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Editor

Flagella and Cilia

Types, Structure and Functions

Cell Biology Research Progress

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NOTICE TO THE READER

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PREFACE

Motility is an inherent property of living organisms, both unicellular and multicellular. One of the principal mechanisms of cell motility is the use of peculiar biological engines – flagella and cilia. These types of movers already appear in prokaryotic cells. However, despite the similar function, bacteria flagellum and eukaryote flagella have fundamentally different structures.

Chapter one of this book by Drs. Meijiao Wang, Li Zhang and Hanna Li is devoted to a comparative analysis of the flagella of prokaryotes and eukaryotes. It's believed that flagellum in eukaryotic cells appeared for the first time in ancient flagellates.

In chapter two, Drs. P. Huitorel, M. Cachon and J. Cosson summarize the results of their long-term studies of flagellum dinoflagellates. The "evolutionary invention" of the ancient flagellates proved to be so successful that the axonemal structure in flagellum has not changed for hundreds of millions of years.

In the third chapter, Drs. V. Bondarenko, G. Prokopchuk and J. Cosson reported the analyses of kinetic characteristics of flagella motions in fish using the most modern methodologies.

In chapter four, Drs. R. Uzbekov, A. Garanina, J. Burlaud-Gaillard and C. Bressac described spermiogenesis of the parasitic wasps Cotesia congregata. Their data showed that significant shortening of the flagella

occurs during the formation of the mature spermatozoon and this flagella has been the shortest spermatozoon flagella described in the animal kingdom until now. Centriole in this spermatozoon is transformed into a special structure known as the "cogwheel structure" that does not contain microtubules. In the process of multicellular organism evolution, flagella, which ensure the mobility of individual cells, gave origin to two types of cilia. Motile cilia in the tissues like cerebral ventricles, respiratory epithelium and oviducts moved liquid flows relatively to immobile cell layers. The second type of cilia (primary cilia) lost motility function and acquired cellular sensitivity function. Moving and sensitive cilia grow from basal bodies, which originate from centrioles.

Chapter five by Drs. I. Alieva, C. Staub, S. Uzbekova and R. Uzbekov discusses which of the centrioles – mother or daughter – creates the moving cilium and sensitive cilium.

In chapter six, Drs. D. Conkar and E. Nur Firat-Karalar describe in detail the biochemical aspects of primary cilium assembly pathways, intraflagellar transport and ectosome release. This chapter provides an overview of the trafficking pathways involved in ciliary compartmentalization and describes the primary ciliary as a sensitive "cell's antenna", participating in many regulatory processes in the cell.

Defects in flagella and cilia cause many hereditary diseases. Different examples of ciliopathy are described in chapter seven by Drs. E. Bragina, E. Blanchard and R. Uzbekov. A wide review of experimental models, organisms and analytical methods to study flagella and cilia are presented to readers who want to learn about their main research directives.

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Chapter 7

ULTRASTRUCTURAL AND FUNCTIONAL ABNORMALITIES IN VARIOUS VARIANTS OF CILIOPATHY

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ABSTRACT

The importance of cilia and flagella research has emerged in recent years when it became clear that they play an important role in the normal functioning of organs and tissues. "Ciliopathies" are complex multi-system human disorders of cilia and flagella which affect almost all organs, such as kidney, brain, eye, airways and skeleton. This disease includes many syndromes, such as primary ciliary dyskinesia (PCD), autosomal dominant and recessive polycystic kidney diseases, nephrono-phthisis, and some syndromes (for review, see Mitchison, Valente, 2017; Gonçalves, Pelletier, 2017; Reiter, Leroux, 2017). Despite the success of molecular biology in the study of genes whose mutations lead to the development of ciliopathies, the ultrastructural study of cilia and flagella remains, in some cases, an important diagnostic instrument. Here we present a mini-review concerning ultrastructure of normal cilia and flagella and some pathological conditions.

STRUCTURE OF NORMAL CILIA AND FLAGELLA

Human motile cilia can be divided into categories based on their structure and function. Motile cilia can create flow in the surrounding fluid (such as removing mucus and debris from the lung) and embryo movement in the endometrium before implantation. The sperm flagellum is also a motile axonemal structure, although the wave pattern is very different from that of the other motile cilia. Sperm motility is carried out in the male and female urogenital tract and is an important factor of fertility.

The cilium is a structure that is localized on the surface of certain epithelial cells, 1-10 microns in length. The term cilia is used when there are a large number of these organelles on the cell surface, while the term flagella relates to the case when there are one or two. The length of a human sperm flagellum is 40-45 microns. The centre part of cilia and flagella is occupied by the axoneme. The ultrastructure of axoneme in all eukaryotic cells is similar but biochemical composition is labile (Konno et al., 2015). The axoneme is formed by nine double microtubules (MTs) called doublets, located in a circle around two single MTs (C1 and C2) in

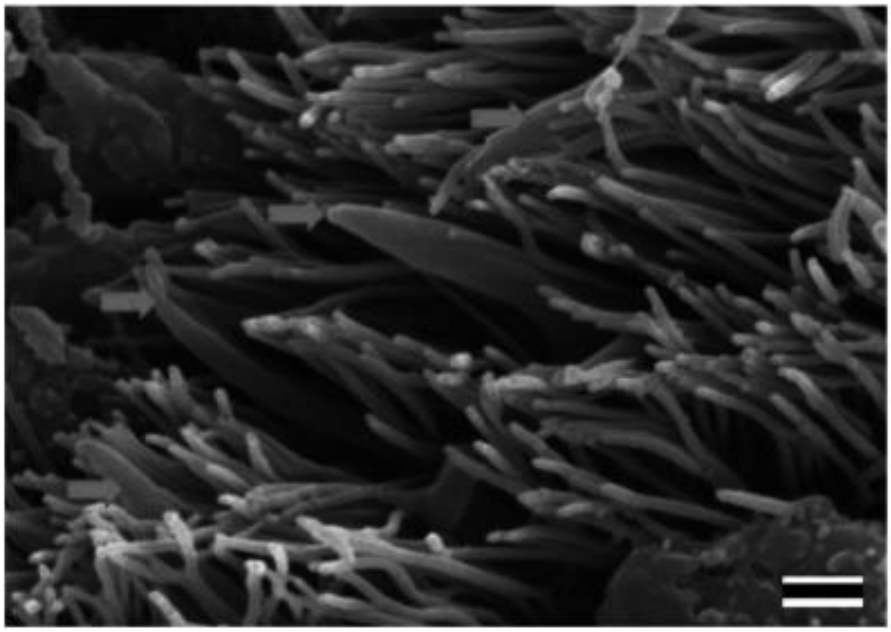

Figure 7. Atypical thickened cilia (arrows). Epithelium of the oviduct. Scanning electron microscopy. Scale bar 1 µm.

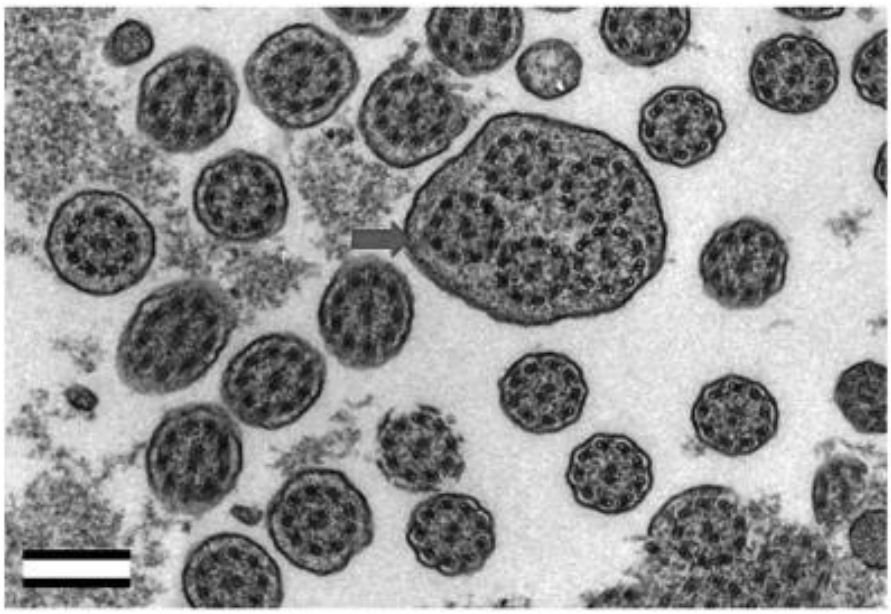

Figure 8. Transverse section through multi-axonemal cilia (arrow). Epithelium of the oviduct. Transmission electron microscopy. Scale bar 300 nm.