

33.4 WATER VASCULAR SYSTEM (OR AMBULACRAL SYSTEM)

Water vascular system (or ambulacral system) is a typical and unique feature of echinoderms. It represents a specialized part of coelom, being developed from the left hydrocoel of the larva. It consists of a system of canals containing sea water and amoeboid corpuscles. The canals have muscular walls and are lined by a ciliated epithelium. It helps in locomotion.

Structure

Water vascular system (WVS) of *Asterias* consists of the following parts (Fig. 33.11):

1. Madreporite
2. Stone canal
3. Ring canal
4. Tiedmann's bodies
5. Radial canals
6. Lateral or transverse canals
7. Tube feet

1. Madreporite. It is a light-coloured, sieve-like, button-shaped or circular calcareous skeletal plate. It is located on the aboral surface of the central disc in inter-radial position. The surface of madreporite is marked by a number of radiating narrow, straight or wavy grooves or

furrows (Fig. 33.12). The furrows are covered with ciliated epithelium and at their bottom they contain about 250 minute pores. Each pore opens into **pore canals**. The pore canals unite to form larger **collecting canals** within the substance of madreporite. Collecting canals lead into a sac-like **ampulla** below the madreporite. Ampulla is continued as a canal inside the stone canal.

2. Stone canal. It is S-shaped vertical canal which extends downwards (orally) and opens into a ring canal. Its wall is supported by a series of calcified rings and is lined internally with tall ciliated cells. The beating of cilia draw water into the canal. The stone canal is a simple tube in a young starfish, but in adult, its wall produces a prominent **ridge** in the lumen of stone canal. The ridge is bifurcated to form two spirally rolled **lamellae** (Fig. 33.12). They ensure water circulation.

During its course, the stone canal along with an **axial gland** ensheathed by a wide, thin-walled tubular coelomic-sac, called **axial sinus**. This entire structure is called **axial complex**.

3. Ring canal. It is also called **ring vessel** or **water ring**. It is a wide five-sided (pentagonal) canal in the oral region around the oesophagus.

In most starfishes, but not in *Asterias*, the ring canal gives off from the inner side in each inter-radius a large, thin-walled, contractile, pear-shaped sac, the **polian vesicle**. The polian vesicles store water and help in regulating pressure in the water vascular system. They also manufacture amoeboid cells of water vascular system (Box 33.4).

4. Tiedmann's bodies. From its inner side, the ring canal produces five pairs of greatly folded pouches, called **racemose vesicles** or **Tiedmann's bodies**. Each pair of these bodies has an inter-radial position. The cavity of each Tiedmann's bodies is divided into a number of chambers which communicate with the ring canal. In *Asterias*, there are only **nine** Tiedmann's bodies. The 10th body is absent and its place is occupied by the stone canal (Fig. 33.11).

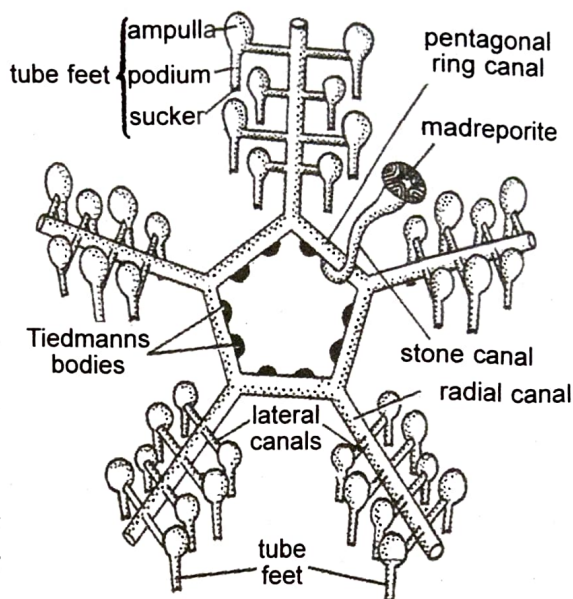


Fig. 33.11. *Asterias*. Water vascular system.

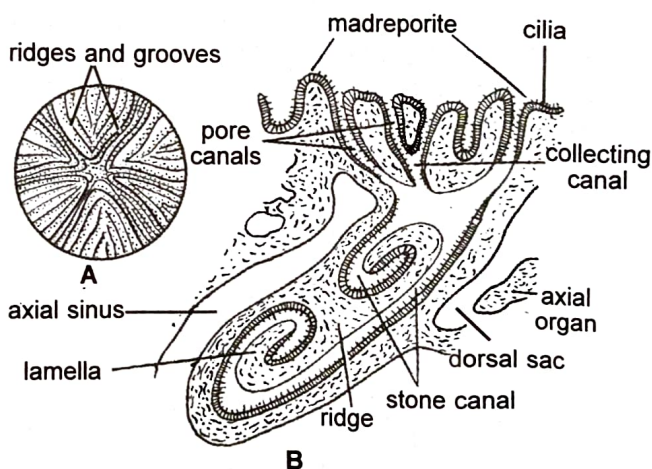


Fig. 33.12. *Asterias*. Madreporite. A—Surface view; B—Vertical section.

Box 33.3 Stone canal

Stone canal is a part of the water vascular system of echinoderms. It connects madreporite with the ring canal. In starfish (*Asterias*), it is a S-shaped tube. It is called **stone canal** because its wall contains calcareous deposits. The lumen of stone canal is divided by a longitudinal ridge. In *Henricia*, the ridge is a simple bulging in the lumen of stone canal. In *Asterias*, this ridge is

bifurcated into two vertical lamellae which are rolled inwards (Fig. 33.13A). In *Astropecten*, the coiled lamellae become very complicated and extend between the wall from one side to another of the lumen (Fig. 33.13B). In *Culcita*, the whole lumen of stone canal becomes divided into a number of irregular chambers (Fig. 33.13C).

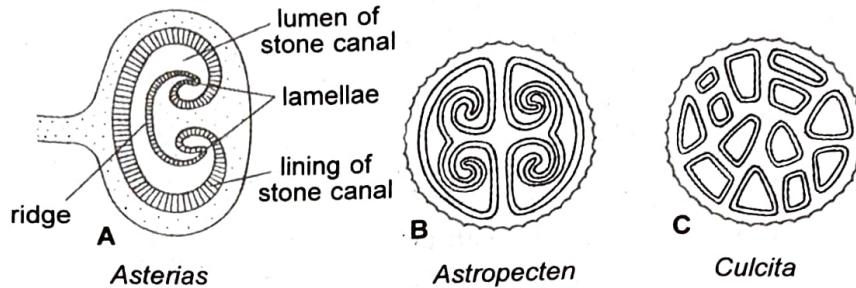


Fig. 33.13. Sectional view of stone canal in various Asteroids. A—*Asterias*; B—*Astropecten*; C—*Culcita*.

Among echinoderms stone canal show many other morphological variations. In Ophiuroidea, the stone canal is devoid of calcareous deposition and opens in one of the oral plates. In *Ophiactis virens*, the stone canals are many. In *Trichaster elegans*, there are five stone canals. In *Thyone*, the stone canal is branched.

Box 33.4 Polian vesicles in Echinodermata

The polian vesicles are special type of appendages of ring canals of water vascular system. They occur in all echinoderms except crinoids. These arise as thin-walled, bladder-like, pear shaped, ovoid or rounded sacs from the ring canal and hang freely into coelom. Polian vesicles open into ring canal by a narrow neck. The polian vesicles vary in size and number. They are absent in *Asterias rubens* but present in other sea stars. Many sea stars contain five polian vesicles inter-radially in the disc. In holothurians, their number varies from one to many. In *Astropecten*, a few polian vesicles open into ring canal by one common stalk (Fig. 33.14B).

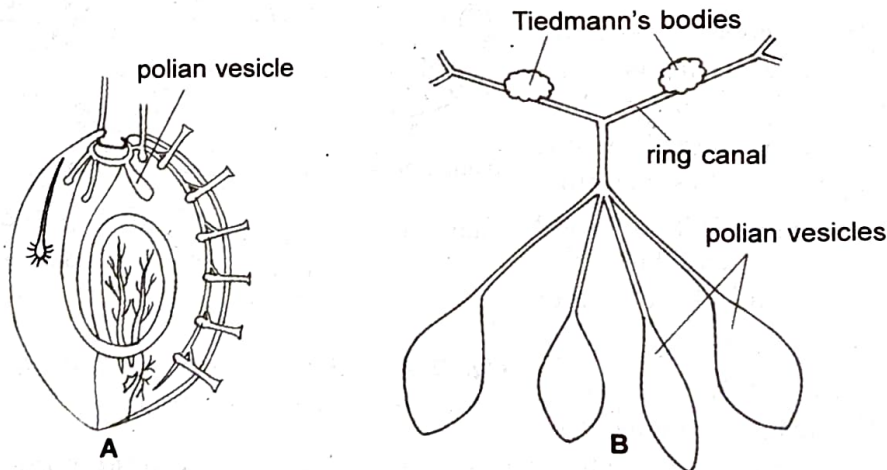


Fig. 33.14. A—Polian vesicle in *Holothuria*; B—Polian vesicles in *Astropecten*.

The actual function of Tiedmann's bodies is still unknown. They are supposed to be lymphatic glands to manufacture the **amoebocytes** of water vascular system. **Furguson (1984)** demonstrated that some sea water passes through these bodies into the perivisceral coelom. According to him these bodies participate in the production of coelomic fluid.

5. Radial canals. From the outer surface of the ring canal are given out five long, ciliated **radial canals**. One radial canal extends into each arm upto its extremity through the ambulacral groove of the arm. Radial canals run on the oral side of the ossicles and terminate as the lumen of terminal median tentacles.

6. Lateral or transverse canals. In each arm, the radial canal gives out two series of short, narrow, transverse branches called **lateral, transverse or podial canals**. Each lateral canal contains a **valve** to prevent backward flow of fluid into the radial canal and it opens into ampulla at the base of a tube foot.

7. Tube feet. A **tube foot or podium** is a hollow, elastic, thin-walled, closed sac-like structure. It contains an upper sac-like **ampulla**, a middle tubular **podium** and a lower disc-like **flattened sucker**. The ampulla lies within the arm, projecting into the coelom above the **ambulacral pore** which is a gap between the adjacent ambulacral ossicles for the passage of podium (Fig. 33.16). Tube feet, in fact, are external projections of the body wall; each of them has a lining of **ciliated epithelium** and a covering of **coelomic epithelium or peritoneum**. Between these two epithelia lie **connective tissue and longitudinal muscle fibres**. Contraction of the muscles of a side causes bending of a podium.

The podia are arranged in two double rows along the length of the ambulacral groove. They are chief locomotory and respiratory organs of *Asterias*.

Function

The water vascular system is lined with cilia and is filled with a fluid very similar to sea water. This fluid, however, contains **coelomocytes**, a little **protein** and a high concentration of **potassium ions**. The system operates as **hydraulic system** and brings about locomotion, adhesion to the substratum and the capture and handling of food. All these functions are performed by the help of tube feet.

1. Locomotion. The beating of cilia causes water to enter through madreporite. It passes into the tube feet (= podia) and their ampullae. When the ampulla contracts, the valve in the **lateral canal** closes, and water (fluid) is pressed into tube feet which get distended (upto 5 cm) due to their muscular walls. The podium comes in contact with the substratum and the sucker adheres to it. Adhesion is also has a chemical base. The podium secretes a substance that makes bonds with the surface of substratum. Another secretion breaks the bonds and sucker becomes free (Thomas and Hermans 1985).

After their fixation with substratum, the tube feet contract in unison and push the body forward. Due to contraction of muscles, the fluid from each tube foot, returned to the ampulla and tube foot is shortened. This lessens the pressure at the tip so that the suckers detach. The same process is repeated again and again to bring about locomotion. In a section of arm most **podia** perform the same step and the animal moves forward. The action of podia is highly coordinated. During locomotion one or two arms act as leading arms and podia in all the arms move in same direction.

Other parts of the water vascular system—the madreporite, stone canal, ring canal and radial canals maintain proper fluid pressure necessary for the working of ampullae and podia. Some fluid is always lost by leakage through podial walls when fluid pressure increases in **podia**. To maintain constant fluid pressure some sea water is drawn through the madreporite. Star fish moves very slowly—15 cm per minute.

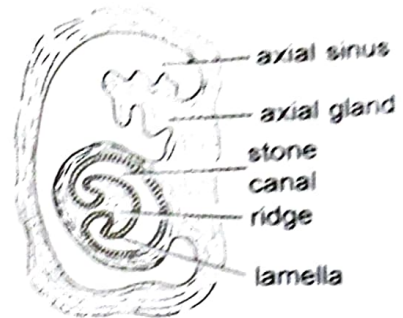


Fig. 33.15. *Asterias*.
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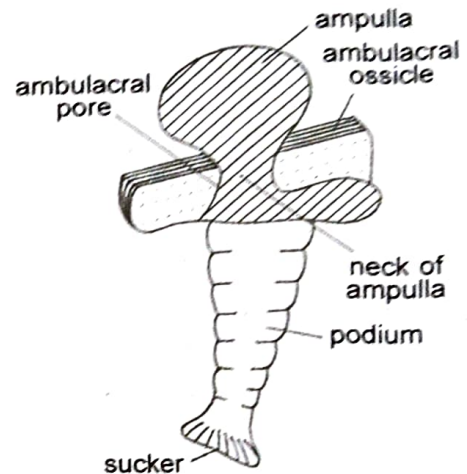


Fig. 33.16. *Asterias*. A tube foot.

2. Climbing. Due to turgidity and terminal suckers, the tube feet are able to take a firm grip of the substratum and this brings about adhesion. Combined action of podial suckers enables starfish to climb vertically over rocks.

3. If a star fish is turned over, it can right itself by folding.

4. Food capture. The suckers of the tube feet are also used to capture food.