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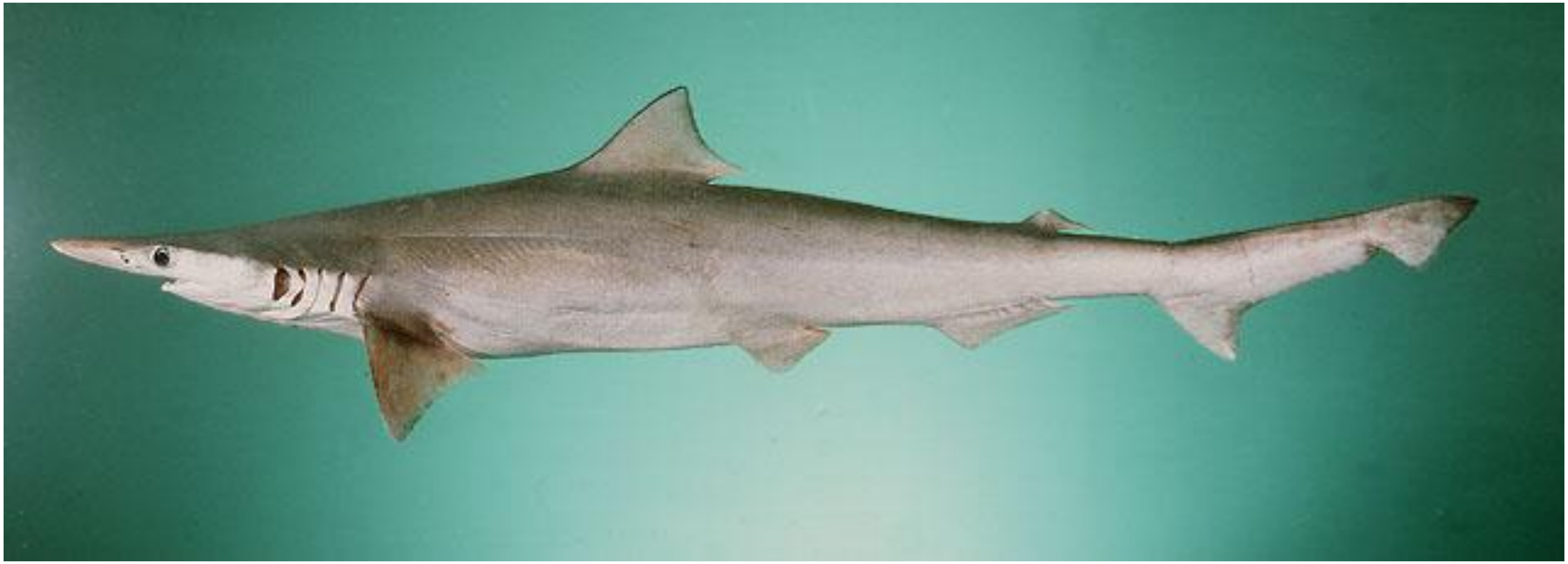
UNIT: 1, TYPE: SCOLIODON



Introductoion

- The genus Scoliodon is distinguished from other dogfishes by having an elongated snout, depressed head and a compressed body.
- The teeth are similar in both the jaws.
- The caudal pit and the sub-caudal lobe are prominent and distinct.
- The four Indian species of Scoliodon are: Scoliodon sorrakowah, S. dumerilii, S. palasorrah and S. walbeehmi.

Systematic Position:

Phylum Chordara

- Subphylum Vertebrata(= Craniata)
- Series – Pisces
- Class – Elasmobranchii
- Subclass – Selachii
- Superorder – Selachoidei (= Pleurotremata)
- Order – Lamniformes
- Family – Carcharhiniidae
- Scientific Name (Scoliodon sorrakowah)
- Scoliodon sorrokowah is often spelled S. sorrakowa, It is wiled ‘milk shark’ because its flesh is used to promote lactation in women in India.

Habit and Habitat of Scoliodon:

- The shark is a marine, carnivorous and predaceous animal.
- It eats small pelagic schooling and bottom living bony fishes, including anchovies, codlet, burrowing gobies and Bombay ducks as well as shrimps and cuttle fish.
- Both sexes mature between 1-2 years old and the males reach largest size at the age of about 5 years and females reach largest size at the age of 6 years.
- A common tropical shark of continental and frequently in rocky areas.
- The species is abundant in Indian and Pakistani waters.

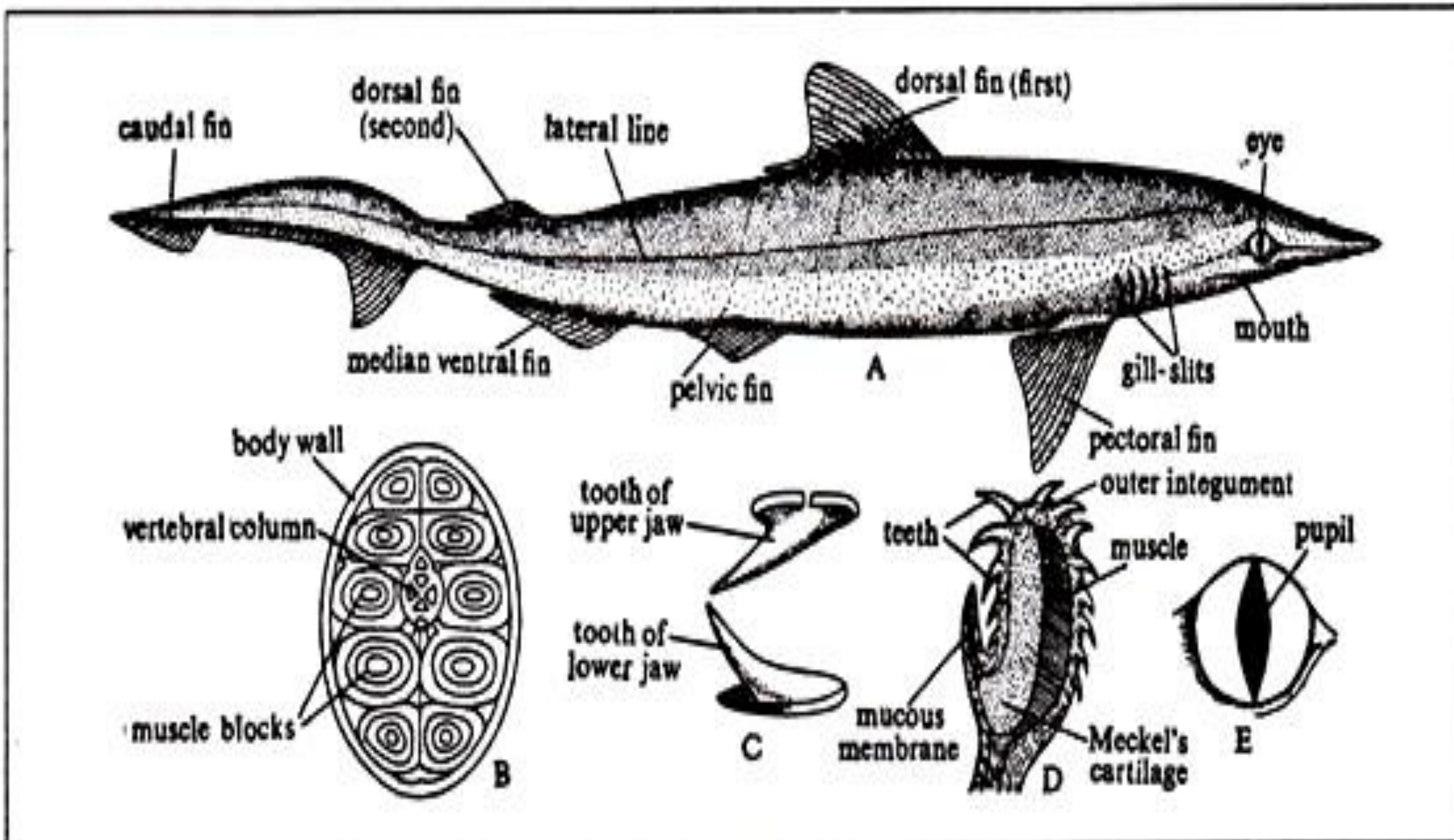


Fig. 6.2 : Structural organisation of *Scoliodon*. A. External features of a female specimen. B. Transverse section through the tail region showing the arrangement of muscle blocks. C. Disposition of teeth in the lower and upper jaws. D. Sectional view of the lower jaw showing the gradual transformation of the placoid scales into teeth. Note that the teeth in *Scoliodon* are transformed scales. E. A front view of an eye (after Thillayampalam, 1928).

Geographical Distribution of Scoliodon:

- Scoliodon has a wide geographical distribution ranging from Zanzibar to Ceylon (Sri Lanka), Ceylon to the Malay Archipelago of the Indian Ocean, Bay of Bengal, Eastern Pacific (from Mexico to Panama), West Indies and eas-tern coasts of South America.
- Fossils of Scoliodon have been discovered in the geological strata from the lower Eocene to later periods.

External Structures of Scoliodon

- Scoliodon is an elongated spindle-shaped animal.
- It has a laterally compressed body.
- A fully-developed specimen of the genus attains a length of about 60 cm.
- The body is divisible into head, trunk and tail.
- The head is dorsoventrally flattened and terminates anteriorly into a dorsoventrally compressed snout.
- The dorsal side of Scoliodon is dark-grey while the under-side is pale white.

Cont……

- The trunk is more or less oval in transverse section.
- It attains maximum thickness in the middle region and the body gradually tapers posteriorly into a long tail (Fig.).
- The tail is also oval in cross-section (Fig.) and bears a heterocercal type of caudal fin, i.e., the posterior end of the vertebral column is bent upwards and lies in the dorsal or epichordal lobe.

Cont…..

- The teeth are replaced if these are broken.
- The teeth of Scliodon are modified scales.
- The scales cover its body and extend inside the jaws to serve as teeth (Fig.).
- The transition of the placoid scales into teeth is amply recorded in the jaw regions.
- Two prominent circular eyes are present.
- Each eye is provided with movable upper and lower eyelids. The third eyelid or nictitating membrane can cover the whole eye in emergency.
- The pupil is a vertical slit-like aperture (Fig.).

Cont….

- The nostrils are placed one at each angle of the mouth.
- These are exclusively olfactory in function and have no connection with the mouth cavity.
- Each nostril is partly covered by a small fold of skin.
- Posterior to the eyes there are five vertical slits on each side.
- They are called gill or branchial slits.
- The branchial slits lead into the gill-pouches which in turn open into the pharyngeal cavity.

Cont….

- The cloaca opens to the exterior by a cloacal aperture which is located in between the two pelvic fins. The cloacal aperture is an elongated opening.
- The cloaca is a common chamber, into which anus, urinary and genital apertures open. On each side of the cloaca lies the abdominal pores.
- The abdominal pores are paired structures and situated on elevated papillae to communicate the coelom to the outside.
- A faint lateral line is present. Beneath this line a canal is present. The canal opens to the exterior by minute pores at intervals.
- Many pores, called ampullary pores, are also present on the head.

Fins:

- As in other fishes, Scoliodon bears unpaired and paired fins which are actually flap-like integumentary extensions of the body.
- These are flexible and are stiffened by cartilaginous rods or horny fin-rays.
- All the fins are directed backwards which is of positive advantage in swift forward movement in water.

Median unpaired fins:

- The fins under this category include two dorsals, one caudal and one ventral fin.
- The dorsal fins are triangular in outline.
- The anterior dorsal is larger and situated at about the middle of the body.
- The posterior dorsal is comparatively small and occupies a median position between the first dorsal and the tip of tail

Cont….

- The caudal fin has one ill- developed ventral lobe (hypochordal) which is divided into two parts.
- Two shallow depressions, called caudal pits, are regarded as the diagnostic features of the genus.
- These are present at the root of the tail, one at the dorsal surface and another on the ventral.
- The median ventral fin is located in the mid-ventral line and just anterior to the caudal fin.

Lateral paired fins:

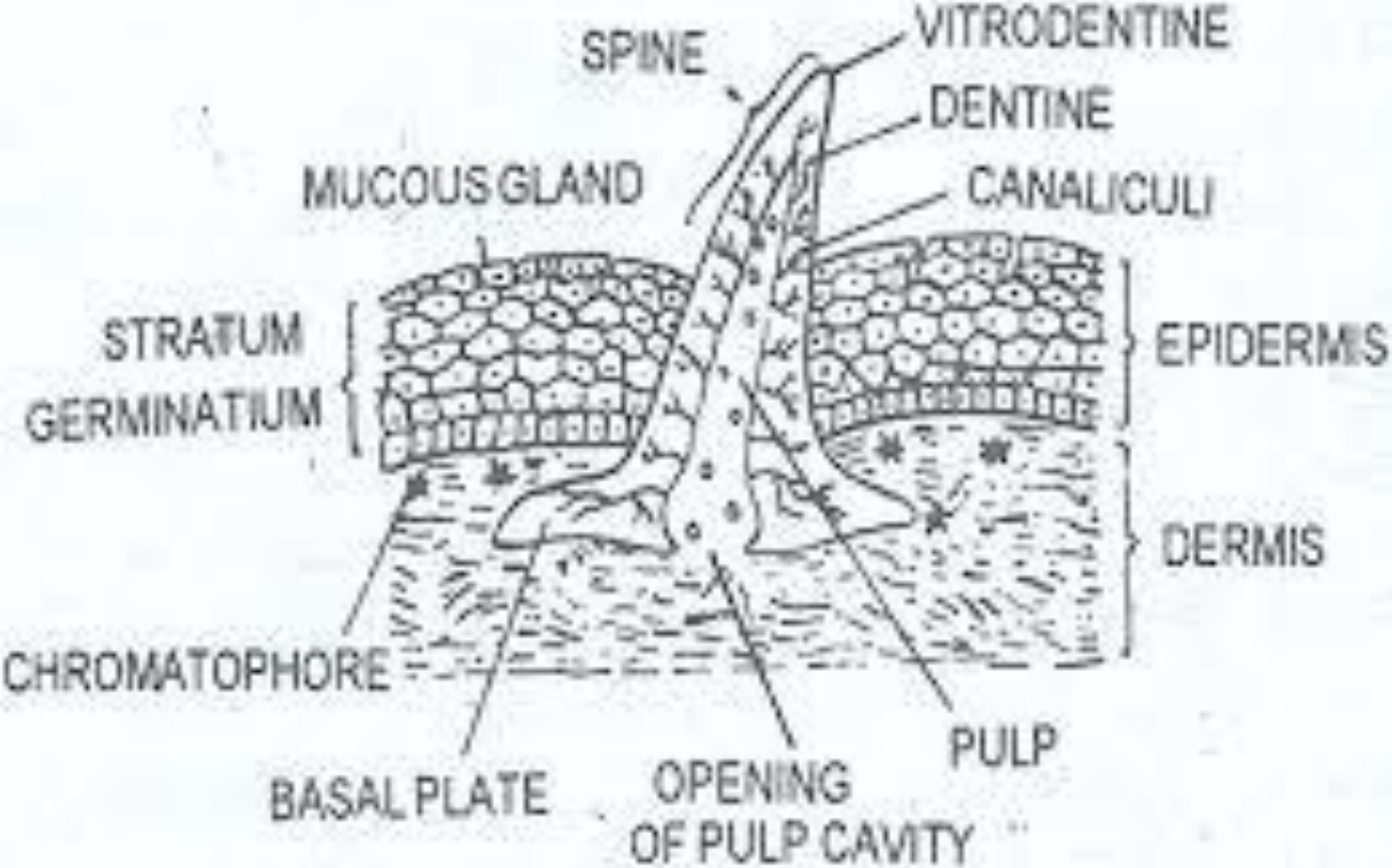
- Two pectoral and two pelvic fins constitute the lateral paired fins.
- The pectoral fins are large and are situated posterior to the gill-clefts.
- The pelvic fins are much smaller.
- In females, these are simple but in males each of them is connected with a copulatory organ called myxipterygium or clasper.
- Clasper is rod-like in appearance having a dorsal groove leading to a siphon at its base.

Skin of Scoliodon:

- The integument is composed of an outer epidermis and an inner dermis.
- The epidermis is composed of epithelial cells inter-mixed with numerous unicellular mucous glands.
- In the young stage the epithelial cells are ciliated. But in an adult the cilia are lost.
- **The dermis is composed of three layers:**

Cont….

- (i) Stratum laxum,
- (ii) Stratum compactum and
- (iii) Subcutaneous layer.
- The stratum laxum is the outer layer and lacks fibres.
- The median layer is the stratum compactum which is fibrous in nature.
- The basal plate of the placoid scale is tied to this layer by fibres.
- The subcutaneous layer is variable in thickness and contains fine fibres arranged in a reticular fashion.



V. S. OF SKIN OF SCOLIODON

Muscular System of Scoliodon:

- Between the endoskeleton and the skin there are closely packed muscles.
- The muscles are highly developed in the trunk and tail regions and exhibit distinct segmental arrangement.
- There are numerous myotomes which are separated from one another by partitions made up of tough connective tissue called the myocommata.

Cont……

- The muscle fibres run parallel to the length of the body in each myotome.
- In the head region, the muscles do not exhibit any sign of segmentation and have become specialised to control the movement of the jaws, pharynx and eyes.
- In the trunk region, the muscles are greatly thickened on the dorsal side on each side of the vertebral column, whereas in the tail region the muscles are equally developed round the vertebral column (see Fig.).

Skeletal Structures of Scoliodon:

- Scoliodon possesses well-developed exoskeletal and endoskeletal structures.
- The exoskeleton includes predominantly the scales which are present all over the body.
- The endoskeleton embraces the axial and appendicular skeleton.

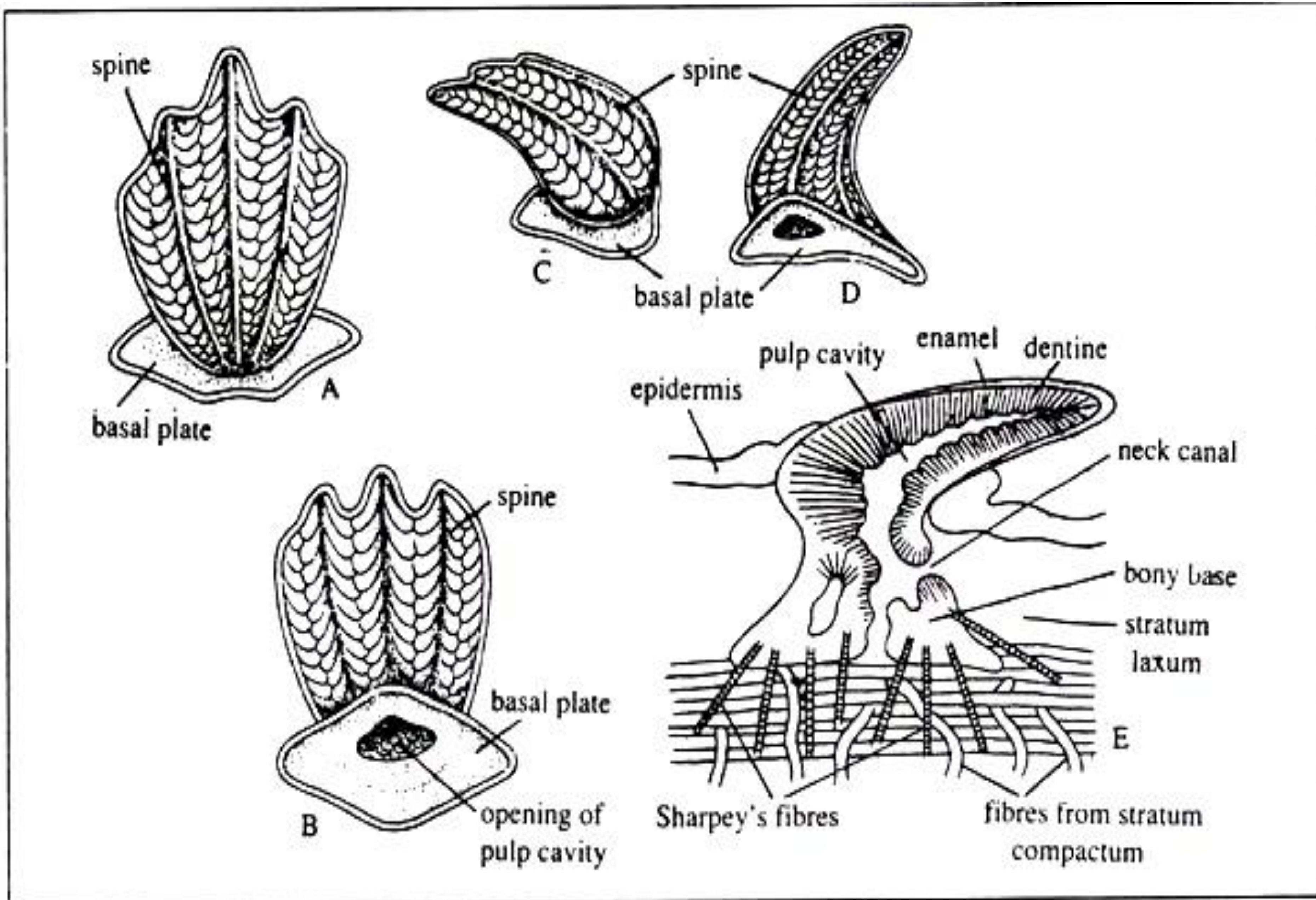


Fig. 6.3 : Placoid scales of *Scoliodon*. A. Dorsal view. B. Ventral view. C. Dorsolateral view. D. Ventrolateral view. E. Diagrammatic sectional view (after various sources).

Exoskeleton

- The entire surface of the body is covered by oblique rows of placoid scales(Fig.).
- A typical placoid scale has a basal plate made up of calcified tissue which remains embedded in the skin and a backwardly directed spine projecting out of skin.
- The basal plate is held in the dermis by Sharpey’s and other fibres (Fig. 6.3E).
- A perforation is present at the base of the spine which communicates the pulp cavity of the basal plate with the pulp cavity in the spine.

Cont…..

- The spine is composed of dentine coated externally with enamel. The nature of enamel is controversial.
- It is called the fibro dentine, because it is formed as the calcification of the fibrous material between the dentine and the enamel organ.
- The scales covering the body extend inside the jaws, where they act as teeth.
- Placoid scale has dual source of origin and develops partly from epidermis and partly from dermis.
- The basal plate as well as the dentine of the spine is the derivatives of the mesoderm.
- The enamel is derived from the ectodermal enamel organ.

Locomotion in Scoliodon:

- The movement of Scoliodon is caused by the activities of the myotomal longitudinal muscle fibres and is also aided by movement of the fins.
- In the phylogenetic history of the fishes, the fins were primarily employed to raise the body off the bottom, but these become secondarily used in swimming by producing undulatory movements.
- The longitudinal muscle fibres composing the myotomes play the important role in swimming.
- The myotomes are placed on either side of the incompressible vertebral column which acts as a lever upon which the myotomes work.

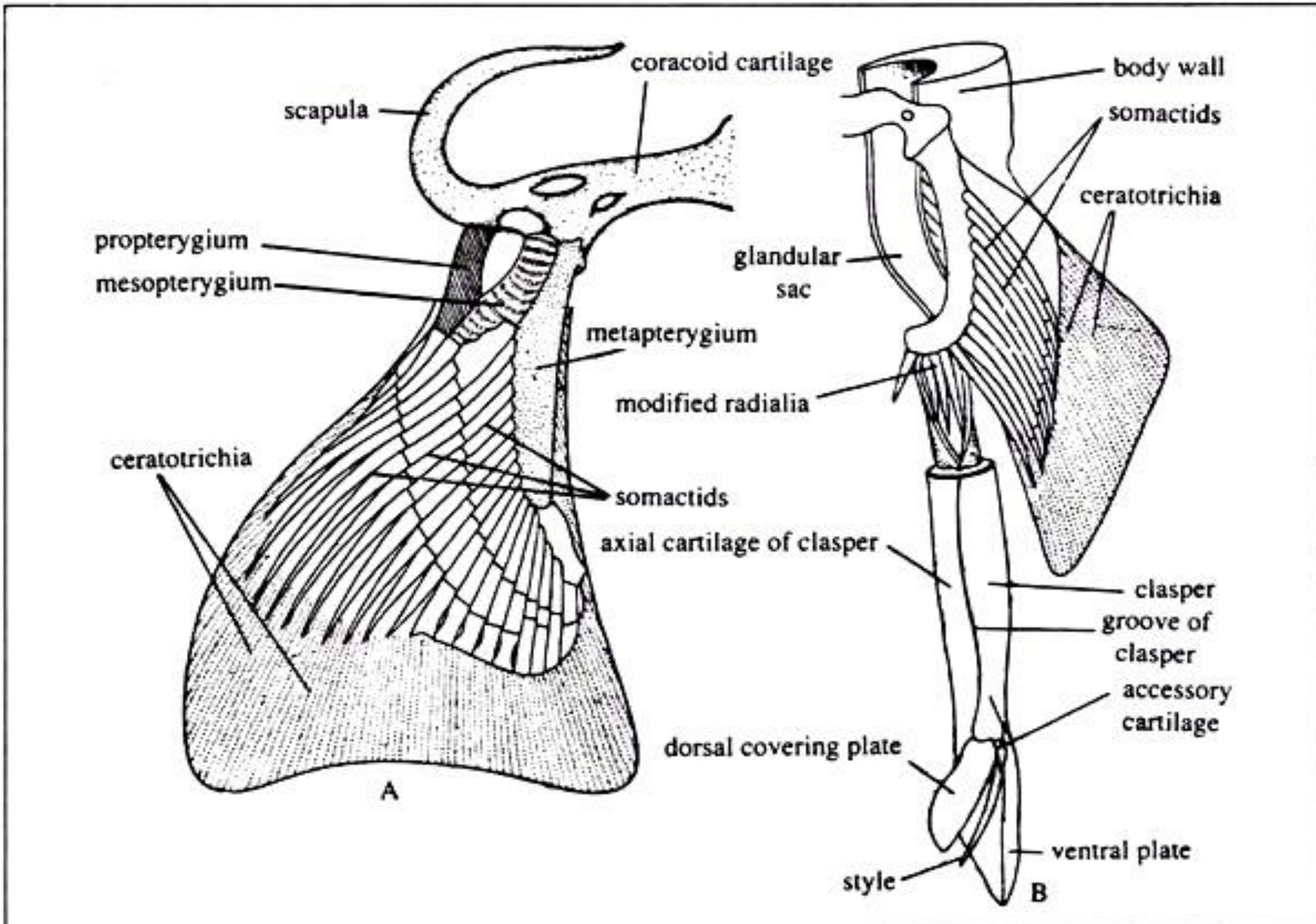


Fig. 6.5 : Appendicular skeleton of *Scoliodon* (after Thillayampalam). A. Half of the pectoral girdle and fin (ventral view). B. Half of the pelvic girdle and fin of a male (dorsal view).

Cont….

- The contractility of the myotomes thus causes the bending of the body.
- During forward progression the contraction of the myotomes occurs along the anteroposterior direction in such a way that the waves of curvature pass down each side of the body alternately from the head to the tail.
- Such contraction is called **the metachronal contraction.**
- It has been calculated that about **54 waves are produced per minute during steady swimming**.

Cont…..

- The controlling factors governing such contraction of muscles are not fully known.
- In Scoliodon, the transaction of the spinal cord behind the medulla oblongata is capable of producing swimming movements for several days.
- This phenomenon suggests that rhythm of contraction is largely governed by the spinal cord, but the influence of brain on the whole process is yet unsolved.

Cont.....

- The body and fins are specially modified to maintain an equilibrium in water during swimming.
- The dorsal fin is well-developed and helps to restore stability and helps in the restoration of equilibrium, if there is any deviation along the vertical axis of the body.
- The pectoral fins play a very important role in turning of the fish by the unilateral breaking with the pectoral fins.

Cont…..

- The pectoral fins also help to maintain stability in the vertical plane.
- The movable pectoral fins lift the head upwards and this is compensated by the heterocercal tail.
- The hypochordal lobe is flexible and the epichordal part is rigid.
- The flexibility of the hypochordal lobe gives a vertical lift of the tail.
- The pelvic fins have no utility in locomotion and usually help in reproductive functions, specially in males.

Coelom of Scoliodon:

- In Scoliodon, the coelom is spacious and is divided into a smallest pericardial cavity and an extensive abdominal cavity.
- These two cavities are separated by the septum transversum and communicate with one another through pericardioperitoneal canal situated in the septum.
- The abdominal cavity contains the viscera (Fig. 6.6) and opens to the exterior through a pair of abdominal pores.
- The pericardial coelom houses the heart.

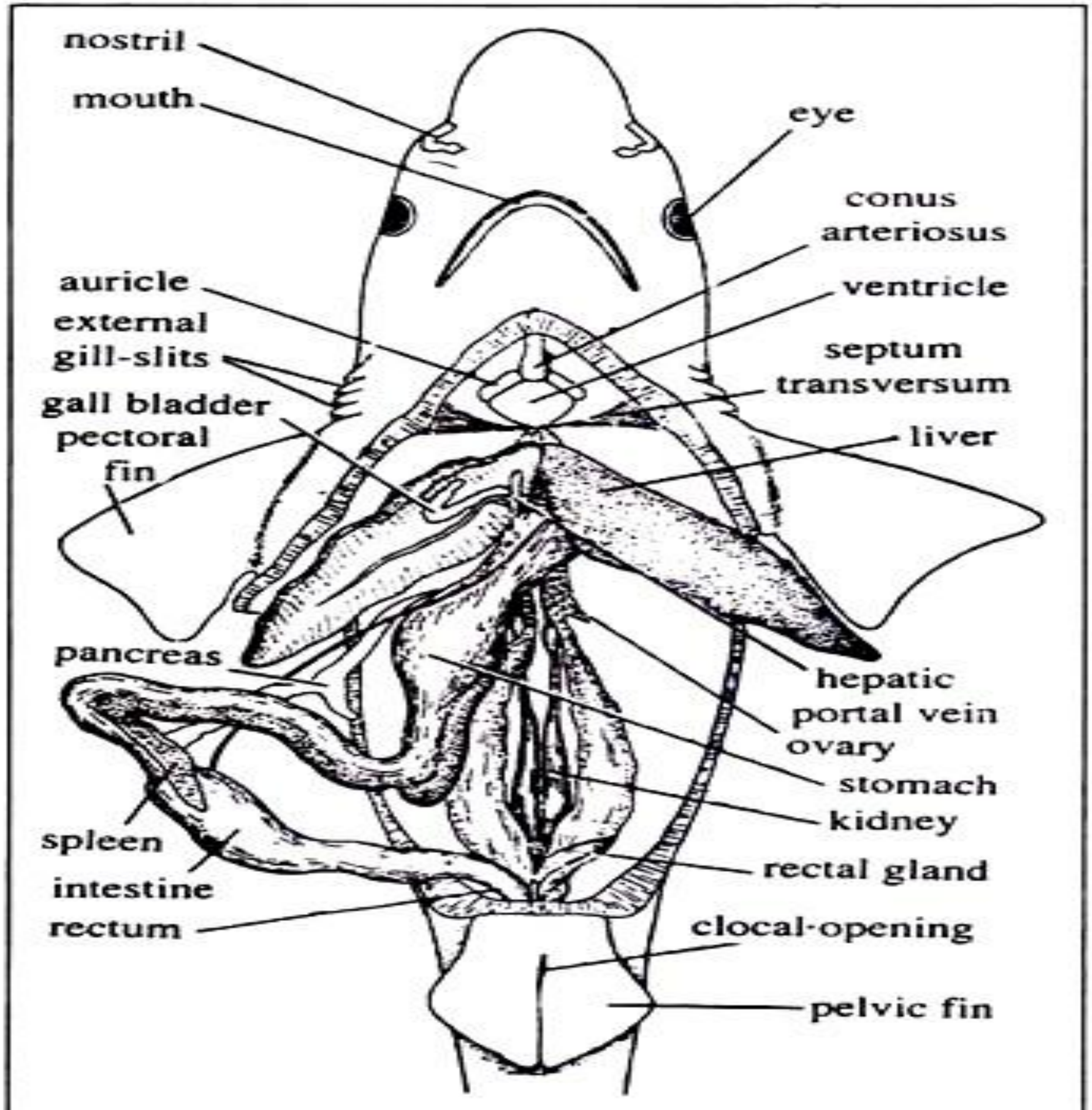


Fig. 6.6 : Dissection of a female *Scoliodon* to show the position of the internal organs (after Thillayampalam, 1928).

Digestive System of Scoliodon

- The digestive system consists of the alimentary canal and the digestive glands.
- The alimentary canal starts with the mouth and terminates in the anus.
- The mouth leads into a spacious buccal cavity which is lined with mucous membrane.

Cont….

- The floor of the buccal cavity becomes folded to form a non-muscular and non-granular **‘tongue**’.
- The mucous membrane is very thick and rough due to the presence of dermal denticles or teeth. The teeth are very sharp and are obliquely placed (see Fig. 6.2C).
- **The teeth** are homodont (i.e., the teeth are similar in shape) and lyodont (possesses several sets of teeth functioning in succession).

Cont…

- The buccal cavity leads into pharynx.
- On either side of the pharynx there lie the internal openings of the spiracles and five branchial clefts.
- The mucous membrane of the pharyngeal wall contains numerous dermal denticles.
- The pharynx leads into a narrow oesophagus.
- The inner mucous membrane of the pharynx is raised to form longitudinal folds.

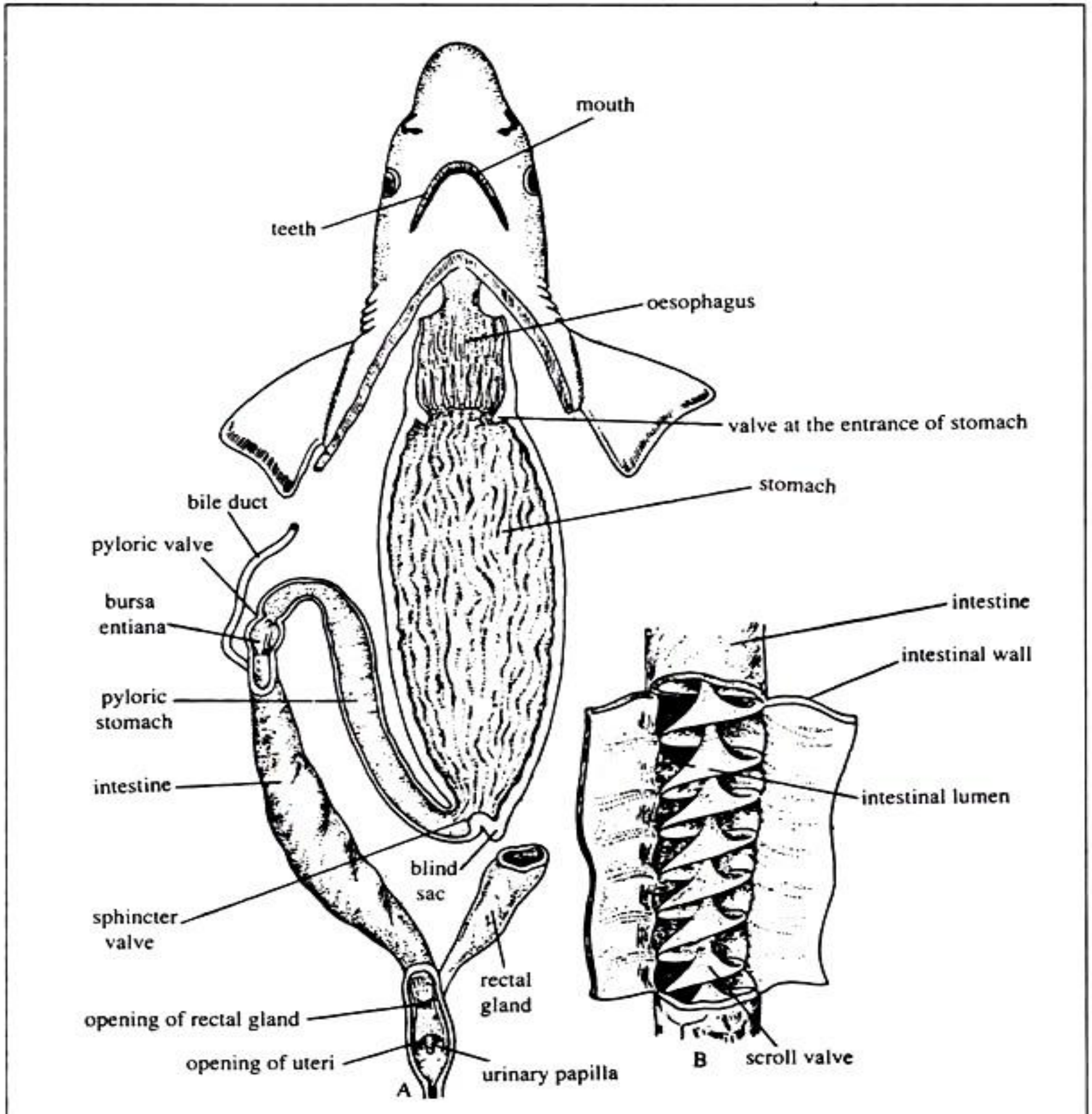


Fig. 6.7 : Digestive system of *Scoliodon*. A. Entire digestive tract. The oesophagus, stomach and rectum are dissected longitudinally to show the internal details. B. A portion of the intestine is cut open to show the scroll valve (after various sources).

Cont…

- The oesophagus dilates posteriorly to form a large stomach.
- The stomach is highly muscular and is bent on itself to form a J-shaped configuration.
- The long limb of the stomach is continuous with the oesophagus and the shorter one passes into the intestine.
- The entrance of the oesophagus into the stomach is provided with a crescentic fold which serves as the valve.

Cont…..

- The long anterior limb is called the cardiac stomach and the short posterior limb is designated as the pyloric stomach.
- A small outgrowth often called 'blind sac' is present at the junction of the cardiac and pyloric limbs.
- The inner lining of the cardiac stomach is folded longitudinally like that of oesophagus (Fig. 6.7A).
- The internal lining of the pyloric stomach is mostly smooth though slight foldings are observed at the distal end.

Cont…..

- The pyloric valve, at the end of the pylorus, guards the entrance of it into a thick-walled small chamber called the bursaentiana.
- At the end of pyloric stomach a small globular, muscular sac is present containing continuation of longitudinal folds of pyloric stomach is called **Bursaentiana.**
- The bursaentiana is immediately followed by wide tubular intestine which becomes narrowed posteriorly as the rectum.
- The rectum opens into the cloaca.
- A tubular caecal or rectal or digit form gland opens into the rectum.

Cont…

- The inner surface of the intestine becomes folded to form an anticlockwise spiral of approximately two and a half turns.
- This is called the scroll valve (Fig. 6.7B) which increases the absorptive surface of the intestine.
- The passage of food slows down in scroll valve to ensure proper absorption.
- The intestine is not connected with mesentery and is opened into the rectum.

Cont….

- Rectum:
- It is a short narrow straight tube suspended by mesorectum. In between ileum and rectum there is rectal valve containing circular muscles.
- It receives rectal gland which is similar to medulla of kidney and excretes excess salts. Rectum leads to cloaca.
- Cloaca: It is short terminal chamber, which receives ducts of urinogenital system. It has a pair of abdominal pores.
- Cloacal aperture: It is a small longitudinal aperture present between two pelvic fins.

Glands of the Alimentary Canal:

- The glands of alimentary canal (digestive glands) are liver and pancreas.
- **a. Liver, Rectal Gland, and Spleen:**
- The liver is an elongated yellowish gland, consisting of two lobes which extend back along the greater part of the abdominal cavity.
- The two lobes are united anteriorly and attached to septum transversum by a ligament, but remain apart posteriorly

Cont….

- The right lobe of the liver carries a V-shaped thin-walled sac, the gall bladder, which stores the bile secreted by the liver.
- The gall bladder communicates with the anterior end of the intestine through bile-duct.
- In a full grown specimen the bile duct is about 3 cm long.
- The liver produces bile, stores glycogen and fat. It also destroys worn-out red blood corpuscles since Kupffer cells are present.

Cont…

- **b. Pancreas:**
- The pancreas is a compact bilobed gland situated in the angle between the cardiac and pyloric stomach.
- It comprises a longer dorsal lobe running parallel to the posterior part of the cardiac stomach and a smaller ventral lobe lying closely applied to the pyloric stomach.
- The pancreatic duct opens into the intestine just opposite to the opening of the bile-duct.

Cont…

- **c. Rectal Gland:**
- The rectal or caecal gland is a short thick hollow diverticulum arising from the dorsal wall of the rectum.
- It is richly vascularised and formed of lymphoid tissue.
- It discharges a fluid into the intestinal lumen but the physiological effect of the fluid is unknown.
- **d. Spleen:**
- It is a large lymphoid organ attached with the cardiac and pyloric stomach.
- It produced lymphocytes and, thus, has no physiological relation with the alimentary canal.

Food and Physiology of Digestion:

- Dogfish (Scoliodon) is carnivorous and feeds mainly on other fishes, but the diet may also include rock-crabs, lobsters and spider-crabs.
- Food is swallowed without mastication.
- The teeth of Dogfish (Scoliodon) only prevent the escape of prey from the mouth and do not perform the function of mastication.
- Probably the teeth may be used for tearing the food.
- Since there are no salivary glands in the mouth there is no digestion in the buccal cavity.

Cont……

- The wall of the pharynx possesses numerous mucous glands.
- The secretion of these glands has no digestive function but simply helps in the passage of food. The oesophagus also has no digestive function.
- The digestion starts only in the cardiac stomach.
- The mucous membrane of cardiac stomach secretes the gastric juice which contains pepsin and hydrochloric acid that converts proteins into syntonin, proteoses and peptones.
- The gastric juice is not able to digest chitin.

Cont….

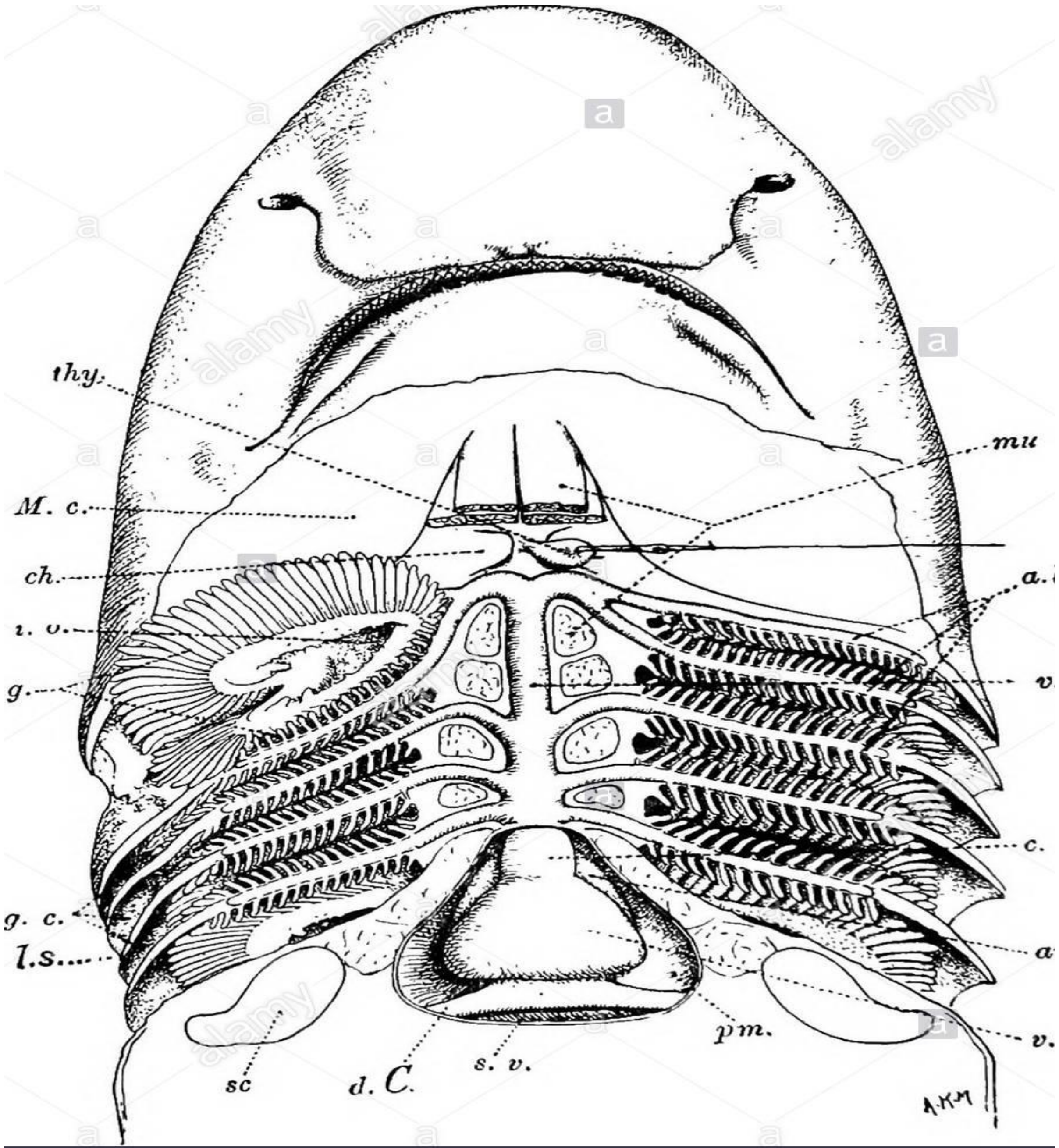
- The pyloric stomach and scroll-valve have no digestive activity of their own but they activate the pancreas.
- The pancreas secretes trypsin, amylopsin, and lipase. As the semi-digested food enters the intestine it is acted upon “by the bile and the pancreatic juice.
- The bile makes the food alkaline and, thus, helps the action of pancreatic juice.
- The trypsin acts on the remaining proteins, the amylopsin converts starch into sugar and lipase turns fats into fatty acids.
- The digested food is absorbed into the blood over the extensive surfaces of the intestine and scroll-valve.

Respiratory System of Scoliodon:

- In scoliodon, the respiration is aquatic, i.e., respiration in water and it breathes by means of gills borne in a series of gill pouches on either side of the pharynx.
- Water enters the mouth and after passing through the buccal cavity, pharynx, gill-pouches and goes out through the gill slits after bathing the gills.

Respiratory Organs:

- There are five pairs of lateral gill-pouches situated in the lateral walls of the pharynx and are arranged in a series on their side.
- Each gill-pouch is compressed antero-posteriorly and communicates with the cavity of the pharynx through a large internal branchial aperture and with the exterior through a narrow external branchial aperture (commonly called gill slit).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Gill sectional view

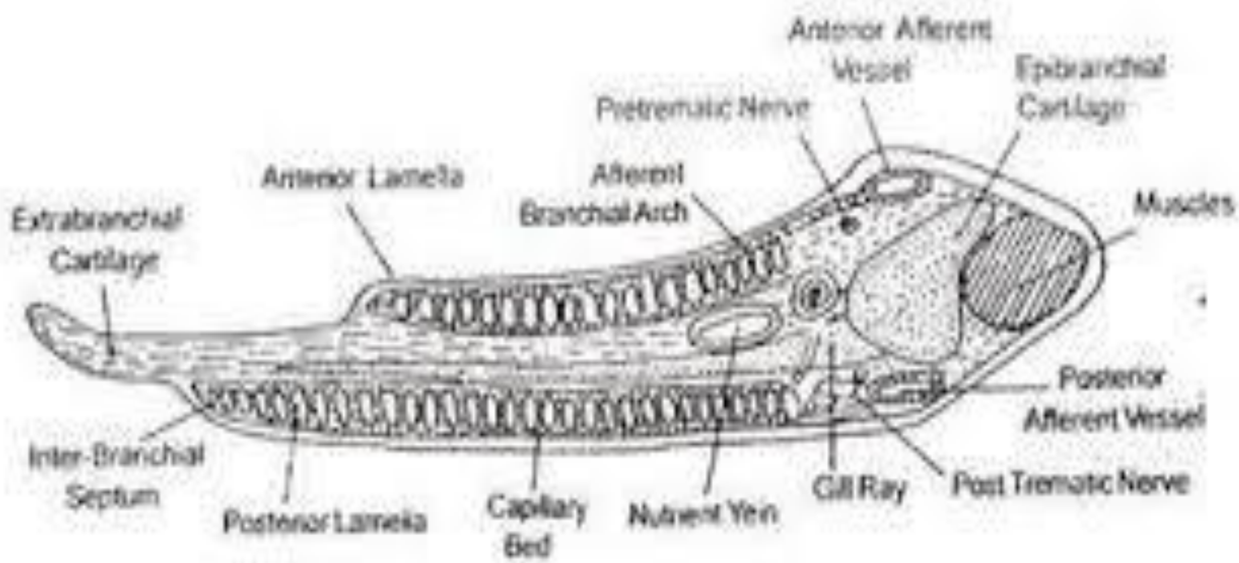

Fig.7.6 Scoliodon – horizontal section of a holobranch, arrows indicate the flow of blood.

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- The endodermal mucous membrane of gill-pouches is raised in to a series of horizontal folds to form lamelliform branchial lamellae.
- The branchial lamellae have a rich blood supply, and they have a very thin covering membrane through which blood is exposed to seawater for an exchange of gases.

Cont……

- Each gill-pouch has two sets of gill-limellae is a **half gill or hemi branch**, so that gill-pouch has two by muscular interbranchial septa of connective tissue (they should more correctly be called interabranchial septa because each lies between two successive gill-pouches).
- The interbranchial septa extend well beyond the branchial lamellae, and then each bends posteriorly to protect the lamellae.

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- The inner part of each interbrachial septum has a supporting visceral arch from which cartilaginous gill rays arise in a single row and project into the interbranchial septum for further support.
- Visceral arches also give out rigid comb-like gill rackers, which protect the internal branchial apertures from food.

Cont……

- Each visceral arch supports the posterior branchial lamellae or hemibranch of one gill-pouch and the anterior branchial lamellae, or hemibranch of the gill cleft behind it.
- These two hemibranches with their interbranchial septum and the visceral arch constitute **a complete gill or holobranch.**
- The posterior hemibranch of each holobranch is larger than the anterior one.

Cont…….

- Between the mandibular hyoid arches of each side is a spiracle. In most Elasmobranches the spiracle bears branchial lamellae and opens to the exterior by an external branchial aperture. It is supplied with arterial blood and plays no part in respiration.
- But in Scoliodon the spiracles are vestigial pits in the pharynx with no lamellae or external branchial aperture.
- The hyoid arch bears only a hemibranch posteriorly. The first four branchial arches bear a holobranch each, the fifth branchial arch has no branchial lamellae, and thus scoliodon has nine hemibranches on each side.

Mechanism of Respiration:

- The floor of the buccopharyngeal cavity is despressed by hypobranchial (hypoglossal) muscles and the mouth is opened at the same time the viscera arches expand the wall of the pharynx,
- so that sea-water containing dissolved oxygen rushes in through the mouth.

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- Entry of the water into external brachial apertures is prevented by an anterior fold is then raised and the mouth is closed, and contractions of the wall of the pharynx force the water into internal branchial apertures, the oesophagus being closed, and then into gill –clefts, where it washes the branchial lamellae and goes out of the external branchial apertures.

Cont…….

- In the branchial lamellae, the blood flows from the tip towards the base that is in a direction opposite to that of the water current, so that the blood just before leaving the lamellae meets the highest concentration of oxygen and the lowest of carbon dioxide takes place between the blood and seawater.
- The respiratory movements are caused by pharyngeal muscles, which are innervated by V, VII, and IX and X cranial nerves and the spinal nerve.

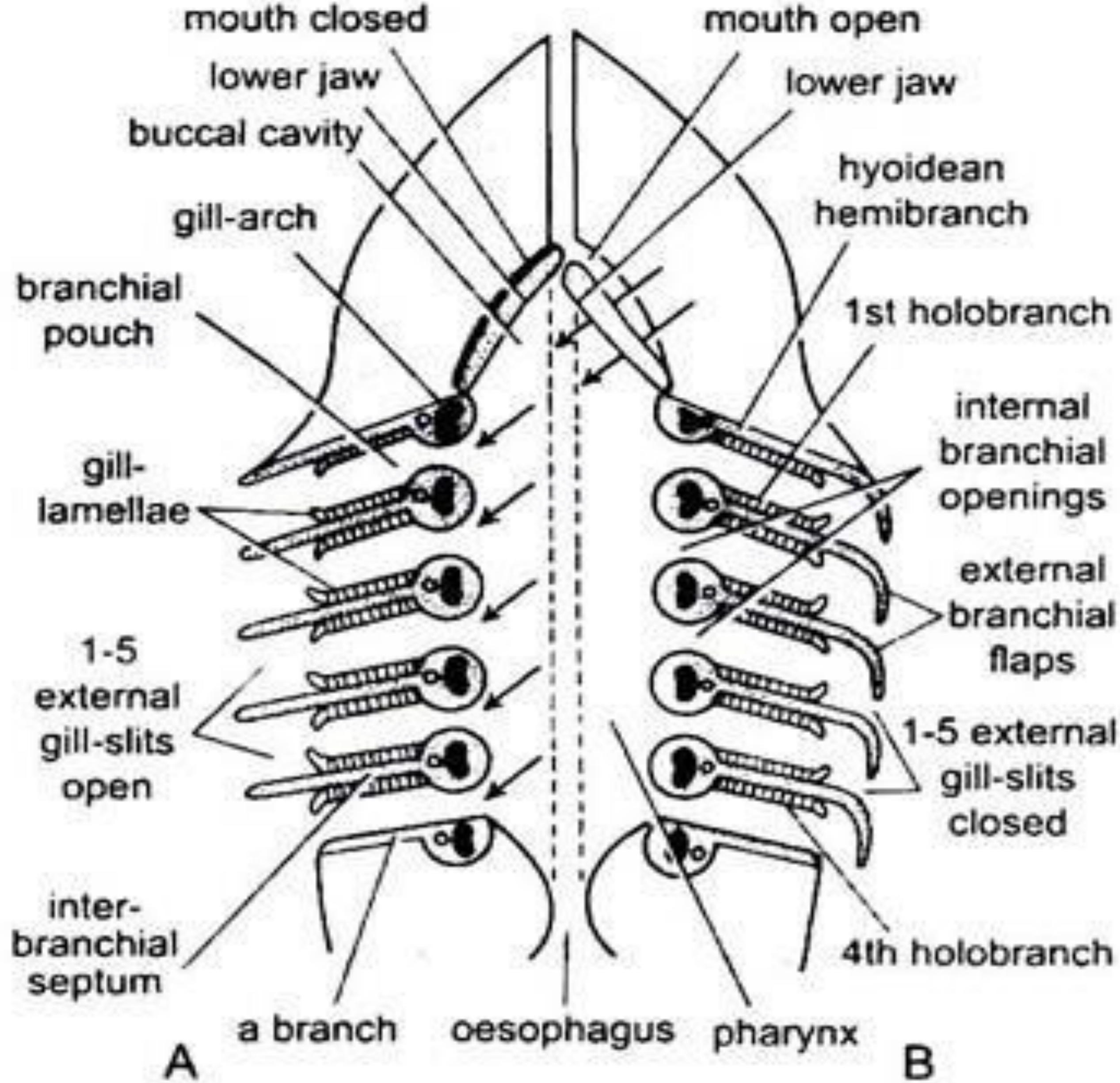


Fig. 14.27. *Scoliodon.* Respiratory mechanism. A–Expiration; B–Inspiration.

Physiology of Respiration:

- Fresh seawater entering the gill pouches with the respiratory current contained within the capillaries of the gill lamellae merely by the thin and permeable membranous walls of the capillaries,
- the oxygen of the water passes by endosmosis through the thin capillaries walls into the blood passes into the water by a process of exomosis.

Cont….

- The oxygen is carrieded by the blood to all the parts of the body, while carbon dioxide brought to the gill in the venous blood is eliminated by the water of the outgoing respiratory current.
- As the blood makes a complete circuit in the capillaries of the gills in a very short time, it is evident that exchange of gases also takes place very quickly.

Circulatory System of Scoliodon:

- **The circulatory system consists of:**
- (a) The circulatory fluid, called blood, (b) The heart,
- (c) The arteries and (d) The veins.
- **Blood:**
- The blood consists of a colourless plasma and corpuscles are suspended in the plasma.
- Two kinds of corpuscles are encountered; the RBC (or erythrocytes) and the WBC (or leucocytes).
- The erythrocytes are oval bodies containing a nucleus.
- The haemoglobin is present in the erythrocytes.
- The leucocytes are amoeboid in structure.

Scoliodon : **Heart and Pericardium**

- The heart of Dogfish (Scoliodon) lies mid-ventrally beneath the pharynx in the head region.
- It is a simple dorso-ventrally **bent S-shaped** muscular tube. It lies in the pericardial cavity, bounded by a two layered membranous pericardium.
- It is a median triangular cavity lying between the gills with the apex directed forwards, and is almost completely occupied by the heart.
- The heart of Scoliodon contains only the impure blood, hence, it is **called venous or branchial heart.**

The heart consists of four chambers:

(a) The sinus venosus

(b) The atrium,

(c) The ventricle and

(d) The conus arteriosus.

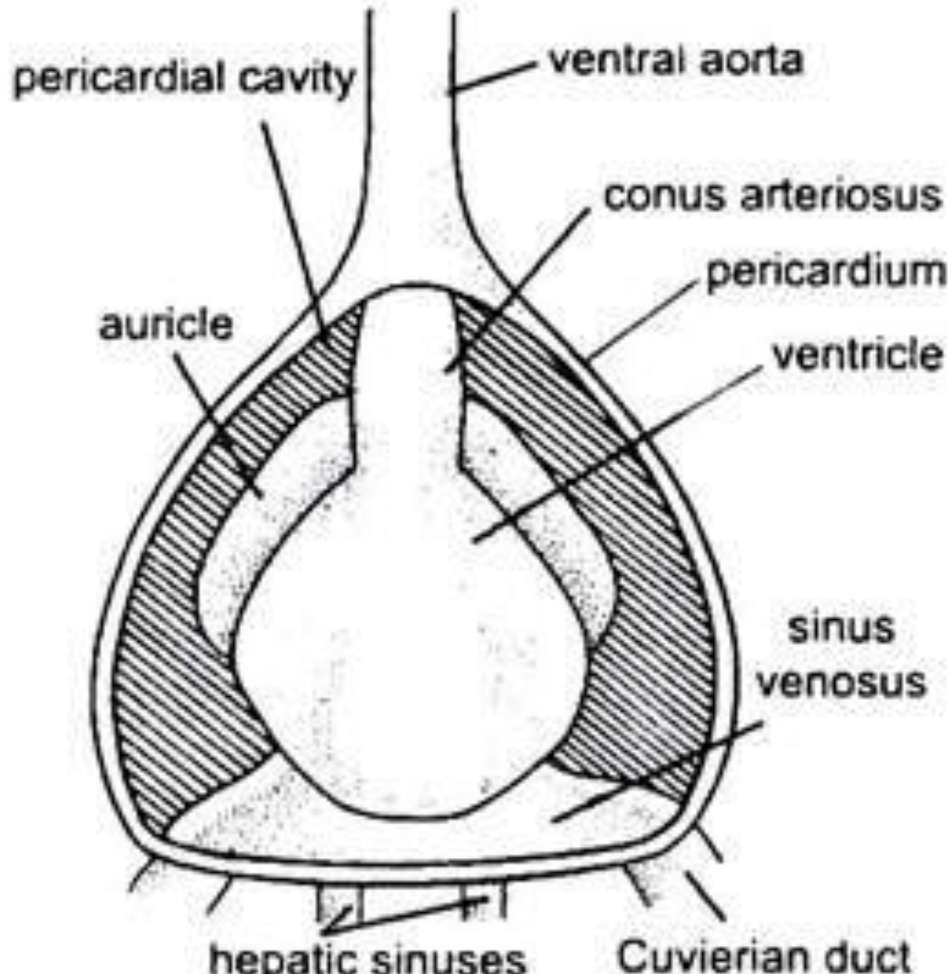


Fig. 14.28. *Scoliodon*. Pericardium and heart in ventral side.

(a) Sinus Venosus:

- The sinus venosus is a triangular, thin walled posterior chamber extended transversely and lying fused along the base of the pericardial cavity.
- Laterally it receives two large veins, the ducti Cuvieri, one on each side, while two hepatic sinuses open into it in the postero-median line.
- The sinus venosus opens anteriorly into the atrium through the sinu-atrial or sinu-auricular aperture, guarded by a pair of membranous valves, the sinu atrial valves.
- These valves prevent the backward flow of the blood.

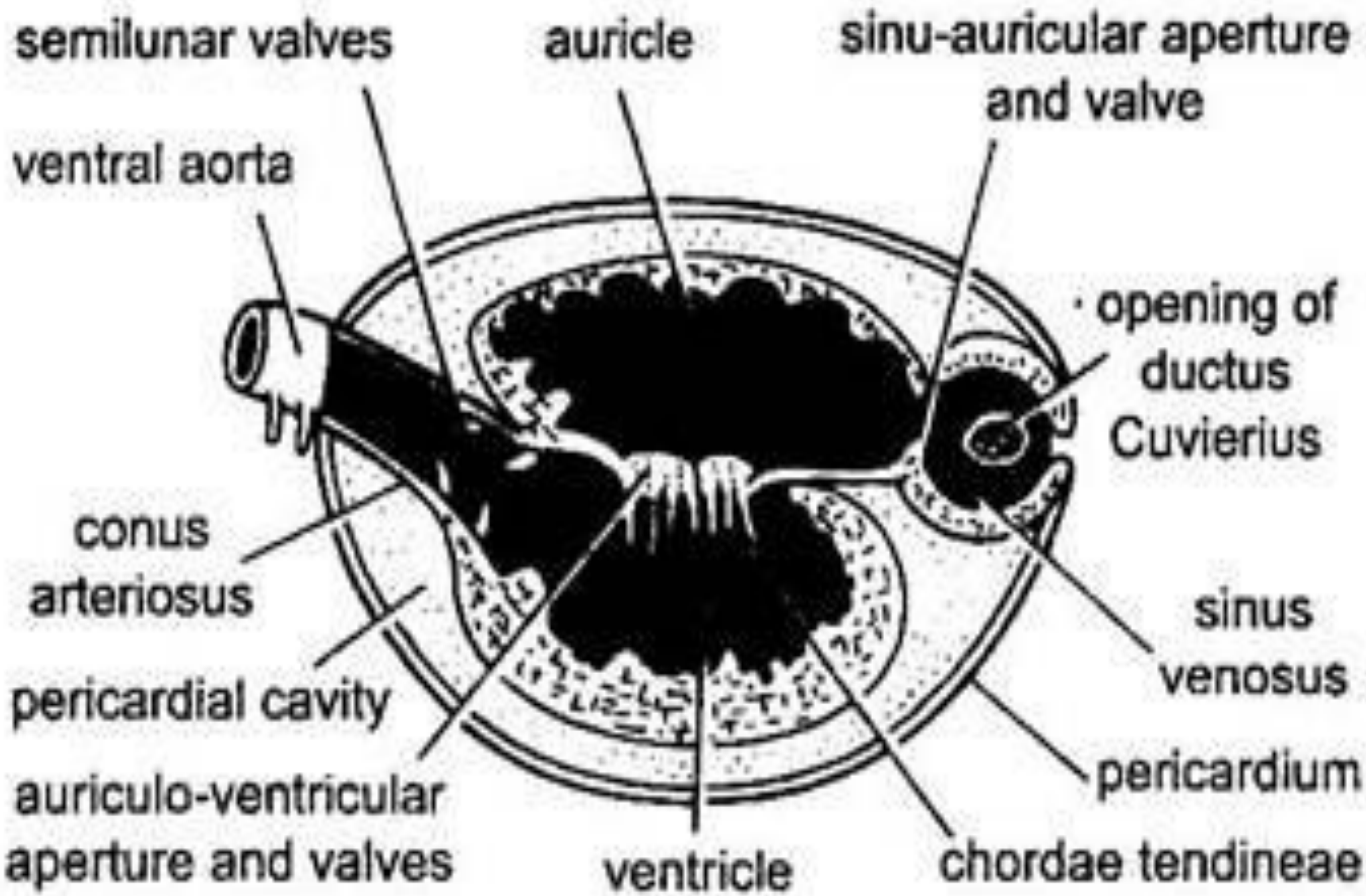


Fig. 14.29. *Scoliodon*. Pericardium and heart in sagittal section.

(b) Auricle:

- The atrium (auricle) is a large triangular sac, lying in front of the sinus venosus and dorsally to the ventricle.
- It occupies the dorsal half of the pericardial cavity. Its walls are somewhat thicker than those of the sinus venosus.
- Its lateral posterior angles produced into processes which project laterally at the sides of the ventricle like ears it opens into the ventricle through the atrio-ventricular aperture, guarded by a bilabiate valve which prevents the backward flow of the blood.

(c) Ventricle:

- The ventricle is the most prominent pear-shaped chamber of the heart It has very thick muscular walls because it propels the blood to the entire body.
- The inner surface of the ventricle is produced into numerous muscular strands which give it a spongy texture.
- The opposite walls are held in place by chordae tendineae and also protect the ventricle to expand beyond its capacity.
- It communicates dorsally with the atrium through the atrio-ventricular aperture and anteriorly with the conus arteriosus.

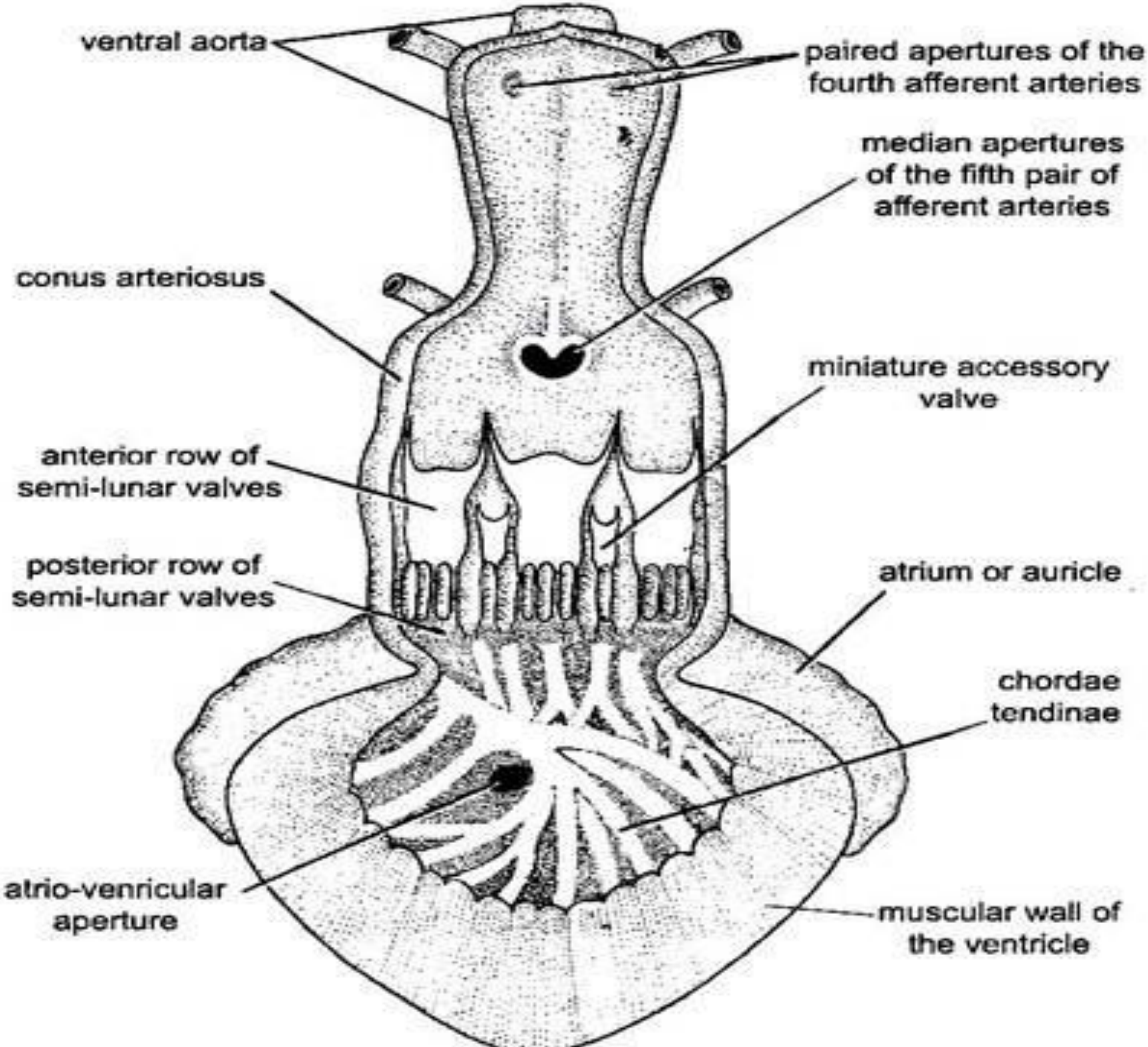


Fig. 14.30. *Scoliodon.* Heart dissected from ventral side to show internal structure.

(d) Conus Arteriosus:

- The conus arteriosus is a stout muscular tube which arises from the ventricle and extends up to the anterior end of the pericardial cavity.
- Its inner wall is provided with two transverse rows of semilunar valves, each row containing three valves, one dorsal and two ventro-laterals in position.
- In addition to these, there is always a small accessory valve on either side of the dorsal valve.
- The anterior valves are larger than the posterior valves.

Cont….

- The free-ends of the valves are connected to the walls of the ventricle by fine tendinous threads to keep the valves in position.
- These valves prevent the backward flow of blood into the ventricle.
- The conus arteriosus is continued forward through the wall of the pericardium as the ventral aorta.
- The ventricle and conus constitute the forwarding pump for the blood.

Working:

- The heart of dogfish is venous type since it receives only venous or deoxygenated blood.
- The blood also flows through the heart only once (single circulation). Heart pumps the venous blood into the gills for aeration.
- For this purpose, the different chambers of the heart rhythmically contract at regular intervals in a definite sequence—first sinus venosus → auricle → ventricle → conus arteriosus.
- Contraction of the heart is called systole and relaxation is called diastole. The valves at different places prevent the backward flow of blood into the preceding chambers. The walls of the heart are also supplied oxygenated blood through coronary vessels.

Nervous System of Scoliodon:

- **The nervous system of Scoliodon includes:**
- (i) The central nervous system,
- (ii) The peripheral nervous system and
- (iii) The autonomous nervous system.
- **Central nervous system:**
- The central nervous system consists of brain and the spinal cord.
- **Brain:**
- The brain is highly organized and shows many advancements over that of the Agnathans.

The brain is divided into three primary parts:

- (a) The forebrain or prosencephalon,
- (b) The midbrain or mesencephalon and
- (c) The hindbrain or rhombencephalon.
- The forebrain consists of a massive undivided cerebral hemisphere. The cerebral hemisphere is relatively larger than that of other fishes. From the anterior end of cerebral hemisphere arise two stout olfactory peduncles, each terminates into a large bilobe olfactory lobe (Fig. 6.12).

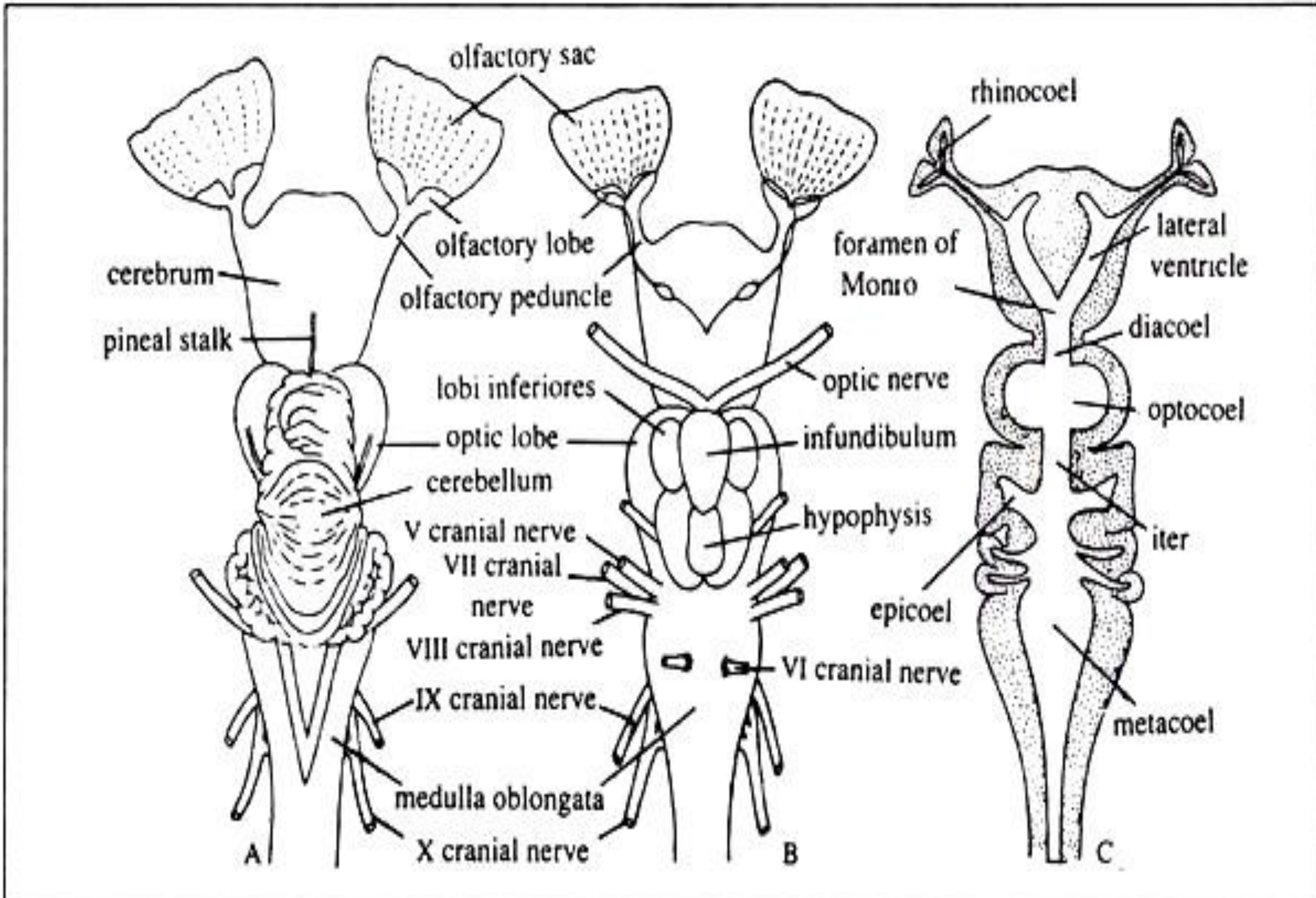


Fig. 6.12 : Brain of *Scoliodon*. A. Dorsal view. B. Ventral view. C. Diagrammatic longitudinal section. Note the position of different ventricles.

Brain cont…..

- The olfactory lobes lie close to the olfactory capsules. Each olfactory nerve is composed of many bundles of nerve fibers. The surface of the cerebrum is smooth and the walls are thick.
- A small opening called the neuropore is present on the mid-ventral surface of the cerebrum.
- The posterior part of fore-brain (diencephalon) is very short. The roof of the diencephalon is thin, non-nervous and contains the anterior choroid plexus.
- The lateral walls of the diencephalon form two thickened bodies, called thalami.

Cont…….

- A long and slender tube, the pineal organ or epiphysis cerebri projects from the roof of the diencephalon up to the membrane covering the anterior frontanella.
- The floor of the diencephalon (or hypothalamus) is well formed. A hollow infundibulum is given off from the floor of the diencephalon.
- The infundibulum is dilated to form two oval thick walled bodies, called lobi inferiores whose distal ends are produced into two thin walled glandular sacs, called sacci vasculosi. The lobi inferiors are the centres for **gustation and smell.**

Cont…..

- The sacci vasculosi is believed to be a centre for reception of the pressure of cerebrospinal fluid and at the same time they produce cerebrospinal fluid.
- The hypophysis is attached to the infundibulum.
- The optic chiasma lies in front of the infundibulum.
- The optic chiasma is formed by the decussation of the nerve fibres of two optic nerves (Fig.).

Mid brain

- The midbrain is large and consists of two round optic lobes.
- The optic lobes are situated behind the diencephalon.
- The floor and the side walls are relatively thicker.
- **The midbrain is considered as the centre of co-ordination.**

Hind rain

- The hindbrain consists of a highly developed cerebellum and a medulla oblongata.
- The dorsal surface of the cerebellum produces many irregular convolutions.
- The cerebellum contains a small cavity.
- **The cerebellum is also a centre of co-ordination.**
- The cerebellum is divided into three lobes by two well-marked transverse furrows.

Cont.....

- The medulla oblongata is triangular and the anterior end gives a pair of hollow corpora restiformia with trace of convolutions in adults.
- The **medulla controls respiration**.
- Two corpora restiformia are connected by the transverse nerve band. The roof of the medulla oblongata is non-nervous and bears the posterior choroid plexus.
- **The hind- brain controls swimming movements**.

Cont……

- The ventricles of the brain are moderately developed (Fig. 6.12C).
- The cerebral hemispheres contain narrow lateral ventricle.
- The third ventricle is extended forward about half the length of the cerebral hemispheres.
- The floor of the fourth ventricle is very much thickened.
- The fourth ventricle is large and extends dorsally into the cerebellum and is continuous behind with the cavity of the spinal cord.

Cont…

- The iter (i.e., the communicating duct between the third and the fourth ventricles) is wider.
- Although the cerebrum is undivided, there are two lateral ventricles which are continued to the rhinocoels (cavity of the olfactory lobes).

Spinal cord:

- The spinal cord in Scoliodon shows definite advancement towards the plan of higher vertebrates, The spinal cord is provided with pia mater only.
- The grey matter is arranged into the dorsal and the ventral horns.
- The dorsal horns are united to form a single broad region, as a result the grey matter assumes a shape of an inverted ‘T’.

Peripheral nervous system:

- The peripheral nervous system includes the cranial nerves and spinal nerves.
- **Cranial nerves:**
- There are ten pairs of cranial nerves in all the fishes. An extra pair of anterior terminal or pre-olfactory nerves is present in Scoliodon.
- **The terminal** nerves are designated as cranial **nerve no. 0.**
- **The first** pair of cranial nerves are the **olfactory** nerves which originate from the olfactory lobes and innervate the olfactory sacs.

Cranial nerves cont….

- The terminal nerves are situated between the two olfactory lobes.
- These nerves emerge from the telencephalon and bear a ganglion, called ganglion terminate, near the origin.
- These nerves supply **the nasal septum and the external nostril.**
- The **second pair** of cranial nerves are the **optic nerves** which, after the origin from the optic thalami, form the optic chiasma and supply the **eyes.**

Cont…….

- The **third cranial** nerve is called **oculomotor nerve** which originates from the ventral surface of the mesencephalon and supplies the anterior, superior and inferior recti and the inferior oblique muscles of each eye ball.
- **The fourth** cranial nerve is called **trochlear or pathetic nerve** which arises from the dorsolateral surface of the midbrain and supplies the superior oblique eye muscle.

Cont…….

- **The fifth cranial nerve is the trigeminal which has three branches:**
- (a) **Ophthalmicus superficialis** which supplies the skin of the snout;
- (b) The **maxillaris** which is divided into maxillaris superior supplying nerves to the skin of the upper jaw and maxillaris inferior innervating the posterior part of the upper jaw;
- (c) The **mandibularis** innervating the muscles of the lower jaw.

Cont…….

- Another nerve called ophthalmicus profundus becomes secondarily associated with the trigeminal to supply nerves to the eye ball and the dorsal surface of the snout (Fig. 6.13).
- The **sixth** cranial nerve is the **abducens** which supplies the posterior rectus muscle of the eye ball.

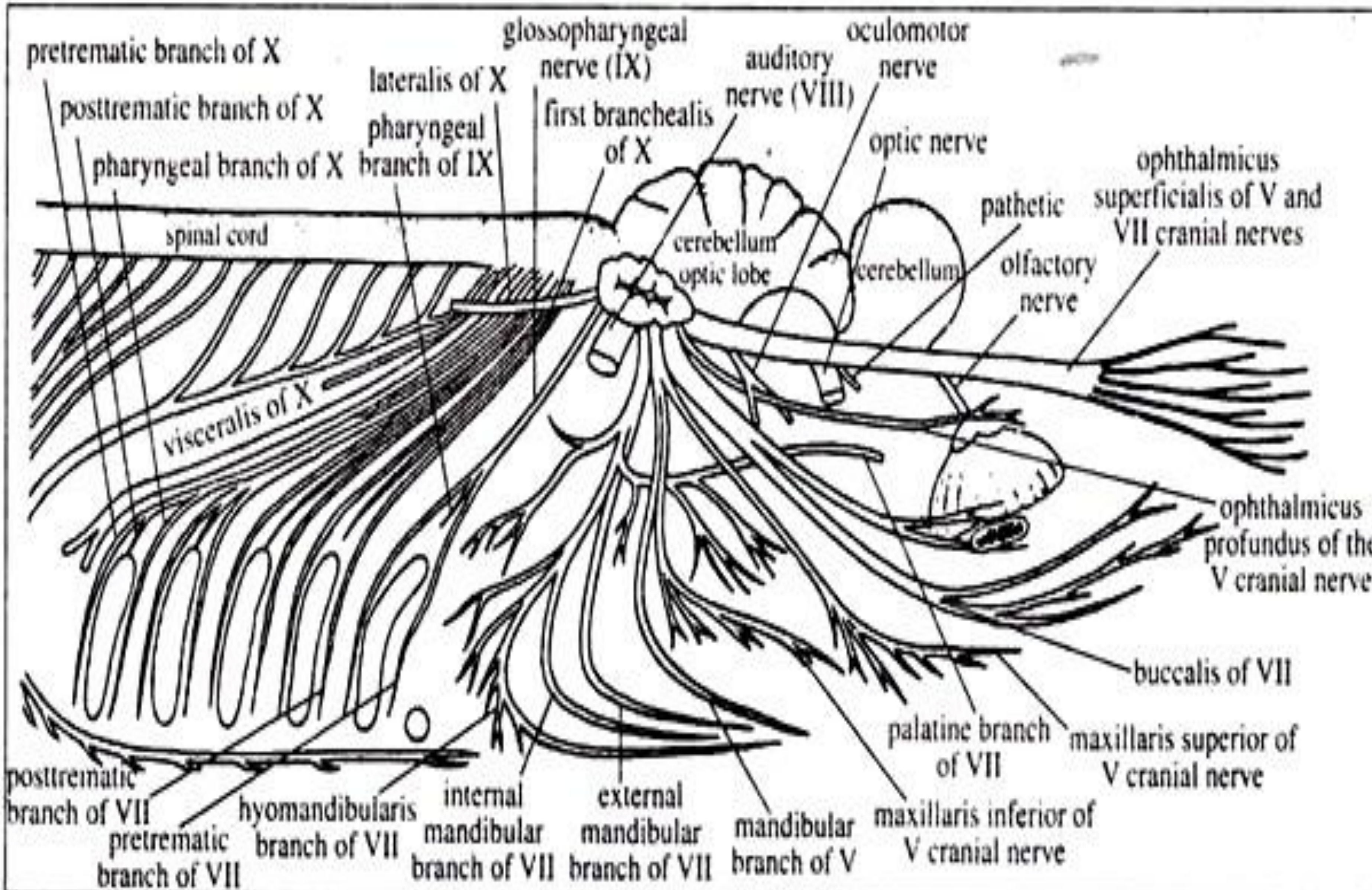


Fig. 6.13 : Schematic view of the origin and distribution of cranial and spinal nerves of *Scoliodon* (after Thillayampalam, 1928).

Cont…….

- **The seventh cranial nerve is known as facial which divides into two branches:**
- (i) The ophthalmicus superficialis branch like that of the fifth cranial nerve and
- (ii) A bundle of mixed nerves which subdivides into three routes:
- (a) A ramus buccalis innervating the infra orbital canal of the snout,
- (b) A ramus hyomandibularis supplying nerves to the lower jaw and throat and
- (c) A ramus palatinus giving nerve supply to the roof of the buccal cavity and the pharynx.
- **The eighth** cranial nerve is called **auditory** which gives the vestibular and saccular branches to the internal ear.

Cont…….

- **The ninth** cranial nerve is the **glossopharyngeal** which, in the region of the first gill-cleft, divides into a small pretrematic nerve and a large posttraumatic nerve.
- These nerves supply branches to the pharynx, pharyngeal muscles and the mucous membrane surrounding the first gill-slit.
- The **tenth** cranial nerve is the **vagus** which arises by multiple roots and gives off many branches.
- **The branches are:**
- (i) The brachial nerves supplying the gills,
- (ii) The lateralis supplying the lateral line sense organs and gives numerous branches along its course.

Cont…….

- **Terminal nerve (Cranial nerve ‘0’):**
- A new cranial nerve was first recorded in 1894 which connects the anterior end of cerebral hemispheres.
- It was first identified in Protopterus and had since been recorded in all gnathostomes excepting birds.
- To avoid confusion which would result if the long established nomenclature and symbols of other cranial nerves were altered, this newly reported cranial nerve was named terminal nerve or cranial nerve ‘0’.
- The terminal nerve leaves the anteroventral portion of the cerebral hemisphere and passes into the mucous membrane of the olfactory organ.

Cont…….

- It is a sensory nerve and possesses one or more ganglia. The terminal nerve is best developed in elasmobranchs.
- In amphibians, reptiles and mammals the terminal nerve is intimately associated with the vomeronasal organ (Jacobson's organ).
- The functional significance of the terminal nerve is not yet fully ascertained.
- It has been suggested that it may represent the remnants of an anterior branchial nerve which has lost its significance in course of evolution.

Spinal nerves:

- The spinal nerves arise from the spinal cord. Each has one dorsal and one ventral root.
- The dorsal root bears a ganglionic swelling.
- After emerging out through the vertebral column, the dorsal and the ventral roots unite to form a common mixed nerve.
- **Each spinal nerve gives three branches, such as:**
- (a) Ramus dorsalis,
- (b) Ramus ventralis and
- (c) Ramus communicans to join with the autonomous nervous system.

Autonomous nervous system:

- This system is made up of a series of paired ganglia arranged irregularly on the dorsal wall of the kidney and the posterior cardinal sinuses.
- The gastric ganglion is the largest ganglion and sends nerves to the viscera.
- There is usually one ganglion in each segment.
- In Scoliodon the successive ganglia are not in distinct continuous chain.

Sense Organs of Scoliodon:

- The nervous system is associated with highly developed sense organs,
- Eyes,
- Olfactory sac
- Internal ear and
- Ampulla of Lorenzini (Fig.).
- Lateral line system

Eyes:

- The eyes are built on the principle of a photographic camera. The eye ball is composed of three layers: the sclera, choroid and retina.
- The sclera is cartilaginous. The pupil is a vertical slit and it cannot be dilated or contracted. The retinal layer consists of rods and cones.
- A large number of **guanine plates** are present on the inner surface of the choroid layer which is called **tapetum lucidum.**
- **It acts as reflector**. The crystalline lens is spherical.
- The lens is kept in position by suspensory ligament which extends from the margins of the lens to the ciliary processes.

Cont….

- The ciliary processes are longitudinal folds of the choroid layer. The eye is kept in its position in the orbit by six extrinsic eye muscles.
- Besides the eye muscles there are an optic nerve and a cartilaginous optic pedicle (Figs.).
- These eye muscles are attached with the eye ball in two groups.
- **The first group include:**
- (i) Superior rectus,
- (ii) Inferior rectus,
- (iii) Anterior rectus and
- (iv) Posterior rectus.

Cont….

- **The second group include:**
- (i) Superior oblique and
- (ii) Inferior oblique.
- The superior rectus muscle runs outwards and upwards and is inserted on the dorsal side of the eye ball.
- The inferior rectus muscle extends outwards and down wards to be inserted on the ventral side of the eye ball.
- The anterior rectus muscle runs out wards and downwards and is attached to the ventral surface of the eye ball. The posterior rectus muscle runs backwards and is attached with the posterior surface of the eye ball.

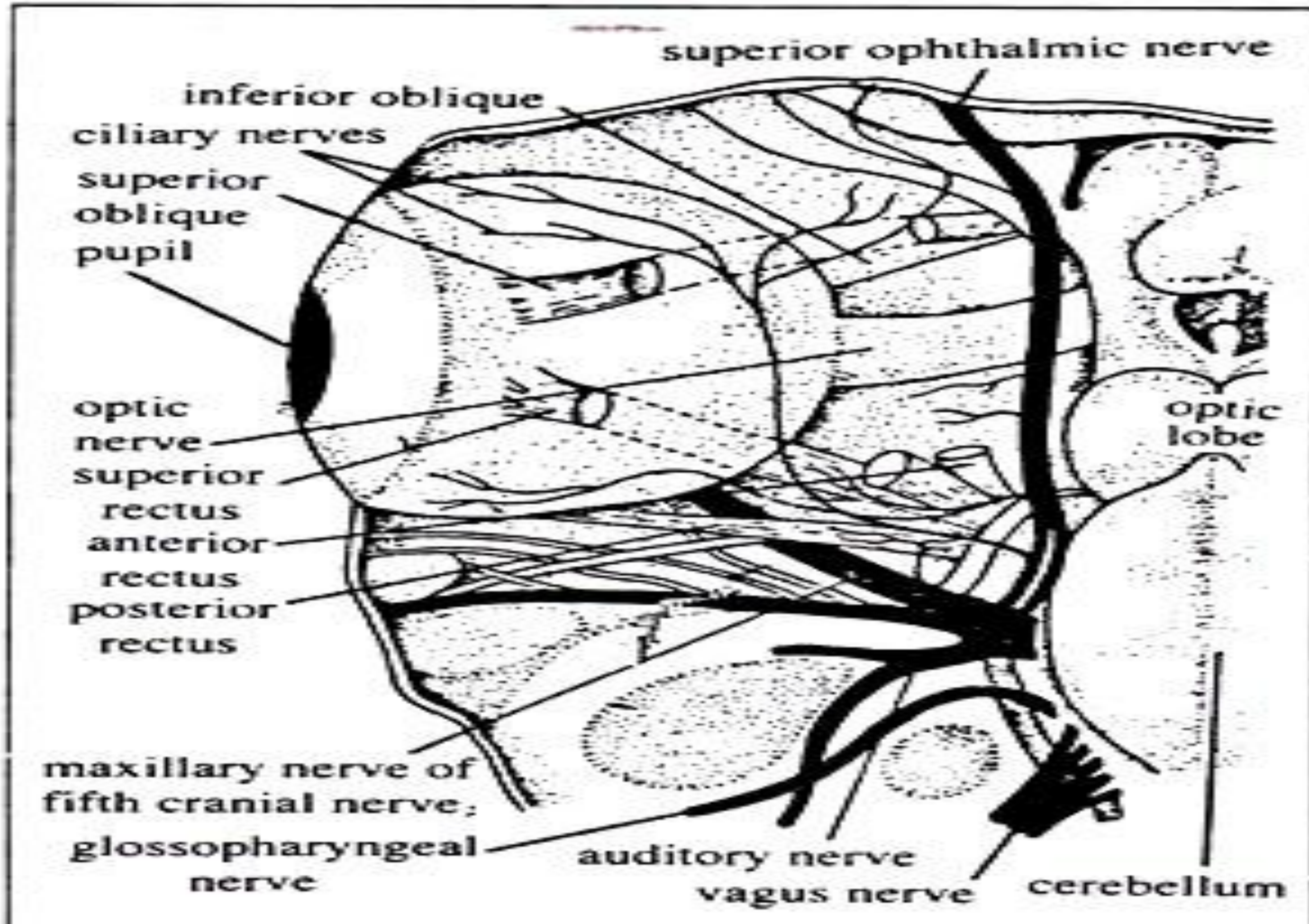


Fig. 6.15 : Orbit of *Scoliodon*. Note the relationship of the eye with the brain, muscles, nerves (after Young, 1981).

Cont….

- The superior oblique muscle is attached on the dorsal surface of the orbit just in front of the insertion region of the superior rectus muscle.
- The inferior oblique muscle is attached to the ventral surface of the eye ball just in front of the inferior rectus muscle.
- The eyes of Scoliodon are quite prominent and are proportionately larger in size.
- The eyes are laterally placed and each eye has its own range of vision, i.e., Scoliodon has **monocular** vision. Scoliodon is possibly colour blind (Fig.).

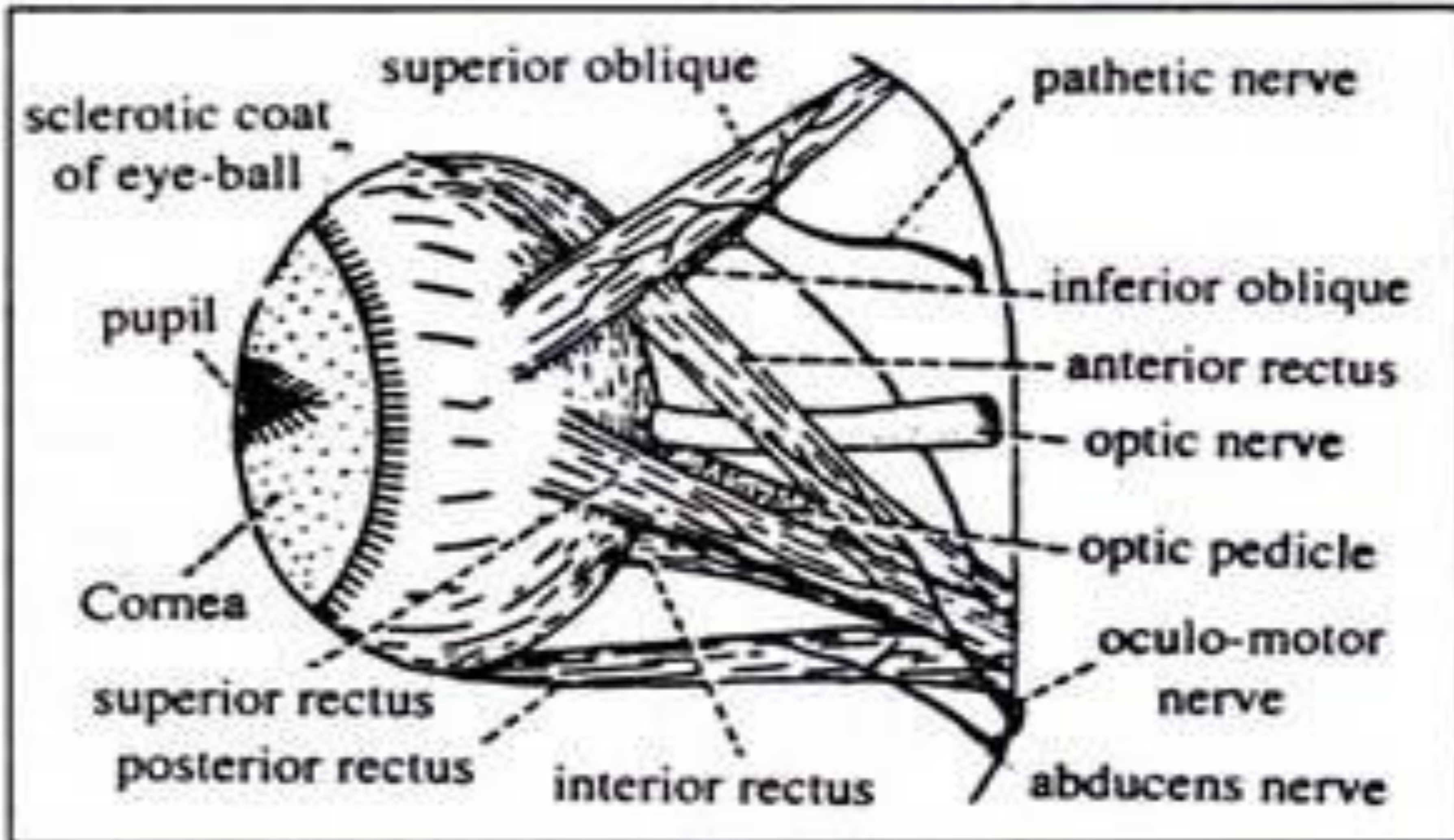


Fig. 6.16 : Showing the disposition of different extrinsic eye muscles of *scoliodon* (after Thillayampalam, 1928).

Olfactory organs:

- There are two blind sac-like olfactory organs situated in front of the mouth. Each olfactory sac is placed in a cartilaginous capsule and does not communicate with the buccal cavity.
- The mucous membrane of the olfactory sac is thrown into two series of folds called Schneiderian folds which are placed by the median raphe (see Fig.).
- The Schneiderian folds are composed of olfactory sense cells and supporting cells.
- The olfactory sense organs are greatly developed in Scoliodon. Physiologically each nasal opening is divided by three muscular nasal valves into a median excurrent siphon and a lateral incurrent siphon.

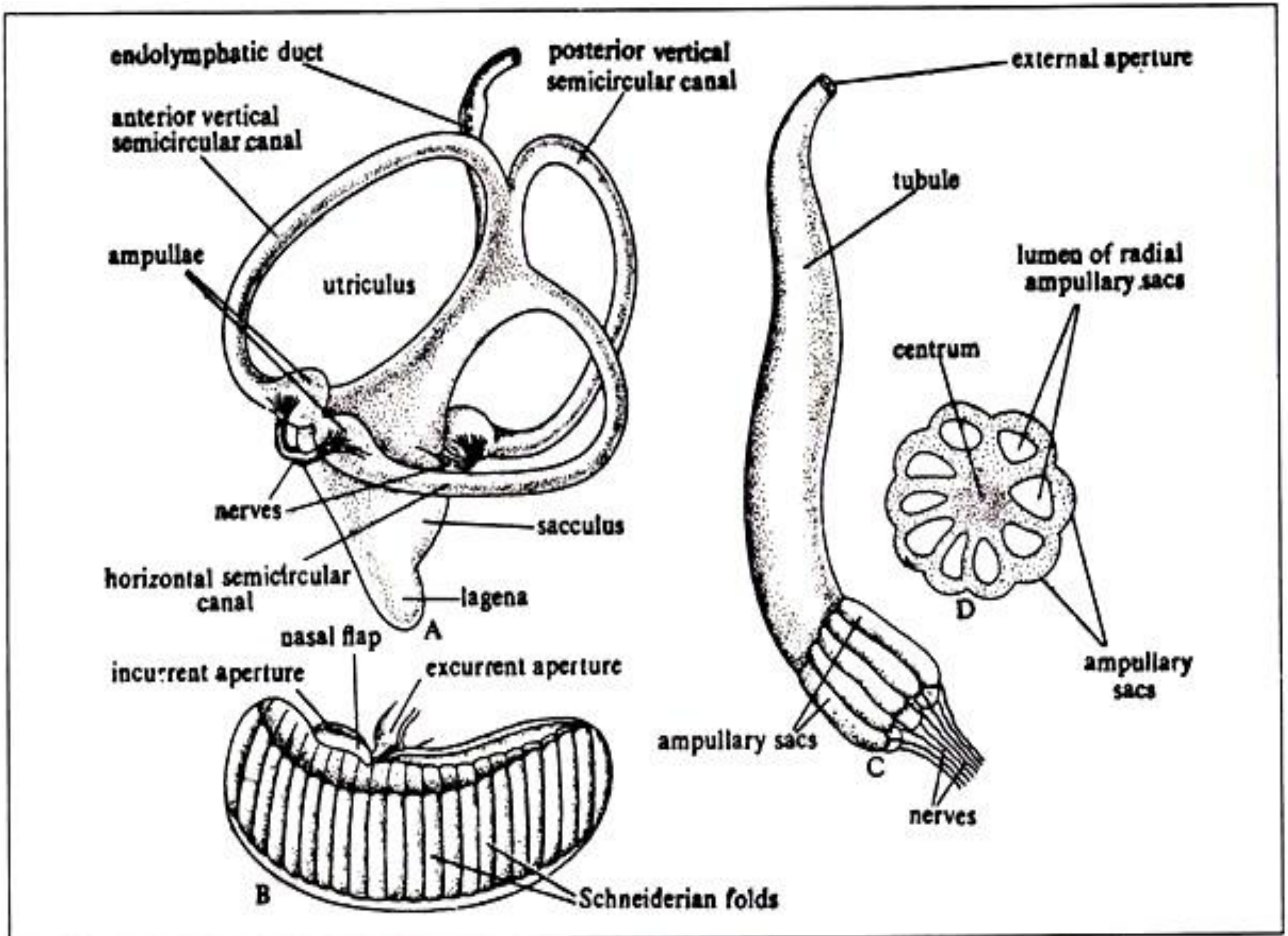


Fig. 6.14 : Sense organs of *Scoliodon*. A. Internal ear. B. Olfactory sac (dissected to show the inner nasal flaps). C. An ampulla of Lorenzini. D. Sectional view of an ampullary sac.

Internal ear:

- The internal ear or the membranous labyrinth of Scoliodon is a closed ectodermal sac.
- It consists of three semicircular canals and a central body differentiated into an anterior utriculus and a ventral sacculus (see Fig.).
- The three semicircular canals are arranged in three planes of the body and open into the central body by both ends.
- But one end of each canal dilates to form ampulla.

Cont….

- The utriculus gives off an invagination called recessus utriculi beneath the ampullae of the anterior vertical and horizontal semicircular canals.
- The sacculus gives a posterior outgrowth called the lagena. The membranous labyrinth is placed in a cartilaginous auditory capsule.
- The inner cavity is filled with a fluid called the endolymph into which many calcareous bodies (otoliths) are present.
- The space between the membranous labyrinth and the auditory capsule is filled with the perilymph.
- A long tube called the endolymphatic duct communicates the cavity of sacculus to the exterior through a small opening.

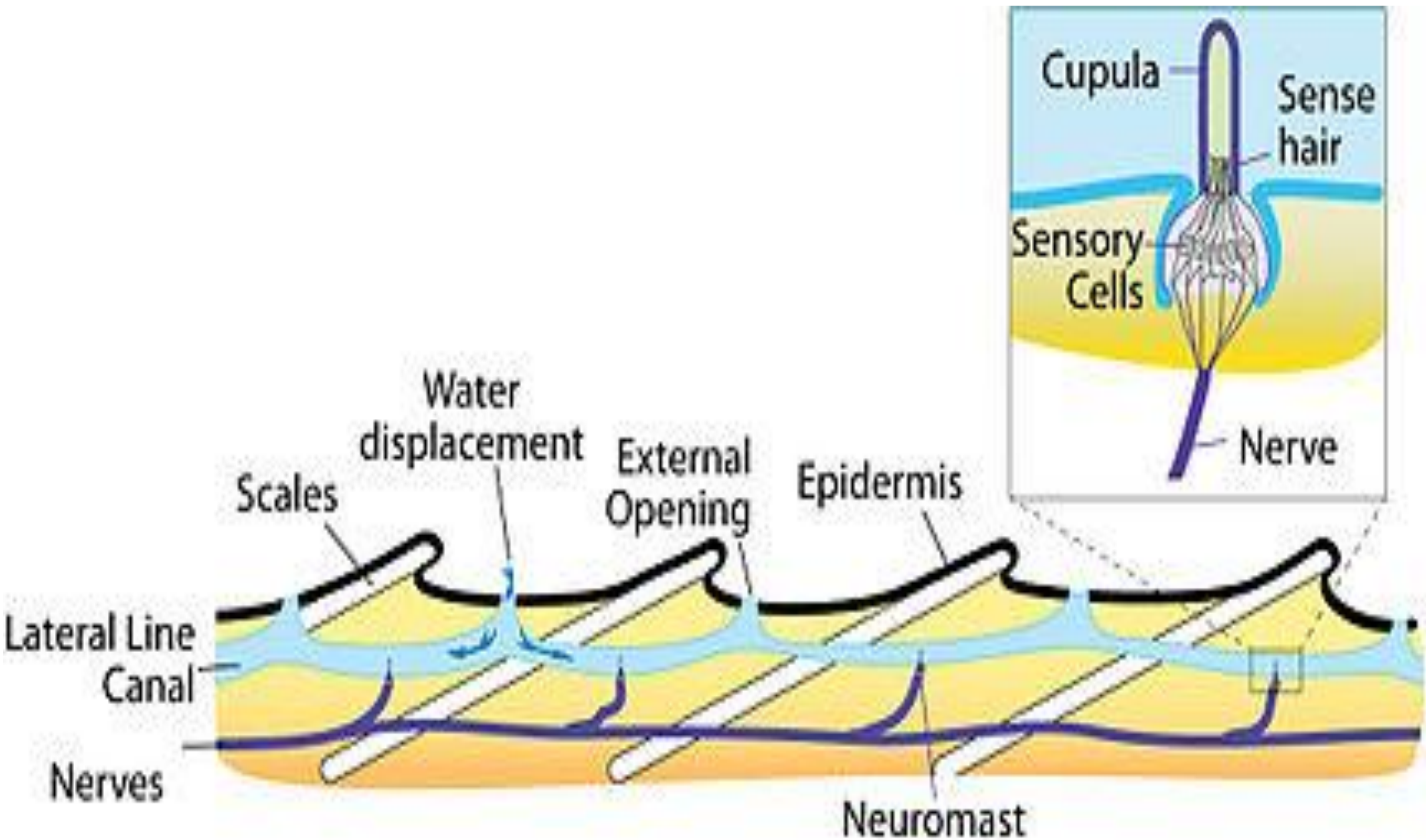
Cont…..

- **The membranous labyrinth of Scoliodon performs three functions:**
- (a) It helps in orientation in relation to gravity,
- (b) It accelerates in changing the direction during swimming and
- (c) It helps in hearing.
- The utriculus together with the semicircular canals is responsible for the orientation and acceleration, while the sacculus is meant for hearing.
- The internal ears are the statoacoustic organs in Scoliodon.

Neuromast organs:

- **These organs comprise of:**
- (i) The lateral line receptors and
- (ii) The pit organs.
- The lateral line sense organs lie inside the lateral line canal.
- These sense organs are the epidermal derivatives and are called neuromasts which remain embedded in the wall of the lateral line canal.
- This canal communicates to the exterior by minute pores.

Lateral line organ-Neuromast organ



Cont…..

- The pit organs occur on the lateral and dorsal sides of the head.
- They are actually ectodermal pits connected by groups of sense cells.
- The neuromast organs help to orient the body in relation to currents and waves and are designated as rheoreceptors.

Ampullae of Lorenzini:

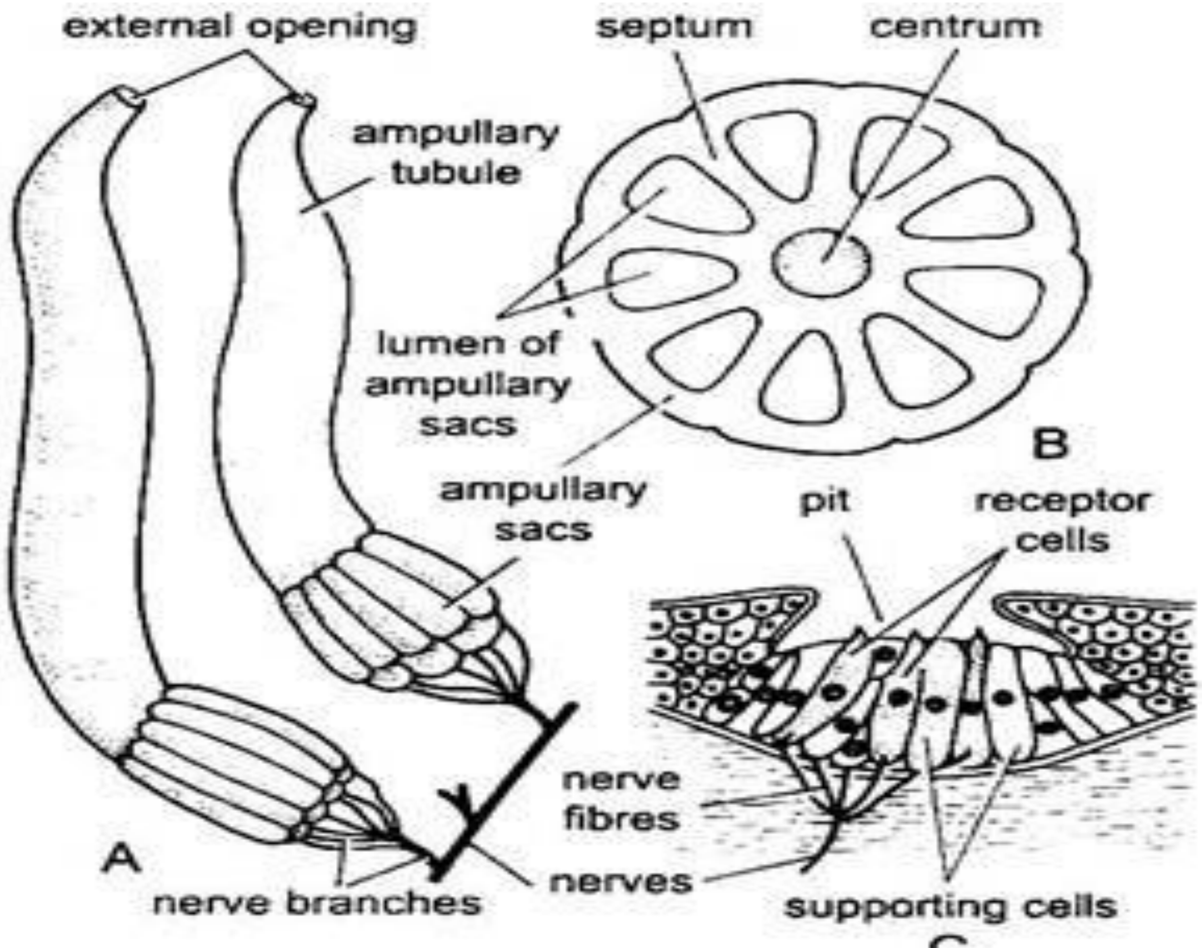


Fig. 14.46. *Scoliodon*. A–Two complete ampullae of Lorenzini in side view; B–T.S. through ampullary sacs; C–A pit organ in V.S.

Ampullae of Lorenzini:

- Enumerable pores on the dorsal and the ventral sides of the head lead into a long tube which terminates into radially arranged ampullary sacs (see Fig.).
- The ampullae lie in clusters and each of these consists of eight or nine chambers arranged radially around a central core called centrum (see Fig.).
- Two types of cells are encountered in the ampullae—glandular cells and sensory cells.
- The ampullae get the names according to their location.
- These sense organs are **the thermoreceptors** and are also the **pressure receptors.**

Urinogenital Organs of Dogfish (Scoliodon)

- In all the vertebrates the excretory and reproductive organs are closely related to each other and are, therefore, dealt together.
- The two systems together are known as urino-genital system and the organs as urinogenital organs.
- In Dogfish (Scoliodon), the sexes are separate and the sexual dimorphism is conspicuous.
- The male Scoliodon possesses two cylindrical hollow copulatory organs, the claspers which are modifications of pelvic fins.
- The claspers are absent in female.

Male Urinogenital Organs:

1. Excretory Organs:

- The excretory organs in male consist of pair of kidneys, ureters and unpaired urinogenital sinus.
- The kidney of Dogfish (Scoliodon) is mesonephric.
- Each kidney is a long flattened and ribbon-like glandular structure lying dorsally to the peritoneum on either side of the median line and attached to the dorsal abdominal wall.
- They extend through the entire length of the body cavity from the root of the liver in front up to the cloaca behind.

Cont…

- Each kidney is distinguished into an anterior slender, non-excretory portion, the genital kidney (cranial mesonephros) and a posterior thicker, excretory part, renal kidney (caudal mesonephros).
- The posterior region of the kidney is greatly thickened, laterally compressed and forms the chief organs of excretion called opisthonephros.
- While, the anterior region is reduced and becomes comparatively narrow and takes the function of conveying genital products and is, therefore, called the epididymis.

Cont…

- The substance of the opisthonephric kidney is made up of coiled glandular uriniferous tubules.
- Each uriniferous tubule comprises a Bowman’s capsule enclosing the glomerulus and a coiled renal tubule, several of which open into a common collecting tubule.
- The renal tubules have a special urea-absorbing segment.
- The collecting tubules of each kidney open independently into a common duct, the ureter which finally opens posteriorly into a wide median chamber, the urinogenital sinus.
- The urinogenital sinus opens into the cloaca through an aperture located at the tip of a small urinogenital papilla.

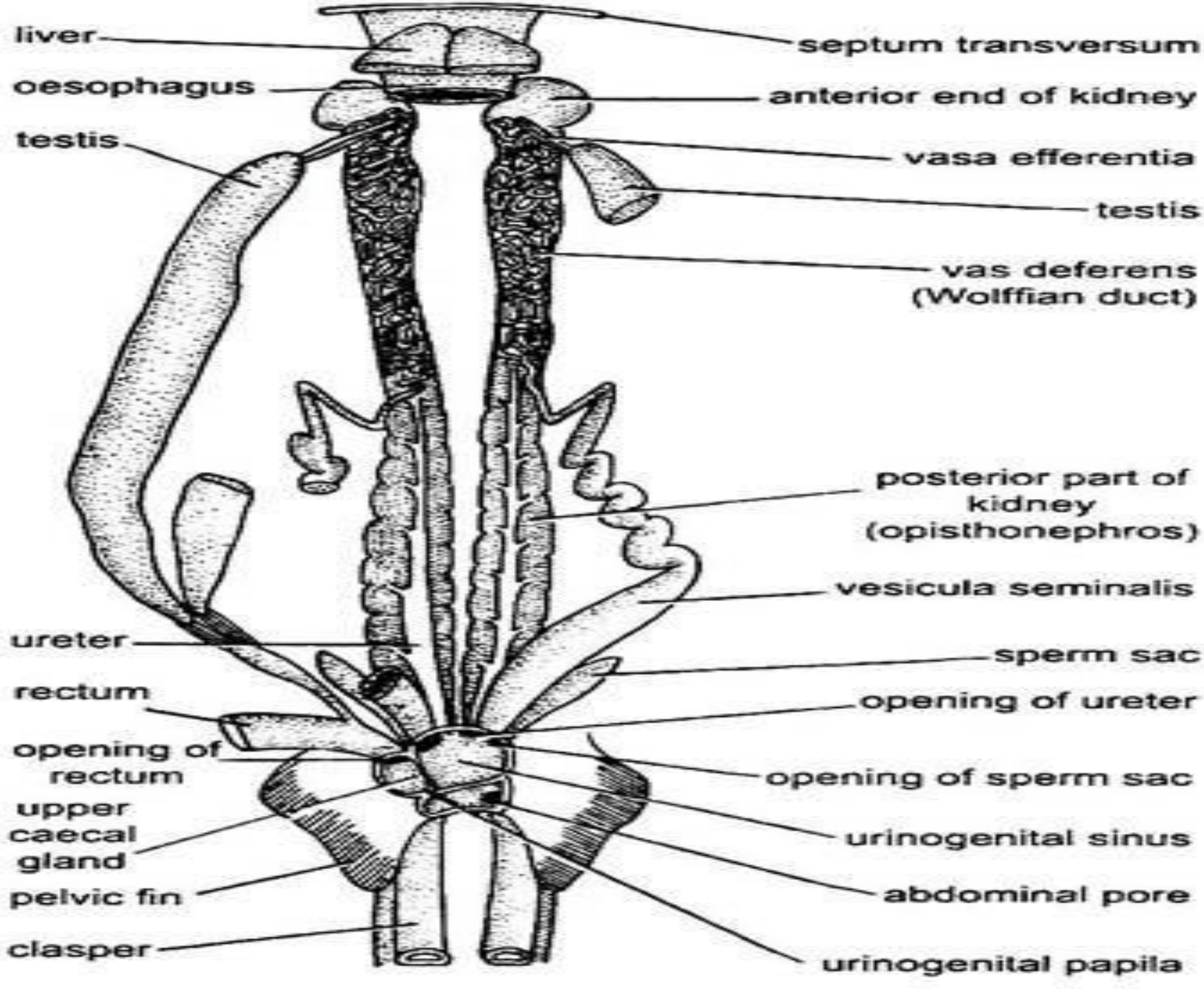


Fig. 14.47. *Scoliodon*. Male urinogenital organs.

2. Reproductive Organs:

- The reproductive organs include a pair of testes, a pair of vas deferens, and a pair of seminal vesicles.
- **Testes:**
- There are two elongated testes lying one on either side of the middle line.
- Each testis extends from the base of the liver in front to the caecal gland behind.
- The testes are attached to the dorsal body wall by a fold of peritoneum called the mesorchium and to the caecal gland behind by a non-glandular tissue.
- Each testis is made up of numerous narrow seminiferous tubules lined with germinal cells which produce sperms by spermatogenesis.

Cont….

- From each testis arise several thin tubular vasa efferentia which open into the anterior end of a large, narrow closely coiled tube occupying the entire part of the anterior part of the kidney or epididymis but becomes very much enlarged posteriorly to form the wide straight vesicula seminalis or seminal vesicle in which sperms are stored.

Cont….

- The seminal vesicles of both the sides open behind independently into a large triangular chamber, the urinogenital sinus which in its turn opens into the cloaca on an elevated urinogenital papilla.
- On either side of the urinogenital sinus arises a club-shaped sperm-sac.
- The function of the sperm-sac is unknown.

Accessory Reproductive Organs:

- These are the claspers and siphons.
- The claspers are grooved elongations of the pelvic fins.
- The sperms from the cloaca pass into the claspers and are then transferred to the female, thus, acting as intermittent organs in coition.
- Each clasper has a closed groove with an anterior opening, apopyle lying near the cloaca and a posterior opening called the hypopyle.
- Sperms enter apopyle from the urinogenital papilla and then transferred to the cloaca of female during coitus.

Cont….

- On the ventral side of the body just beneath the skin there is a pair of elongated glandular and muscular sacs, the siphons.
- These sacs extend anteriorly almost to the level of the posterior margin of the pectoral fine where they end blindly.
- Posteriorly these sacs extend as siphon tubes, each of which opens into the anterior opening of clasper of its side.
- The siphons have no direct communication with the male urinogenital organs except they open into the groove of claspers.
- It is believed that sea water enters the siphons during copulation and forced down into the clasper groove forcing into the female cloaca.

Female Urinogenital Organs:

- **1. Excretory Organs:**
- **The excretory organs of female differ from those of the male organs in the following:**
- (i) There is no direct connection between the kidneys and the genital organs.
- (ii) The anterior part of each kidney is extremely reduced and non-excretory.
- (iii) Both the ureters unite behind into a common median ureter which opens by a single median urinary aperture into the triangular chamber, the urinary sinus.
- (iv) The urinary sinus receives the ureters only and the genital duct opens directly into the cloaca.

Cont….

- Each kidney of the female also has two parts, an anterior part which is degenerate and reduced to a narrow tapering strand which is non-renal and non-functional, and a broad posterior part which contains masses of coiled uriniferous tubules.
- From the inner margin of each kidney arises a ureter or Wolffian duct into which open the uriniferous tubules.

Cont…

- The two ureters unite to form a common ureter which opens into a large median urinary sinus.
- The urinary sinus is formed by the enlarged ends of the Wolffian duct.
- The urinary sinus opens into the cloaca by an aperture on a urinary papilla.

2. Reproductive Organs:

- The female reproductive organs comprise a pair of ovaries, a pair of oviducts, shell gland and a pair of uteri.
- **Ovaries:**
- The ovaries are paired organs varying in form and size according to the age of Dogfish (Scoliodon).
- The lobulated overies are situated, one on either side of the vertebral column, just behind the base of liver.
- They are suspended in the body cavity, from the dorsal abdominal wall by a fold of peritoneum, the mesovarium.
- Round follicles project from each ovary, each follicle contains an ovum.

Cont….

- Between the ovary in front and caecal gland behind extends a long tubular strand of tissue, the epigonal organ.
- Oviducts, the two oviducts are the well-developed Mullerian ducts extending the entire length of the body cavity.
- Each oviduct is a long thick-walled muscular tube and their anterior narrow ends unite mid-ventrally beneath the oesophagus near septum transversum and opens into the coelom by a single longitudinal slit, called the oviducal funnel or ostium.

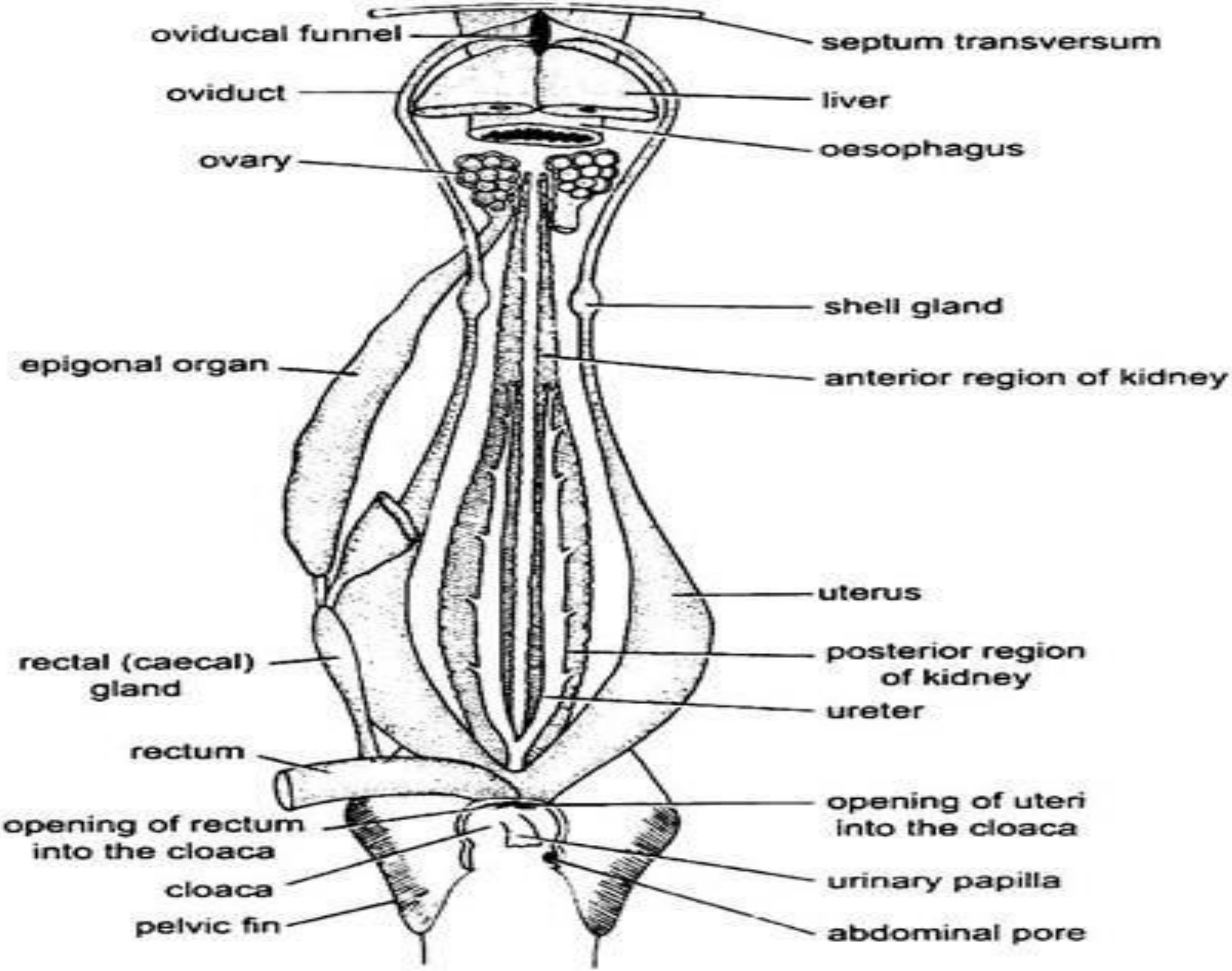


Fig. 14.49. *Scoliodon*. Female urinogenital organs.

Cont.....

- Each oviduct runs backward for a short distance and then enlarges to form the shell gland or oviducal gland. It secretes a thin membrane over the descending fertilized eggs.
- The oviduct then again narrows and then it again dilates to form a sac-like uterus.
- The uteri of both the sides unite to form a short vagina which opens into the cloaca by a large aperture.
- A fold of mucous membrane of this region separates the vagina from the cloaca, and acts as a valve which closes the vagino- cloacal aperture during the development of the embryo within the uterus.

Cont…

- The oviducts have no direct communication with the ovaries so that mature ova are at first shed into the abdominal cavity and later forced by the action of the body-muscles into the oviducts through the single oviducal funnel.
- Fertilization occurs in the section of oviduct between the oviducal funnel and the shell-gland.
- The fertilized ova come into the uterus.
- As Scoliodon is viviparous the posterior portion of the oviduct becomes dilated to form the uterus for the development of the young.

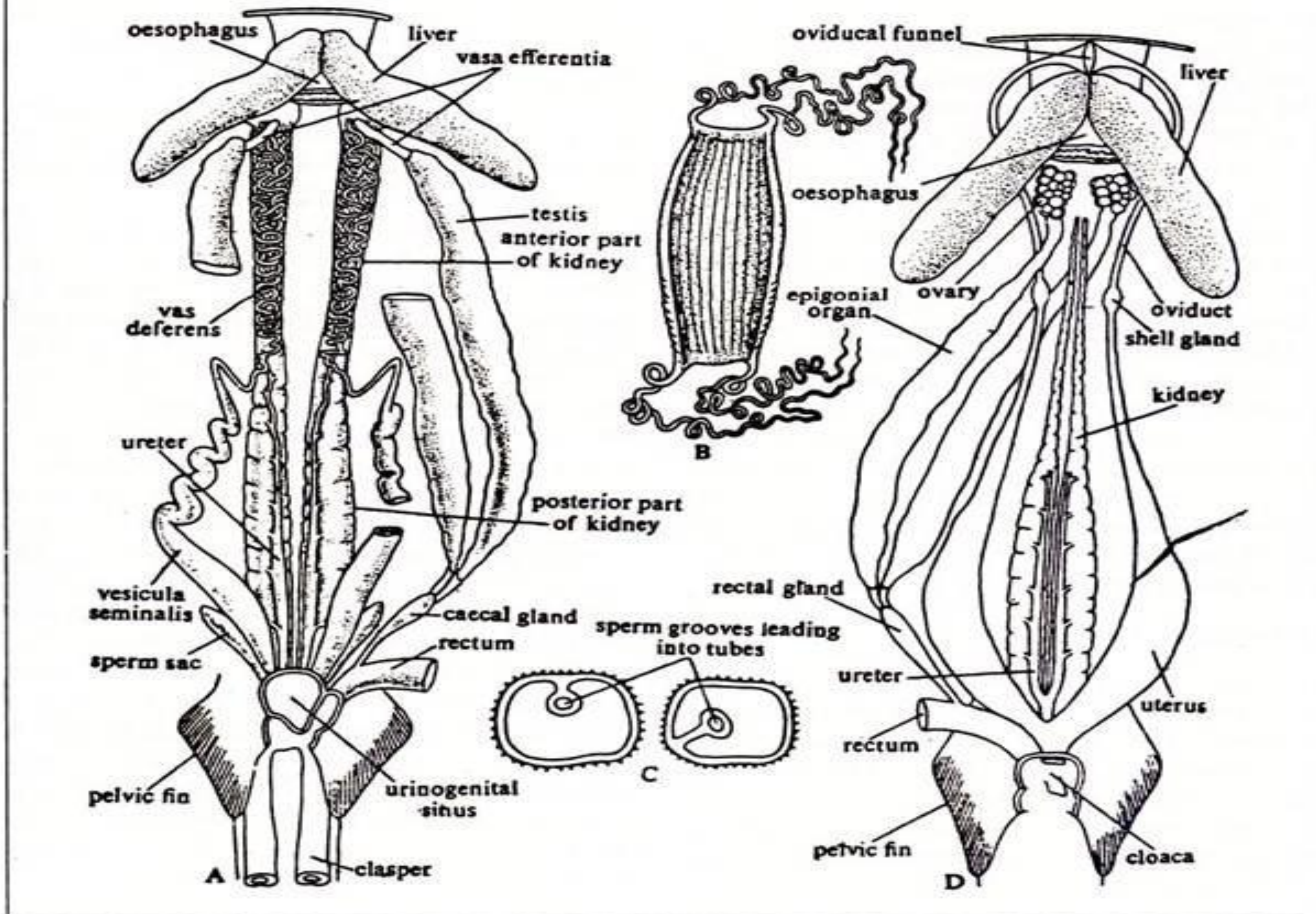


Fig. 6.17 : Reproductive system of dogfish. A. Male reproductive system of *Scoliodon*. B. Egg capsule of *Scyliorhinus*. C. Sectional view of the claspers of *Scoliodon*. D. Female reproductive system of *Scoliodon*.

Cont….

- The number of embryos present inside one uterus varies greatly in different species of Scoliodon.
- In S. sorrakowah about seven embryos have been observed.
- The mucous membrane of the uterus becomes divided into a number of compartments each of which houses an embryo.
- The number of compartments varies directly with the number of embryos.

Cont.....

- The eggs are large and heavily yolked.
- Each egg gets a coating of albumen during its transit down the oviduct.
- The egg, particularly in oviparous forms, is enclosed by horny shell which is oblong in shape.
- The angles of the shell are prolonged into four coiled elongated filamentous processes (Fig.). This condition is not observed in Scoliodon but is observed in case of oviparous sharks.

Economic Importance of Fish

- Fishes form one of the most important group of vertebrates for man, influencing his life in various ways.
- Millions of human beings suffer due to hunger and malnutrition, and fishes form a rich source of food and provide a means to tide over the nutritional difficulties of man.
- In addition to serving as an important item of food, fishes provide several byproducts to us.
- Fish have considerable economic importance are useful as well as harmful to man.

Useful Fishes:

- **1. Fish as Human Food:**
- Fish have formed an important item of human diet.
- Nearly all fish freshwater and marine are edible and have been an important source of protein, fat and vitamins A and D since time immemorial.
- In most fishes, the flesh is white, contains about 13 to 20% of protein and has a food value of 300 to 1600 calories per pound.

Useful Fishes:

- According to Pottinger and Baldwin, fish meat contains atleast 5 of the essential amino acids. Besides this, it contains vitamin A and D together with large amount of phosphorus present in it.
- Important marine fishes include salmon, cod, halibut, herring, eels, tuna, mackerel, and sardines.
- Important freshwater food fishes are cat fish, trout, bass, perch and mullet.
- Even eggs of certain fishes, such as Russian sturgeon are eaten as cavier.

Useful Fishes:

- The major food fishes of India include Labeo, Catla, Cirrhina, Mystus Wallago, Notopterus, Ophiocepholus, etc.
- The cartilaginous sharks, skates and rays are also used as human food in several countries.
- They are eaten by poorer classes of people living along the sea coasts of India and Sri Lanka.
- The canned meat of sharks is sold commercially under the name of gray fish.
- In south-east Asian countries, shark fins are dried and boiled to get a gelatinous material used as soups.

Useful Fishes:

- Fresh fish meat is usually cooked for human consumption.
- However, large quantities are refrigerated, salted, smoked, canned or pickled.
- Today, fisheries of the world carry on business worth several hundred thousand rupees annually and also provide employment to thousands of people.

2. Fish as Food of Cattle:

- The scrap from canneries, as well as entire fishes that are not relished by man, are dried and ground in mill.
- This is called fish meal and is used as artificial food for poultry, pig and cattle.
- Fish meal is produced in several states like Maharashtra, Andhra Pradesh, Tamil Nadu, Bengal and Kerala chiefly from sardines, meckerels, ribbon fish, etc.
- The fish is first cooked in large pots containing sufficient quantity of water, on fire or on steam.

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- The cooked material is then pressed to remove moisture and dried in the sun on suitable platforms.
- The resultant product is then stored, and if preserved in airtight containers after sterilization retains its nutritive value for a long time.
- The fish meal contains about 60% protein and high percentage of calcium phosphate so that it is very valuable for cattle and poultry.
- The manufacture of fish meal can be undertaken as a cottage industry requiring little expenditure.

3. Fish Manure:

- Fish that are unfit for human consumption are used to prepare fish manure for the fields.
- During peak season, when there is a large supply of fish, or they are landed in spoiled condition, they are sun dried on the beach.
- The dried fish is ground and converted to manure, which contains a high percentage of nitrogen and phosphate.
- Mostly sardines are used for preparing fish meal and the waste material forms the fish guano.
- It contains 8.9% nitrogen and phosphate, and when mixed with soil, forms a rich fertilizer for plants.
- It is several times richer than ordinary cattle manure.

4. Fish Oils:

- The most important fishery by product is that of the fish oil, which is of two kinds body oil and liver oil.
- The oil extracted from the whole body of the fish is called fish body oil, while that obtained from liver of certain fish is called the fish liver oil.
- Liver oil contains vitamin A and D, while the body oil contains them in traces.

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- The refined oil from the liver of fishes has a medicinal use, being the source of vitamin A and D.
- The body oil from fish has many uses, such as in painting, varnishing, soap, candle, leather and steel industries.
- For preparing body oil, fish are boiled in large quantity of water. Oil is removed quickly and washed in boiling salt water.

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- Liver oil is prepared from the liver of several species, including sharks and rays.
- Oil is extracted from the liver soon after the fish are caught to avoid action of enzymes.
- Liver is cut into small pieces and boiled in sufficient quantity of water.
- Oil is skimmed from the surface of water and sent for purification.
- Liver oil contains 55-75% fat, 5-10% protein and the rest water. It is of considerable medicinal value.

5. Fish Skin and Leather:

- The skin of several fishes like the sharks and rays are used for making polishing and smoothing material.
- Shark skin leather is of some commercial importance in the manufacture of many useful articles such as shoes and hand bags, etc.
- In Japan, lantern are prepared from the skin of puffer fishes (e.g., Tetrodon).
- Some tribal people used skins of puffer and porcupine fishes (e.g., Diodon) for war helmets.

Cont…

- Crude skins of sharks and rays are used by carpenters and metal workers.
- Shark skin tanned with placoid scales on it is called shagreen.
- It has been used as an abrasive for polishing wood and ivory and also for covering jewel boxes, fine books and sword handle.
- **6. Fish Glue:**
- Liquid glues are prepared from skin, head and other trimmings of certain fishes.
- This glue has an adhesiveness of great power for paper, wood, leather and glass.

7. Isinglass:

- It is a gelatinous product obtained from the air-bladders of certain fishes such as sturgeons, carps, perches, salmons, cat fishes, cods, etc.
- The isinglass is a shining powder and is used for clearing wine, beer, making edible jelly and in the preparation of adhesive material.
- The air-bladder is removed from fish, washed in cold water and flattened by beating it on a piece of wood.
- The bladder is then dried in the sun, and is exported for the preparation of isinglass.
- The finest quality of isinglass is obtained from Russia.

8. Fish Fin:

- The fins of sharks are exported to China where they are used for preparing soup.
- **9. Medicines and Disease Control:**
- The refined oils extracted from livers of cods and sharks are rich in vitamins A and D.
- Pituitary glands yield important extracts for medicines.
- Fishes like top minnows {Gambusia affinis), Trichogaster, Chela, Puntius, Barilius, Danio, Colisa, Rasbora, Esomus, Ambassis, Aplocheilus, Barbus, Panchax, etc., feed voraciously on mosquito larvae.

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- These larvicidal fishes are propagated and distributed widely into ponds, lakes and tanks to destroy mosquito that transmit malaria, yellow fever and other dreadful diseases of tropical countries.
- Certain fishes and their bye-products contribute to useful Ayurvedic and Unani medicines for treatment of duodenal ulcers, skin diseases, night blindness, general weakness, loss of appetite, colds, coughs, bronchitis, ashthma, tuberculosis, etc.

10. Sports and Recreation:

- Sport fishing by individuals and fishing parties is a popular recreation of million of people, as well as a source of food, all over the world.
- The most commonly hunted fishes are the freshwater perch and trout and the marine tarpon.
- However, some of the best game fish is most famous for sport that it provides, but its flesh is not palatable.

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- Many people's hobby is to cultivate certain tropical fishes as pets. Both native as well as foreign fishes are displayed in home aquaria for their beauty and graceful movements.
- Common aquarium fishes are gold fish (Carassius auratus), angel fish (Pterophyllum), sword tail guppy (Xiphophorus), minnow (Gambusia affinis), siamese fighter (Betta splendens), paradise fish (Macropodus), Hemigrammus, Aphyocharax, loach (Botid), Trichogaster, Tilapia, etc.
- Goldfish cultured and not found in nature and the Japanese have produced their several curious artificial varieties. Pet shops now-a-days stock many kinds of fishes for hobbyists and scientists.

11. Fancy Articles:

- Scales of garpike (Lepidosteus) are used for jewelry and novelties.
- From scales of some fish is secured a pigment whose water suspension is known as pearl essence.
- It is used in the manufacture of artificial pearl in Europe, especially in France.

12. Scientific Study:

- Fishes have considerable use as experimental animals, especially in the fields of Genetics, Embryology, Animal Behaviour and Pharmacology.
- Certain fishes such as Latimeria and dipnoans have anatomical features of great zoological interest.
- Fishes like dogfish (Scoliodori), perch (Perca) and carp (Labeo), etc., are dissected for anatomical study in zoological laboratories.
- Researches in ichthyology are conducted for the benefit of fisheries and mankind.

13. Industries:

- As the fish forms a rich source of food, millions of people are engaged in fishing industry and depends on fisheries for their livelihood in various ways.
- Besides those who directly catch the fish for marketing, there are equally large number of people engaged in subsidiary industries like refrigeration, preservation, canning, and in the manufacture of fish products and by products.

Harmful Fishes:

- **1. Destructive:**
- All the cartilaginous fishes are predaceous and feed chiefly on large quantities of crabs, lobsters, squids and other valuable marine animals.
- They cause great harm by destroying eggs, young and even adults of our food fishes.
- Sharks are extremely dangerous in the sea and injure fisherman and damage their nets, steal baits, devour captured fish and drive away squids and fishes to be netted.
- The damage done by these sharks amounts to several hundred thousand rupees.

2. Injurious:

- Some larger sharks and sword fish may capsize small boats and injure or even kill fisherman.
- All sharks, small or big, are a menace to bathers and skin divers in shallow waters.
- The Pirhanas of Central and South America have very strong teeth and are dangerous even to man.

Cont…

- Some fishes like cartilaginous electric ray (Torpedo) have electric organs which give powerful shocks to swimmers and fishermen.
- An extreme case of specialization is the bony electric eel (Electrophorus electricus) of the Amazon. It is nearly 1.5 metres long and the postero-ventral four-fifth part of the body is occupied by the electric organ.
- It can generate electricity up to 600 volts in potential with a maximum output of 1000 watts.
- Carnivorous fishes eat away the larvae of useful insects.

3. Poisonous:

- Poisonous glands are found in many cartilaginous fishes such as sting ray (Trygon) and eagle ray (Myliobatis).
- They can inflict painful wounds, sometimes fatal by the poisonous stings or spines. Poisonous glands are also found in Squalus (dogfish), Heterodontos, Chimaera, Diodon (porcupine fish), Tetrodon (globe fish), scorpion fish, etc.
- These are also capable of causing wounds by their spines or spiny opercula. Flesh of some tropical fishes (e.g., Tetrodon) is also poisonous and may prove fatal to man.

Osmoregulation in Various Kinds of Fishes

- According to habitat, fishes can be distinguished as
- (i) Marine, and (ii) Fresh water.
- (i) The marine fishes fall into two distinct groups,
- (a) Those whose osmotic concentration is the same as or slightly above sea water, e.g., hagfish, elasmobranchs, Latimeria etc.
- This group has no major problem of water balance, because its inside and outside concentrations are equal, there is no osmotic water flow,

Cont…

- (b) Those whose osmotic concentrations are about one third of that of sea water, e.g., lampreys, teleosts, etc.
- These are hyposmotic animals. They live in constant danger of losing water to the osmotically more concentrated medium.
- (ii) The fresh water fishes, on the other hand, have internal concentrations greater than that of their external medium.
- Thus, they are hyperosmotic to the medium. Therefore, the osmotic problems and the means to solve them differ drastically among fishes of different habitats

The cyclostomes have two groups:

- (i) Lampreys, which are anadromous, i.e., live both in sea and in fresh water,
- (ii) Hag- fishes are strictly marine and stenohaline (able to tolerate narrow range of salinity).
- The Lampreys, weather fresh-water or marine, have osmotic concentrations about one-quarter to one-third the concentration of sea-water. Their main problem is similar to that of teleost fish.

Cont…

- These problems are discussed later. The hagfishes are the only true vertebrates whose body fluids have salt concentrations similar to that of sea water.
- In fact, the normal Na^+ concentration in hagfish blood exceeds that in their surroundings.
- Therefore, they have pronounced ionic regulation as an isosmotic animal.

Osmoregulation in Marine Elasmobranchs:

- The common examples of marine elasmobranchs are sharks and rays.
- The salt concentration in their body fluid is roughly one- third the level of the sea-water, but they still maintain osmotic equilibrium.
- This is achieved by adding to the body fluids large amount of organic compounds primarily urea.
- Addition of different organic com-pounds in the body fluid/blood makes the osmotic concentration equal or slightly above the sea-water.

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- In elasmobranchs urea is a normal com-ponent of all body fluids; this is abnormal for other vertebrates.
- In marine elasmobranchs, the tissue cannot function normally in the absence of such a high urea concentration.
- Urea is the end product of protein meta-bolism in vertebrates.
- Generally it is excreted through kidney, but the shark kidney actively reabsorbs this.

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- **The use of urea for maintaining osmotic equilibrium helps these animals to keep salt concentration much lower than those of sea-water**.
- But urea can pose problems in the body functioning.
- It is known that urea destabilizes many proteins, especially enzymes.
- This problem is solved in elasmobranch by the presence of another organic substance **trim-ethylamine (TMAO). TMAO inhibits the effect of urea on enzymes.**
- **Some other urea inhibiting com-pounds are betaine and sarcosine**

Cont….

- Although the elasmobranchs have solved the osmotic problem of life in the sea by being isosmotic, they are still capable of extensive ionic regulation.
- They have sodium concentration much lower than that of sea-water. This means that sodium tends to diffuse from sea-water into the body.
- Sodium enters into the body primarily through the thin epithelium of the gill and then through the ingested food.
- This enhances the sodium level in the body, which must have to be excreted or eliminated from the body.

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- Part of the sodium excretion is under-taken in the kidney.
- Major excretion of Na^+ is performed by a special rectal gland.
- This is a small gland that opens via a duct into the posterior part of the intestine, the rectum.
- The gland secretes a fluid with high sodium and chloride concentrations, which is higher than the sea-water concentration.

Cont…

- The elasmobranch blood is usually slightly more concentrated than sea-water.
- This higher concentration inside causes a slight osmotic inflow of water via the gills.
- In this way, the elasmobranchs slowly gain water osmotically, and this water is used for the formation of urine and for the secretion of rectal gland.
- The excess osmotic concentration is due to the presence of urea.
- But retention of urea solves the otherwise difficult osmotic problem of maintaining a low salt concentration while living in sea.

Osmoregulation in Freshwater Elasmo-branchs:

- Majority of elasmobranchs are marine, few of them are also found in freshwater.
- Some marine species occasionally enters rivers and lakes for various purposes.
- Among freshwater elasmobranchs, Carcharhinus leucas of Lake Nicaragua, four species of elasmobranchs of Perak River in Malaysia and Amazon sting ray Potamotrygon, are remarkable.
- Their blood concentrations are lower than those of strictly marine forms.
- The urea concentration is reduced to less than one third of the value of marine sharks.

Cont…

- The problem of osmotic regulation is reduced due to the low level of solutes in the blood.
- The osmotic inflow of water is diminished because lower salt concentration is easier to maintain.
- The reduced osmotic inflow of water gives less water to be eliminated by the kidney.
- The urine always contains some solutes; therefore, a low urine flow reduces the urinary salt losses.
- Smith (1931) argued that, it is difficult to say whether the lowered blood concentration is a primary adjustment or merely a passive result of the increased inflow of water and concomitant urinary losses.

Osmoregulation in Teleosts:

- Teleost fishes are living both in marine and freshwater. Both types of fishes maintain their osmotic concentration at about the quarter to one-third the level in sea-water (Table 8.9).
- There is another type of fish, which roams both in sea water and fresh water.
- Therefore, it can tolerate a wide range of salinities. These movements are often associated with the life cycle, such as breeding.
- But this change from one environment to the other requires profound changes in the osmoregulatory processes.

(a) Osmoregulation in marine teleosts:

- Marine fishes are hyposmotic with the environment.
- Their main problem is losing body water to the more concentrated sea-water.
- The body water comes out through their body surfaces, in particular the large gill surfaces.
- The gill surface is more permeable to water than general body surface.
- These fishes compensate their inevitable water loss by drinking sea-water.

Cont…

- Drinking of sea-water may restore the water content of the body, but impose another problem.
- Along with the sea-water, large amount of salts are also ingested and absorbed through the intestine.
- So salt concentration of the body increases.
- Now the problem becomes elimination of excess salt. To solve the problem, salts must be excreted in a higher concentration than in the water taken in.
- The teleost kidney cannot serve this purpose, because it cannot produce urine that is more concentrated than the blood.

Cont..

- Therefore, some other organ must participate in solving this problem of eliminating excess salts.
- This is done by the gills. So gills have dual function—one, participation in osmoregulation and second, gas exchange.
- The secretion of salt through gill is an active process, i.e., energy mediated. Because, it takes place from a lower concentration in the blood to a higher concentration in the sur-rounding medium.
- Fig. 8.38 describes the summary of osmoregulation in marine teleosts. Fig. 8.38A shows the movement of water and Fig. 8.38B shows the movement of salts.

Cont..

- The excretion of sodium and chloride in the urine is of minor importance because teleost urine is more dilute than the body fluids.
- However, the kidney plays a major role in the excretion of divalent ions, magnesium and sulfate.
- These ions are not eliminated by the gills, which seems to transport only sodium and chloride.

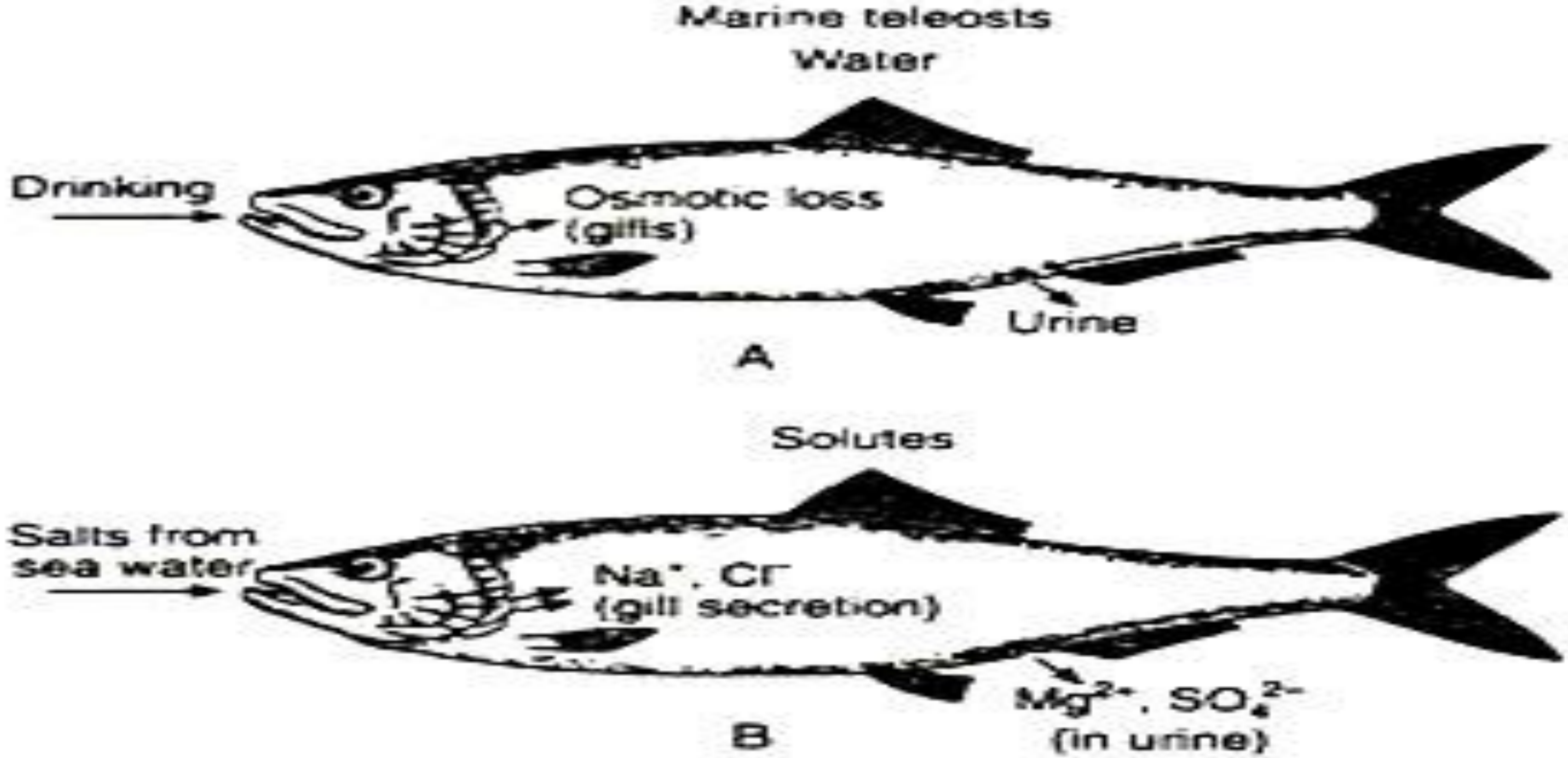

Fig. 8.38 : A marine teleost is osmotically more dilute than the water in which it lives. A. Because of the higher osmotic concentration in the medium, the fish constantly loses water, primarily across the thin gill membranes. Additional water is lost in the urine. B. To compensate for the water loss, the marine teleost drinks substantial amount of sea water. Of the ingested salts, sodium and chloride are absorbed in the intestine and eliminated via the gills by active transport (double arrow, B); magnesium and sulfate are excreted by the kidney

Cont…

- Further studies show that the salt intake is happening not only through drinking sea-water, but also through the general body surface.
- It is also proved that fish adapted to sea-water are relatively permeable to ions and those adapted to fresh water are relatively impermeable.
- The ion transport is carried out, not by the general epithelial cells of the gills, but specifically by some large cells known as chloride cells.
- These cells are also present in the opercular cover of the fish. These cells actively transport chloride ions.

(b) Osmoregulation in fresh-water teleosts:

- The osmotic concentration of the blood of fresh water teleosts in much higher than the surrounding water (~300 mOsm/litre).
- Therefore, their major problem is the osmotic water inflow (Fig. 8.39A).
- Water mainly enters through the highly permeable gills.
- In freshwater teleosts skin is less important in transporting water inside the body, because it is less permeable.

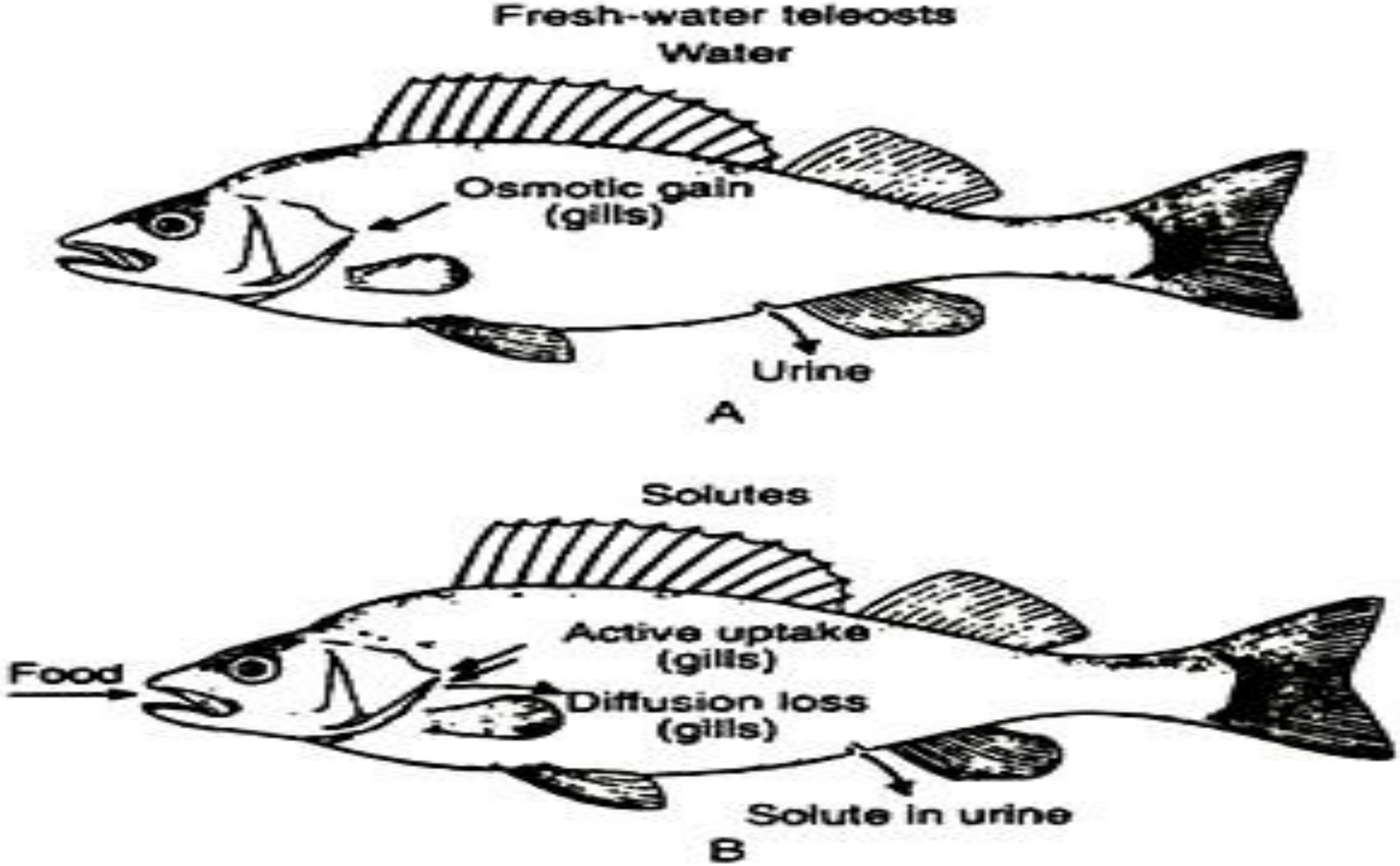

Fig. 8.39 : A fresh-water teleost is osmotically more concentrated than the medium and, therefore, suffers a steady osmotic influx of water, mainly through the gills (A). The excess water is eliminated as urine. Loss of solutes through the gills and in the urine is compensated for primarily through active uptake in the gills (double arrow, B)

Cont…

- The large volume of water is excreted as urine, which is very dilute and may be produced in quantities up to one-third of the body weight per day.
- The urine contains 2 to 10 mmol/litre of solutes. So large urine volume also causes a substantial loss of solutes (Fig. 8.39B).
- This loss is replaced by the gills, which is also slightly permeable to ions.
- Some solutes are taken in with the food, but the main intake is by active transport in the gills.
- It is evident from the studies that skin plays only a minor, if any, role in active absorption.