Some Otoliths of Illinois Fishes

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All vertebrate ears have some form of material in the endolymph that serves to motivate the sensory patches of the equilibrium and hearing regions of the ear. These are usually small crystals of calcium carbonate, although sea sand is often found in the endolymph fluid of the Elasmobranchs, in which the endolymph ducts open to the outside of the head. Continuing through the vertebrates, the same system is always present, but it may take different forms in the hearing region of the ear. The lower fishes, such as sharks, have the fine carbonate crystals, while starting with the ganoids, and ending with the teleosts, there is an agglutination of the sand-like crystals into definite bodies of a larger size. These enlarged structures are found in the utriculus, sacculus and lagena. Amphibia may have otoconia agglutinated into a mass, but in birds, reptiles and mammals, there is no agglutination at all. Peculiarly, the dipnoi have masses of material but no definite otolith bodies.

An analysis of the otoliths shows that they are made up principally of calcium carbonate, with slight additions of other salts, and a small amount of organic material. Since they are attacked by acids, they disintegrate in the digestive system, are destroyed by formaldehyde and must be obtained from fresh specimens, those preserved in alcohol, or in salted specimens.

In intermediate fishes, the semicircular canals lie in the side of the brain case, and the otoliths are easily taken out by splitting the skull and taking out the brain, which leaves the canals and membraneous ear exposed. The same procedure is possible with the lower teleosts such as the Isospondyls, (trout, salmon, etc.), but in the higher teleosts, the otoliths are in such a position that the only way to dissect them out, is to slice off the top of the head, and approach them from the dorsal side. In many fishes, (Percomorphi, Ostariophysi) the sacculus and lagena lie in a tunnel which extends under the floor of the brain case, and are embedded in bone. Percomorphi have a thin bony capsule that is easily removed, but the Ostariophysi, have the otoliths in a heavy bony tunnel and in these, the best method is to remove the block containing them, and then dissolve the bone in KOH. By boiling it gently, the delicate otoliths can be removed uninjured. This method is the only safe one for the members of the Ostariophysi (carp, catfishes, characins, and electric eels).

Knowledge of the otoliths goes back to Aristotle and the early naturalists, who probably saw the otoliths in dissecting and in eating fish heads. During the middle ages, they were considered as somewhat problematical, were worn as amulets, and used in medicine. They were considered as specific for headaches, colic, kidney troubles and for other ills. Since the otoliths have peculiar markings on them, they were often regarded with superstition, and people saw in them pictures of saints, the key to paradise, and other mythical figures that lent themselves to popular superstition. The earliest anatomists considered them as structures that were highly detrimental to the fishes, and thought that they would conduct cold to the brain and thus kill the fishes in cold weather. No real work was done on the otoliths in a scientific way until the beginning of the seventeenth century, when the early students of fish anatomy began to work on the organization of this large group. The otoliths were recognized early as having some value in classification and were thus used by some of the early anatomists.

Otoliths are found in three parts of the ear: the utriculus, sacculus and lagena. The otoliths are given names according to their position in the ear. The stone from the utriculus is called the lapillus, or utriculith; that from the sacculus the sagitta or sacculith; that from the lagena, the asteriscus or lagenalith. They are placed so that they have a definite relation to the receiving macula of these ear regions. The utriculith is usually quite small, and is not as distinctive in shape as the others, although a general symmetry is always present, and it is possible to separate rights and lefts with ease. The sacculith is usually the most striking, both from its size and configuration, and the mesial face usually has a distinctive pattern, that is correlated with the receiving macula. Many points present themselves concerning this pattern on the inner face that may be used in the determination of similar forms. In most fishes the sacculith is of considerable size, as in the drums, and the weakfishes receive their generic name Otolithus, from the striking otoliths. The greatest break in the type of sacculith comes in the Ostariophysi, where the lagenalith is enlarged and the sacculith reduced to a very delicate, fragile winged spike. The lagenalith is distinctive enough so that it is possible to separate it from the others, and it is always possible to separate rights from lefts. Numerous experiments have been made to determine the use of these structures in hearing, and it is generally assumed that they act in connection with the sensory patches of the hearing part of the ear. They are held in place by slight membranes and their movements are slight. From the great variability of the otoliths it seems probable that there is some relation between the habits and type of ear structures.

The structure of the otoliths shows that it is built up in concentric layers so it is assumed that a new layer is added each year. In section these seasonal rings appear, and in many species they are quite distinct. These seasonal rings are of a different color and texture, and in a number of species lend themselves readily to age determination. In old animals the rings become somewhat blurred so that the reading is much more difficult and in this they resemble scales. In spite of some irregularities, the growth rings are of distinct value in age determination. Studies made of a long series of otoliths, of the same species, and with a wide range of sizes, show that the variability is surprisingly small. While some defective otoliths are found, they are generally true to type, and a series of a hundred specimens will show but little variation. In other words, there is little change with growth and age, and the changes in size are proportional. Otoliths differ much in their clearness, and while some are so clear that the rings are plain, others are opaque, and it is necessary to use some clearing material to make the rings show at all. Some appear to be quite chalky and rough but generally the texture is fine and clear cut.

Since there are three otoliths, there are many possible combinations, and in a systematic study of fishes, these different elements can be used very effectively. There is a wide range in shape, size, markings, and position in the skull, so that it is possible to use them in systematic work. It is at once evident that there are numerous problems that have not even been touched as to the cause of the great variation in size and shape, and also their functional significance. It seems logical to suppose that the great variation in size and shape must have some relation to the habitat in which fishes live, and to the peculiar conditions to which the different species are subjected. There must be a great variation in the needs of fishes, since in some habitats, the ear would be a most valuable sense, while in others, the value to the animal would be slight or conjectural. The fact that the sacculus usually has the largest otolith, and that it is usually more varied, appears to indicate that this part of the hearing ear is most important in fish sense reception, but a reversal of this size relation occurs in the Ostariophysi, where the sacculith is small and the lagenalith large. In this case the lagenalith appears to have the functional importance usually given to the sacculith. Some anatomists believe that the names should be reversed in this case, and that the supposed lagenalith is really the sacculith in a changed position.

The use of the otoliths in fish work has been somewhat neglected in the United States since most of the papers dealing with them are of European origin. A long series of papers by A. N. Frost made something of a survey of the whole fish group, while others on the Continent have made important contributions both in fossil fishes and in present day forms.

There is a real significance in the value of otoliths to systematic work, and it is shown that the differences in the combinations of the otoliths can be used to separate orders, families, genera and often species. An added use comes in the ability to identify the food material of carnivorous fishes and even other fish-eating animals (Cormorants and fish-eating birds, and other vertebrates). The otoliths are retained in the stomach for some time before they are destroyed by the acids, thus making food identification possible. This has been used and has proved of value to students of fish food habits. To be of value it is necessary to have large collections of otoliths identified and cataloged as one would arrange a collection of fishes for study. Small black cards to which the otoliths are attached by black celluloid are very useful. This arrangement permits classification, storage, and ready access at all times.

Much work has been done on the otoliths of fossil fishes, because certain geological horizons contain abundant specimens. It is not difficult to account for these accumulations, when one has seen some of the fish holocausts that occur so often in nature, when millions of fishes are killed, and left in windrows along the shores. With a knowledge of the modern forms, it is possible to work out fossil faunas with some accuracy, and to establish the fish horizons on a scientific basis.

Because of the structure of the otoliths and the growth by adding layers, it is possible to make use of them in age determination and for growth rate. Some fishes lend themselves easily to studies of this type, especially when the otoliths are clear or only slightly opaque. When the otoliths are chalky, grinding and sectioning must be used. With age there is a gradual infiltration and a gradual loss of the distinctness of the rings, so that the value for accurate age determination is greatly lessened.

Since there are three of the otoliths, and since the patterns of the three are quite variable, they do offer a very promising field for the study of the relationship of specie genera, families and orders. The tie that binds the Ostariophysi are certainly not apparent from the outside of the animals, although all have Weberian ossicles, but the relationship is strikingly verified however, by the types of the otoliths, which in this case are of distinctive shape, and also imbedded in the floor of the brain case.