WATER VASCULAR SYSTEM IN ECHINODERMS

Introduction to water vascular system:

The water vascular system is enterocoelic in origin and arises from the left hydrocoel. It exhibits radial symmetry from the beginning and is equally developed in all echinoderms.

This system lies just above the haemal system. It is primarily locomotory in function and also sub-serves the function of tactile and respiratory organs in some cases. The excretory role of water vascular system, suggested by some workers, is not yet fully ascertained.

Histological picture reveals that the canals have an inner lining of flat ciliated epithelium, a layer of longitudinal muscles, a connective tissue layer and an outermost layer of flat ciliated cells.

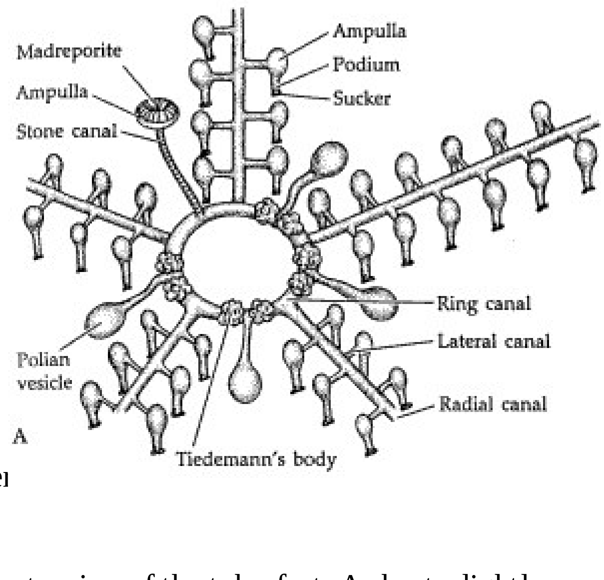
Contents of water vascular system:

The canals of the water vascular system contain a fluid of albuminous nature. It contains sea water and leucocytes. Existence of red corpuscles is recorded in an ophiuroid, ophiactis virens. Binyon (1964) has shown that the level of potassium in the fluid may be as much as 60% above the sea water value. Boolootian (1966) has recognised 14 different types of amoebocytes in this fluid.

General plan of water vascular system:

The water vascular system in different classes of echinodermata has almost the same structural organisation. It comprises of a few canals together with some appendages attached to these canals. The typical arrangement of the water vascular system is exhibited by asterias.

The water vascular system includes a circumoral canal (circular ambulacral or ring canal) situated around the mouth which gives tubular radial extensions, called radial canals. The number of the radial canals is usually five. But the number corresponds to the number of the radii of the body.



Each radial canal ends blindly at the end of the arm and gives off along its course lateral vessels, each joining a tube-foot. Each tube- foot is a hollow conical or cylindrical process with an ampulla and a terminal sucker. The junction between the later valves which assist in locomotion.

The contraction of the ampullae results in the extension of the tube-feet. A short, slightly curved, cylindrical and vertically disposed stone or sand canal is present between the madreporite and the ring canal. The stone canal opens into the ring canal at the oral end and into the madreporic ampulla at the aboral end.

The madreporite is a skeletal plate-like structure placed at the aboral side. It is perforated by pores, called the madreporic pores, which lead into madreporic ampulla or vesicle from where the stone canal starts. The stone canal is surrounded by a wider canal, called axial sinus, the wall of which becomes folded to form the axial organ or dorsal organ or ovoid gland or heart. The role of axial organ is not fully known.

Besides the main vessels, some appendages become associated with the system. Inter-radially located and connected with the ring canal, there are polian vesicles and tiedemann's bodies. The polian vesicles are bladder-like sacs with narrower neck.

They are contractile and usually manufacture amoeboid cells. The tiedemann's bodies are glandular in nature and consist of a number of branched tubules. They are yellowish in colour and give origin to cells for the water vascular system.

Modifications of the water vascular system in different classes:

The water vascular system is equally developed in all echinoderms and has basically the same structural plan. In the different classes, slight deviations from the basic plan are encountered. The variations are due to their adaptations to different modes of living.

Madreporite:

In asteroidean (fig. 21.7b), it is a calcareous sieve-like plate and is situated amorally. The increase in number of the madreporite is observed in many asteroidea. The number of madreporite is 3 in asterias caponises, 4 in a, tenuispina, 16 in acanthaster echinites.

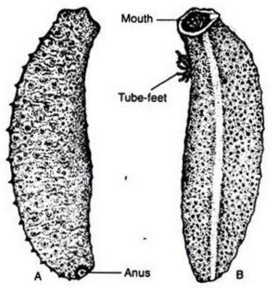


Fig. 21.16: External features of *Holothuria*. A. Aboral view. B. Oral view.

The madreporite is provided with many secondary water-pores. Most of the water-pores lead into stone canal and rest into the axial sinus in adults.

The water-pores are many in number and develop from one primary larval water-pore. Like asteroidean, in echinoid (fig. 21.16) also the madreporite possesses many pores, but echinocyamus pusillus, is peculiar in having only one water-pore. In ophiuroidea, the madreporite has one water-pore, but in ophiurae and astrophytidae there are several water pores.

In holothuroidea true madreporite is

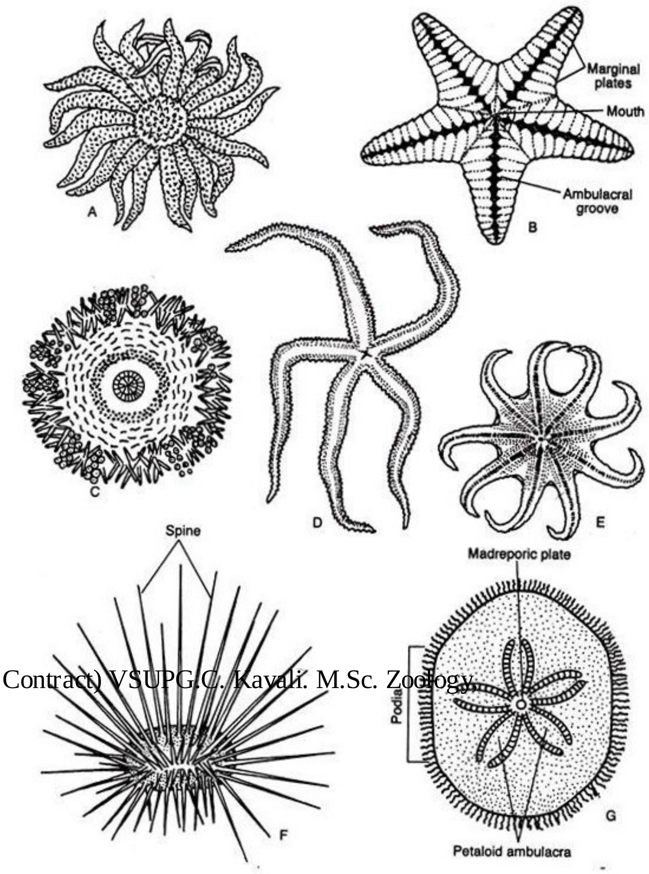


Fig. 21.27: Some important echinoderms. A. *Heliaster*. B. *Ctenodiscus*. C. *Arbacia*. D. *Zoroaster*. E. *Solaster*. F. *Diadema*. G. *Clypeaster*.

absent. Great variations are observed regarding the opening of the stone canal. In pelagothuria it opens to the exterior by one pore and in many elasipodidae there are 2 to 50 or more pores. But in some elasipodidae and molpadidae the stone canal opens into the coelom by many pores instead of opening to the exterior.

In the rest of the holothurians, the stone canal opens into the axial sinus which in turn opens to the exterior by one or more water-pores which are comparable to madreporite. The madreporite in this case may best be called as internal madreporite.

In crinoidea, madreporite is represented by fine water-pores on the body surface and these water-pores lead directly into the body cavity. The water-pores are recorded to be 1500 in antedon bifidia.

Stone canal:

Normally the stone canal is a short, slightly curved and vertically disposed cylindrical tube. It opens into the ring canal at the oral end. It is enclosed by the wall of another wide canal, the axial sinus.

In asteroidea, the stone canal is one and ‘s’-shaped. But in asterias rubes, there are two stone canals. The wall of the stone canal is provided with calcareous ossicles. Development of a longitudinal ridge-like projection makes the stone canal complicated in the different members of the asteroidea (fig. 21.37).

The following conditions are encountered:

(1) In echinaster purpureus, the fold projects as a ridge into the canal. This represents the simplest condition.

(2) In asterina gibbosa, the free terminal end divides into two lamellae which may be coiled. This is seen in asterias and gymnasterias.

(3) In astropecten, the coiled lamellae become very complicated and extend between the walls from one side to another of the lumen.

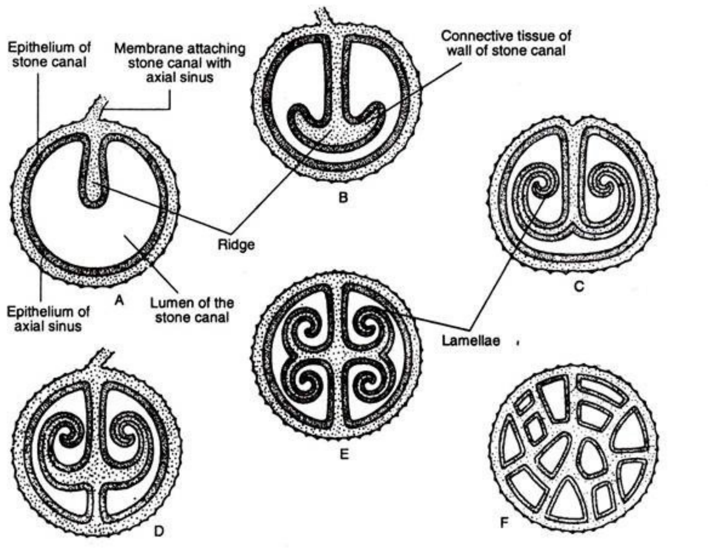


Fig. 21.37: Sectional view of stone canal in various Asteroids. A. *Echinaster.* B. *Asterina.* C. *Asterias.* D & E. *Astropecten.* F. *Culcita.*

(4) In culcita and astropecten aurantiacus, the whole lumen becomes divided into a number of

irregular chambers.

In echinoidea, the stone canal is only one and has soft membranous wall devoid of calcareous matter. In cedaris, the wall of the stone canal is provided with calcareous deposit. The stone canal has an ampulla below the madreporite.

In ophiuroidea, the stone canal is devoid of calcareous deposition and opens in one of the oral plates (sedgwick, 1898). In trichaster elegans, there are five stone canals. In ophiactis virens, the stone canals are many.

In holothuroidea, the stone canal is mostly single but in some cases it may be more than one. The number of accessory stone canal is also variable. Its walls are provided with calcareous matters.

The opening of the stone canal shows greatest variation, particularly in holothurians. The stone canals in all holothurians are attached to body wall. In pelagothuria, the stone canal opens to the exterior by one or many pores. This also is true in many elasipodidae.

In thy one, the stone canal is branched. In some elasipodidae and molpadidae the stone canal ends blindly and opens internally into the coelom by many pores as in the genus elasipoda.

In crinoidea, stone canal as such is absent. Numerous tubes, without calcareous deposits in their walls, emerging from the ring vessel are the representatives of the stone canals of other groups.

Axial sinus and axial organ:

The axial sinus is variously developed in different echinoderms. It is quite distinct from the perivisceral cavity in adult excepting some holothurians and crinoids. The axial sinus is inconspicuous in asteroids, very small in echinoids and ophiuroids. The axial organ, a fold from the wall of the axial sinus, is present in all echinoderms excepting holothurians.

The axial organ comprises connective tissue and cells of germinal rudiment. In echinoids the axial sinus ends blindly and communicates with the stone canal. In crinoids, the portion of the coelom, into which the tubes from the ring vessel open, represents the axial sinus. The axial organ occupies the axis of the body. It consists of anatomising canals embedded in connective tissue.

Ring canal and radial canals. The ring canal is a constant structure in all echinoderms and is situated round the mouth. It gives tubular prolongations along the radii, called radial canals or radial vessels. In asteroidea, the ring canal is pentagonal and is situated in the buccal mem- brane (peristome). It is communicated with the exterior through the stone canal and axial sinus.

In echinoidea, the ring canal is situated at the upper end of the jaws and gives five radial vessels. In ophiuroidea, the condition is same as in asteroidea. In holothuroidea, the ring canal is situated around the oesophagus and the five radial vessels extend towards the oral end and again proceed aborally along the radii of the body.

The radial vessels end blindly and the terminal tentacle, characteristic of asteroidea and echinoidea, is absent. The numbers of radial vessels are five. They are absent in synaptidae. In case of crinoidea, the terminal tentacles are absent and the radial vessels end blindly.

Lateral vessels and tube-feet:

The radial vessels give lateral vessels to the tube-feet. The tube-feet are cylindrical processes and their cavities are continuous with the water vascular system. The tube-feet possess am- pullae at their inner ends and suckers at the terminal ends. The ampullae are present in all echinoderms, except ophiuroidea and crinoidea.

In crinoidea, terminal suckers are absent and the tube-feet are sensory and respiratory in function. In many astropectinidae, each tube-foot is provided with two ampullae. In all the members of the asteroidea the tube-feet are provided with well-developed suctorial disc-like expansions.

In echinoidea, the tube-feet show variations. In endocyclica, the terminal ends of the tube-feet are suctorial and supported by calcareous rings. In cidaridae and echinothuridae, small oral tube-feet project from the perforations of the ambulacral plates which are olfactory in nature. In clypeasteroids, the tube-feet are broad and the walls are devoid of calcareous bodies. They help in respiration.

The cylindrical tube- feet which are suctorial and provided with calcareous rings, are locomotory in function. But in spatangoids, the tube-feet vary quite greatly which are due to their functional activities.

The tube-feet without suckers are respiratory in function; with suckers and calcareous ring are locomotory in function; with expanded terminal disc and filaments around the mouth as the tactile organ; rosette feet act as prehensile organs and seize food from the surroundings.

In ophiuroidea, the orientation of the lateral vessels and the tube-feet is same as in asteroidea, but they are devoid of ampullae and are exclusively sensory in f

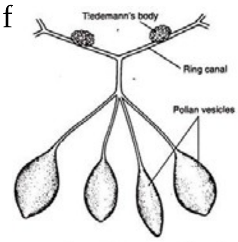


Fig. 21.38: Cluster of polian vesicles of *Astropecten*.

In holothuroidea, lateral branches from the radial vessels go into the tube-feet as well as into the tentacles. Some lateral branches also emerge from the radial vessels and end blindly in the body wall. Ampullae are present in the tube-feet and in the tentacular canals. The tentacular canals are devoid of ampullae in elasipodidae where they arise directly from the ring canal.

Among the crinoidea, in antedon, each lateral branch from the radial vessel supplies three tube-feet. The tube-feet have ampullae. They are purely respiratory and sensory in function.

Polian vesicle and tiedemann's bodies:

The ring canal possesses bladder-like polian vesicles and gland-like tiedemann's bodies. In asteroidea, the number of polian vesicles varies greatly. They are totally absent in Asterias Rubens and a. Glacialis. There are cases where two or many polian vesicles may be present in each inter-radius as seen in astropecten.

In this case, a few vesicles open into the ring canal by one common stalk (fig. 21.38). The tiedemann's bodies are attached to the ring canal and are usually two in each inter-radius excepting that containing the madreporite where only one is present.

Amongst echinoidea, in most and ocylica, a small spongy outgrowth in each inter-radius is present which is supposed to be the polian vesicle. There are five tiedemann's bodies in echinoidea. In ophiuroidea, in each inter-radius excepting that of stone canal, there is a polian vesicle. In ophiactis virens, besides two or three polian vesicles opening in each inter-radius, there are many tubular canal of simroth (supposed to be respiratory in function). The tiedemann's bodies appear to be wanting. Some authorities refer some structures homologous with tiedemann's bodies.

Some say that the radiant protrusions are found in some places. Hyman (1955) also refers that these are tiedemann's bodies. Fedetov (1926) has reported that the radial protrusion is associated with water ring in ophiactum sericeum.

In gorgonocephalus, a bunch of pouch-like structures or branching tubules are present in water ring. He did not mention it as tiedemann's bodies but represented it as specialized structure.

Hyman (1955) said perhaps this structure mentioned in these above animals as homologous with the tiedemann's bodies. In holothuroidea, usually one large polian vesicle is present. In some exceptional cases more than one polian vesicle may be present. In crinoidea, the polian vesicle and tiedemann's bodies are absent.

Functions of the water vascular system:

1. Locomotion:

The main function of the water vascular system is to help in locomotion. Echinoderms having suctorial podia (tube-feet) can adhere to the substratum temporarily. The mechanism of locomotion has discussed in detail under the water vascular system of asterias and echinus.

2. Respiratory and sensory:

In ophiuroidea and holothuroidea the tube-feet (podia) are primarily sensory in function. In echinoidea (in regular urchins), the tube-feet of the aboral side lack terminal disc and are sensory in function (Hyman, 1955).

In spatangoids, the petaloids of the aboral surface are provided with lobulated podia without suckers and are believed to some respiratory in function (Loven, 1883).

3. Excretory:

Nitrogenous wastes are eliminated through the thin areas of the body surface such as the walls of tube-feet.