circular and longitudinal muscles. This device is of great significance for the fishes undergoing rapid vertical movements.

Histological Modifications:

The morphological modifications of the swim-bladder are accompanied by histological modifications in different fishes, the swim-bladder acts as a hydrostatic organ. It helps fishes to sink or ascend to various depths by altering the gas content in the bladder. In fishes having open ductus pneumaticus, the volume of gas content in the bladder can be changed by swallowing or removing air from the bladder.

But in some physostomous and all physoclistous fishes this process of gas transference is done directly from the blood stream. Inside the bladder there is an oxygen-producing device and an oxygen-absorbing device. The swim bladder is a vascular structure but the degree of vascularization varies in different teleosts.

In some species of the families Clupeidae and Salmonidae the capillaries are uniformly present all over the swim-bladder, but in most cases these highly vascular interlacing and tightly packed capillaries form a mass called rete mirabilis. The anterior chamber of swim bladder shows the tendency to become differentiated into oxygen-producing area called red body.

The oxygen is produced by the reduction of the oxyhaemoglobin in the erythrocytes when brought into close contact with the secreting epithelial cells of the gas gland. The red body consists of internal oxygen-secreting cells (gas gland) and supplied by the blood vessels from the retia Mirabella (sing, rete mirabilis).

It forms a complicated structure where the arterial and venous capillaries communicate only after reaching the gas gland. The most primitive condition is observed in Pickerel where the gland is covered by thick glandular epithelium which is thrown into a number of folds. In eels and some other fishes, the red bodies are non- glandular in nature but serve the same physiological function.

The red gland is supplied with blood from the coeliac artery and is returned to the portal vein. The activity of the red gland is controlled by the vagus nerve. In the fishes with functional ductus pneumaticus the gas glands are absent but in eels this function is taken up by the red gland.

In the physoclistous fishes, the anterior region is modified for gas production and the posterior region or chamber is specialised for the absorption of gas into the blood. The posterior chamber becomes excessively thin- walled to facilitate gas diffusion.

Beneath the walls, the gas is absorbed directly into the blood. The formation of the oval in some fishes, is a special development for the absorption of gas. The wall of the oval is very thin and highly vascular. Through this epithelial lining oxygen can easily pass to the network of vessels. This gas absorbing region receives blood supply from the dorsal aorta and the blood is returned to the post cardinal vein. The activities are governed by the sympathetic nerves.

The histological differentiation for the gas production and gas absorption is a very significant achievement in fishes. The gas produced by the red body is mostly oxygen and this oxygen is readily absorbed or diffused from the swim-bladder directly into the capillaries. The oval is modified for gas absorption in many fishes.

By the alternate process of gas production and gas absorption, the internal pressure and volume of the gas content inside the swim-bladder can be increased or decreased. The red body is usually confined to the anterior chamber, but in fishes where the anterior chamber becomes secondarily associated with the auditory function, the gas gland may be confined to the posterior chamber.

7. Shape and Size of Swim-Bladder:

The swim-bladder varies extensively in shape and size. In Umbrina, it is oval shaped and without any appendage. In Atractoscion, it gives off only one pair of simple diverticula that extends from the anterior side. In Kathala, the swim-bladder develops a pair of appendage extending in front of transverse septum into head.

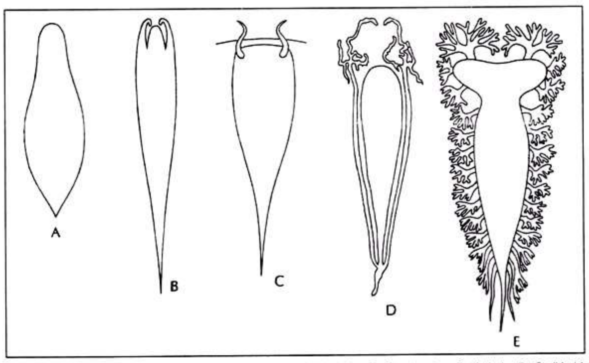

Fig. 6.88 (A–E) : Variations in the shape of swim bladder. A. Umbrina, B. Atractoscion, C. Kathala, D. Otolithoides, E. Johnius.

In some forms it gives off many branched diverticula. In many fishes, the anterior prolongations of the swim-bladder come into close contact with the wall of the space containing the internal ear. In Clupea, the narrow anterior end of the swim-bladder enters into a canal in the basioccipital of the skull and divides into two slender branches.

The anterior end of each branch dilates to form a round swelling and lies in close contact with the internal ear. A more or less similar condition is observed in Tenualosa ilisha. In many fishes finger-like diverticula develop from the swim-bladder.

In Gadus, a pair of diverticula originating from the anterior part of the bladder project into the head region. In Otolithus, each anterolateral end of the swim-bladder gives rise to an outgrowth which sends one anterior and a posterior horn.

In Otolithoides, the appendages attached to posterior end of bladder and at least the main part lying parallel to the bladder. In Corvina lobata, many such branched diverticula develop from the lateral walls of the swim-bladder. In Johnius, it is hammer-shaped with 12 to 15 pairs arborescent appendages, the first branching in the head and the posterior tip are highly pointed.

Usually in most cases, the swim-bladder is divided transversely into an anterior and a posterior chamber as seen in cyprinoids, Esox, Catostomus, Pangassius, Corvina, etc. But the longitudinal division of the swim-bladder is rare.

In Arius the swim-bladder is splitted longitudinally. In Notopterus, a longitudinal septum divides the swim-bladder into two lateral chambers. Due to the presence of septum or septa, the internal cavity of the swim-bladder is either completely or partially divided.

8. Weberian Ossicles:
The perilymphatic sac and the anterior end of the swim-bladder are connected by a series of four ossicles, which are articulated as a conducting chain.

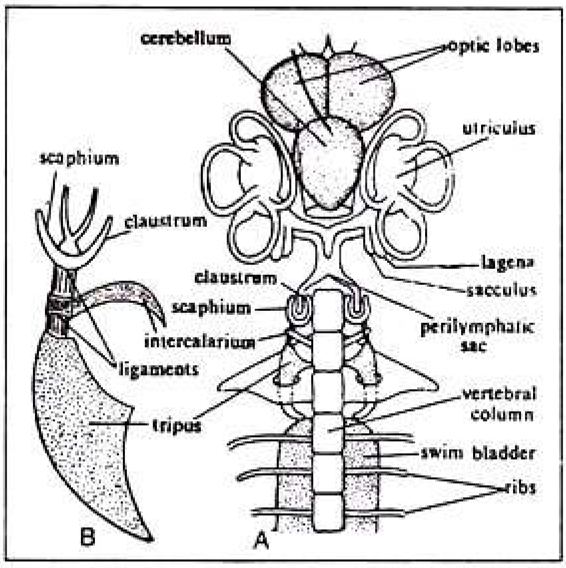

Fig.6.89 : A. Weberian ossicles and their relation with other structures in *Catastomus*. B. Showing the different parts of Weberian ossicles.

Of the four, the tripus, intercalarium and scaphium actually form the chain, while the fourth one, claustrum lies dorsal to the scaphium and lies in the wall of posterior prolongation of the perilymphatic sac. The function of these ossicles is controversial.

It is regarded that the Weberian ossicles either help to intensify sound vibrations and convey these waves to the internal ear of help to understand the state of tension of air pressure in the bladder and transit changes of such pressure to the perilymph to set up a reflex action. There are various views regarding the actual process of derivation of these ossicles.

De Beer (1937) and Watson (1939) regarded that these are detached or modified processes of the first three anterior vertebrae. As regards the actual mode of origin of the four ossicles there are differences of opinion.The claustrum is regarded to be modified interspinous ossicle or modified spine of first vertebra or modified neural arch of first vertebra or modified intercalated cartilage or modified neural process of first cartilage.

The scaphium is considered to be the modified neural arch of the first vertebra or modified rib of the first vertebra or derived from the neural arch of the first vertebra and also from the mesenchyme.

The intercalarium is derived from the neural arch and transverse process of the second vertebra or from the neural arch of the second vertebra and also from the ossified ligament or from the neural arch of the second vertebra only.

The tripus is formed from the rib of the third vertebra and the ossified ligament or from the transverse process of the third vertebra along with ossified wall of the swim-bladder or from the transverse process of the third vertebra and the ribs of third and fourth vertebrae.

9. Functions of Swim-Bladder:
The swim-bladder in fishes performs a variety of functions.

10. Hydrostatic Organ:
It is primarily a hydrostatic organ and helps to keep the weight of the body equal to the volume of the water, the fish displaces. It also serves to equilibrate the body in relation to the surrounding medium by increasing or decreasing the volume of gas content.

In the physostomous fishes the expulsion of the gas from the swim-bladder is caused by way of the ductus pneumaticus, but in the physoclistous fishes where the ductus pneumaticus is absent the superfluous gas is removed by diffusion.

11. Swim-Bladder acts as Adjustable Float:
The swim-bladder also acts as an adjustable float to enable the fishes to swim at any depth with the least effort. When a fish likes to sink, the specific gravity of the body is increased.

When it ascends the swim-bladder is distended and the specific gravity is diminished. By such adjustment, a fish can maintain equilibrium at any level.

12. Swim-Bladder Maintains Proper Centre of Gravity:
The swim bladder helps to maintain the proper centre of gravity by shifting the contained gas from one part of it to the other and this facilitates in exhibiting a variety of movement.

13. Swim-Bladder helps in Respiration:
The respiratory function of the swim-bladder is quite significant. In many fishes living in water in which oxygen content is considerably low, the oxygen produced in the bladder may serve as a source of oxygen. In a few fishes, specially in the dipnoans, the swim bladder becomes modified into the 'lung'. The 'lung' is capable of taking atmospheric air.

14. Swim-Bladder as Resonator:
The swim-bladder is regarded to act as a resonator. It intensifies the vibrations of sound and transmits these to the ear through the Weberian ossicles.