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Optimal branching designs in respiratory systems KEUNHWAN PARK, Institute of Advanced Machines and Design, Seoul National University, WONJUNG KIM, Department of Mechanical Engineering, Sogang University, HO-YOUNG KIM, Department of Mechanical and Aerospace Engineering, Seoul National University — In nature, the size of the flow channels systematically decreases with multiple generations of branching, and a mother branch is ultimately divided into numerous terminal daughters. One important feature of branching designs is an increase in the total cross-sectional area along with generation, which provide more time and area for mass transfer at the terminal branches. However, the expansion of the total cross-sectional area can be costly due to the maintenance of redundant branches or the additional viscous resistance. Accordingly, we expect to find optimal designs in natural branching systems. Here we present two examples of branching designs in respiratory systems: fish gills and human lung airways. Fish gills consist of filaments with well-ordered lamellar structures. By developing a mathematical model of oxygen transfer rate as a function of the dimensions of fish gills, we demonstrate that the interlamellar distance has been optimized to maximize the oxygen transfer rate. Using the same framework, we examine the diameter reduction ratio in human lung airways, which branch by dichotomy with a systematic reduction of their diameters. Our mathematical model for oxygen transport in the airways enables us to unveil the design principle of human lung airways.

Keunhwan Park
Institute of Advanced Machines and Design, Seoul National University

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