrawn from Heyns (1982) by Esther van den Berg, Agricultural Research Council–Plant Protection Research, Pretoria, South Africa)



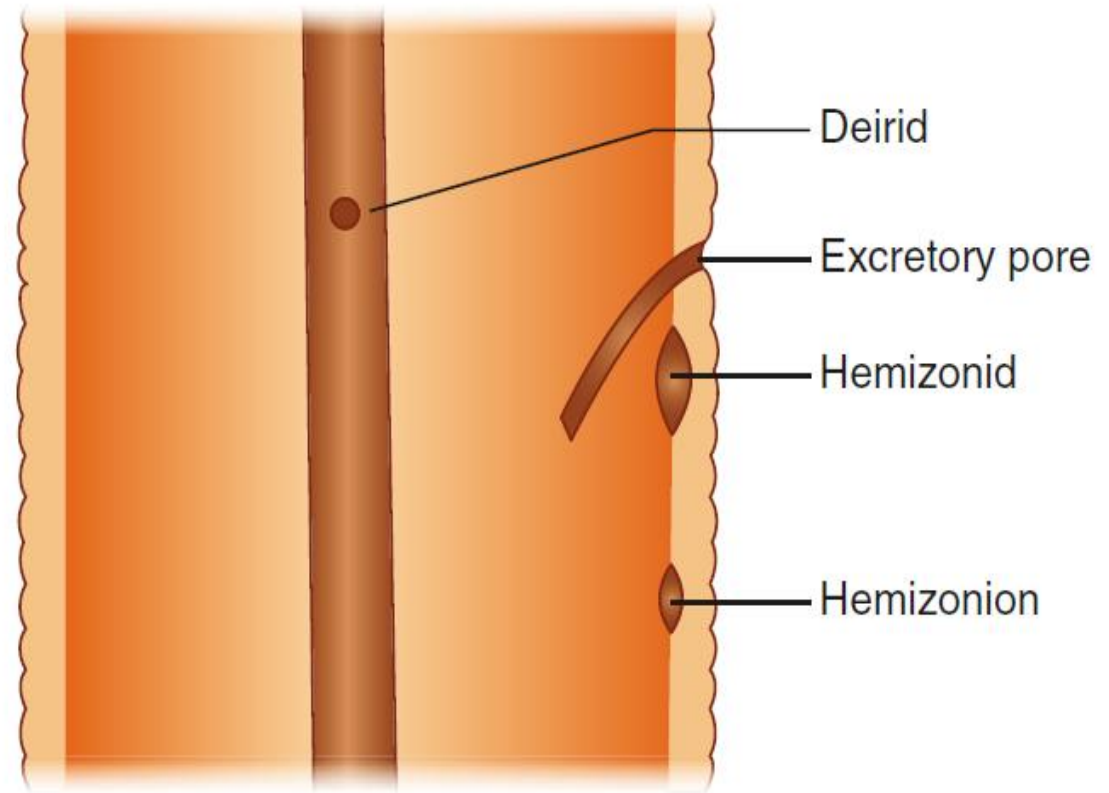
Deirid

- These are a pair of small protuberance, one each in lateral side in the middle of the lateral field.
- These are located in the region of oesophagus at the region of excretory pore.
- These are in some Tylenchida (e.g. Tylenchidae, Neotylenchidae, Merlininae **except Scutylenchus etc.**) but are conspicuous by their absence in others (e.g. **Tylenchorhynchinae, Dolichodorinae, many Criconematids**).
- The deirids are sensory structure but do not appear to have an opening to the exterior.



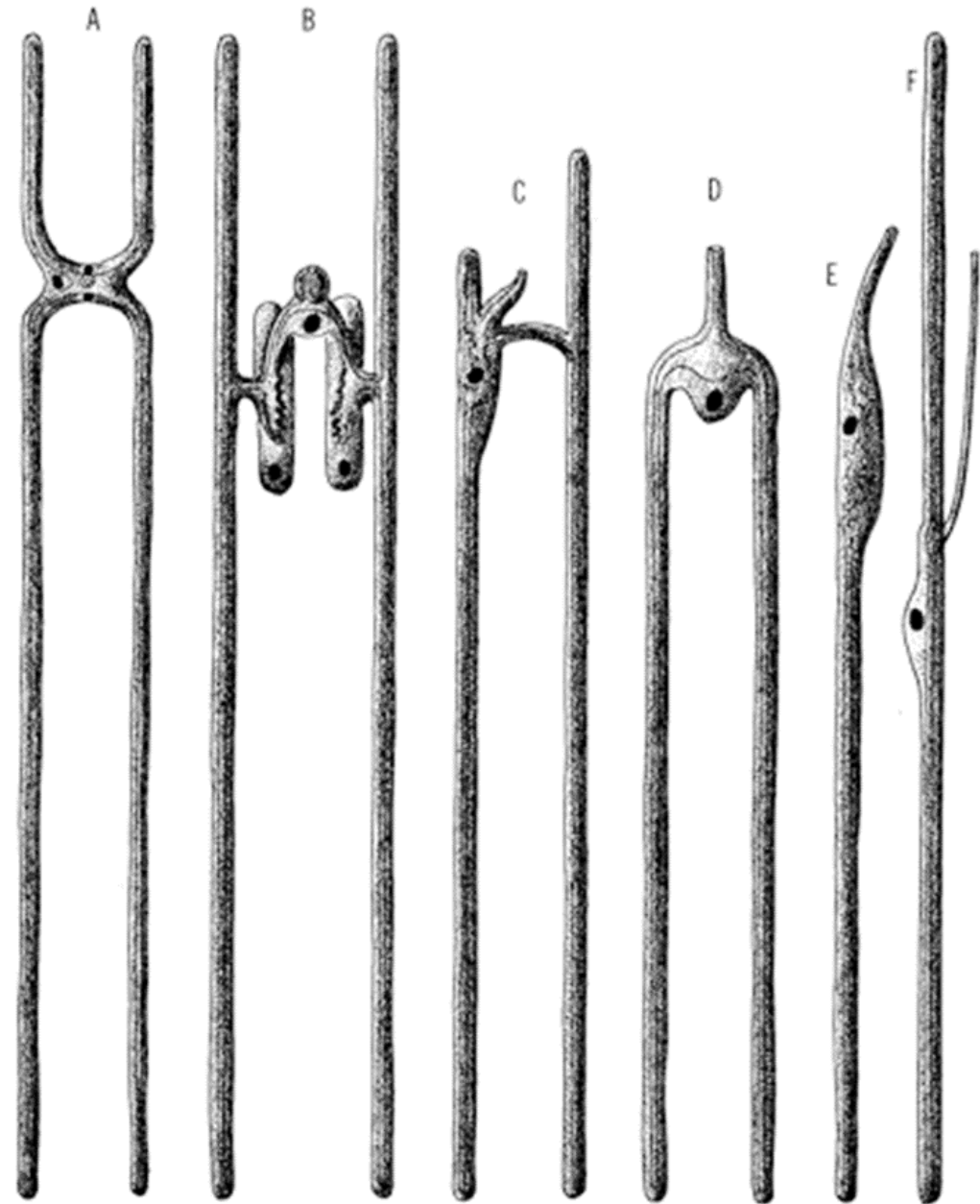
Hemizonid and Hemizonion

- They are highly refractive, biconvex, semi – circular and may be anterior or posterior to the excretory pore.
- Hemizonids is anterior to the excretory pore.
- **The hemizonid represents a ventro-lateral (or subventral) commissure that connects the nerve ring to the ventral nerve cord and is located between the cuticle and hypodermis.**
- Hemizonions are smaller than Hemizoinids and are located posterior to hemizonid.
- **Hemizonoid and hemizonion are believed to be involved in nuerosecretion.**



EXCRETORY SYSTEM

- Two types of excretory systems are present in nematodes-the canalicular and the glandular.
- In canalicular type, longitudinal canals or tubes run almost the entire length of nematode in the lateral hypodermal chords.
- These canals are interconnected and form a terminal excretory duct, which opens to outside through excretory pore, usually located in the esophageal region on the ventral side.
- Most of the plant parasitic nematodes (tylenchids) have the canalicular type of system.



Excretory system

- Glandular type of excretory system consists essentially of a single cell (renette, sinus or cervical cell) which leads to a duct (excretory duct) opening to the Outside through a pore (excretory pore) on the ventral side.
- The whole system lies freely in the pseudocoelom

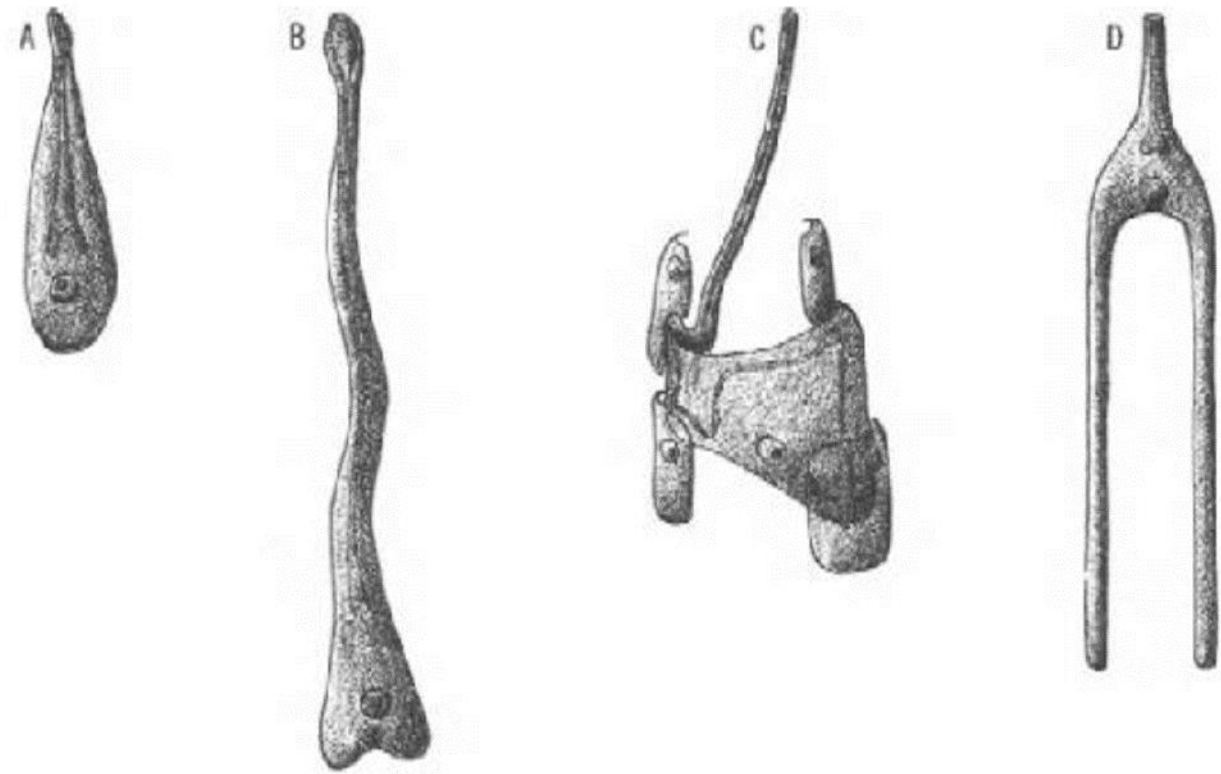


Figure 3.22. Excretory systems in Adenophorea. A. Chromadoria: *Chromadora*. B. Enoplia: *Phanodermopsis*. C. Chromadoria: *Plectus*. D. Chromadoria: *Anonchus* (A,B,D modified from Chitwood; C, redrawn from Maggenti).

Excretory system

- **Based on the type of excretory system, nematodes are divided into 2 groups- Secernentea (canalicular) and Adenophorea (glandular).**
- **The exact function of the so called 'excretory' system is a matter of conjecture.**
- **The main nitrogenous waste materials are excreted by body wall and digestive system.**
- **Moreover, the 'excretory' system is known to 'secrete' gelatinous materials in certain nematodes (e.g. citrus nematode) in which eggs are deposited.**
- **It is also speculated that the 'excretory' system plays important role in osmoregulation, in addition to excretion.**
- **Considering the diversity of functions performed by 'excretory' system, now-a-days, it is also called excretory-secretory system.**

RESPIRATORY AND CIRCULATORY SYSTEMS

- **The well-defined organs for respiration and circulation are lacking in nematodes, however, the systems do work.**
- **Oxygen required in the aerobic plant parasitic nematodes is believed to diffuse through the body cuticle.**
- **Pseudocoelomic fluid filled in the body cavity serves the function of circulatory system.**
- **The fluid is continuous throughout the body length and bathes the different organs.**

Definition

- **In the end, the nematodes may be defined as triploblastic, bilaterally symmetrical, unsegmented, pseudocoelomate invertebrates, with 4 main hypodermal chords, a triradial oesophagus, circum-oesophageal nerve ring, and lacking specialized organs for respiration and circulation.**
- **They have tubular gonads which open separately in females but join alimentary canal in males to open through a cloacal aperture**

