BIOMECHANICAL ASPECTS OF THE EVOLUTION OF SEMICIRCULAR DUCT SYSTEMS

by

M. MULLER

(Experimental Zoology Group, Department of Animal Sciences, Agricultural University, Marijkeweg 40, 6709 PG Wageningen, The Netherlands)

ABSTRACT

The system of semicircular ducts of the vertebrate labyrinth shows a conservative design on which considerable variations are present in individual species. During the last century, a single circular duct model has been used to describe the mechanics of this system. MULLER & VERHAGEN (1988a, b) have constructed a more elaborate model in which three semicircular ducts are mutually interconnected. Thus, endolymph may flow from one duct to another, driven by pressure-differences between the points of confluence of the ducts, even when the rotation takes place only in the plane of a particular duct. The system of interconnected ducts fundamentally differs from a system of three separate ducts. Time constants (indicating the response speed and recovery of the system after rotation) and endolymph displacement (indicating the sensitivity) are now determined by the flow in all parts of the vestibular system. The three-duct theory gives physical evidence for the possible evolution of the semicircular duct system. It is proposed that the early vertebrates already possessed a three-duct system comparable to that of recent Tetrapoda. This three-duct system is preserved in Holocephali, Osteichthyes and Tetrapoda. The two-duct system of recent Agnatha can be considered as a reduction of the original three-duct design, related to their semi-sessile or parasitic lifestyle. The two-plus-one duct system of Elasmobranchii forms a unique evolution-line which can also be derived from the original design.

KEY WORDS: allometry, vestibular, Agnatha, Holocephali.

INTRODUCTION

The semicircular duct system of vertebrates shows a conservative design. In principle, it is composed of three mutually interconnected duct circuits. The circuit formed by the anterior duct, crus commune and utriculus can be considered as the central part of the system. To this part the posterior and the horizontal (= external) duct circuits are connected. A great many variations of this basic design can be observed (fig. 1). In recent Agnatha only the two vertical ducts are present. In the Elasmobranchii the posterior
Fig. 1. Examples of labyrinths of vertebrates. (A) The labyrinth of a hagfish (*Myxine glutinosa*) from dorsomedial. After RETZIUS (1881, 1884). This is the only known labyrinth which is composed of two semicircular ducts forming a single duct ring. (B) A view inside the floor of the left labyrinth of a lamprey (*Lampetra fluviatilis*). After