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Preface

Tree-shaped flow networks (dendritic flow patterns) are essential in the design and functioning of natural and engineered systems. These networks are able to connect, through a fluid flow, one point (source or sink) to a finite-size volume or a finite-size area. A distinctive feature of these networks for fluid distribution is their hierarchical structure and the successive generation of vessel divisions, which become progressively smaller. Tree networks present a close relationship between design and function, because they are not purposeless: Currents are guided in a certain way to achieve a maximized performance. In fact, space and resources are not unlimited, and performance and compactness are achieved through the design that minimizes the “operation cost.” This works for vascular networks, respiratory trees, and river basins, but also for oil and gas transportation, microfluidic manifold, and microchannel cooling systems.

This book is an attempt to present a comprehensive overview of the fundamentals in the area of tree flow networks. Emphasis is placed on the understanding of the design features of these networks and on their significance to the transport phenomena associated with these systems. It is intended to bring into perspective the relevant research that has been performed, mainly that which provides the reader with a comprehensive overview of the topic.

With these aims in mind, the book begins with a brief overview of a general framework within which tree-shaped networks take place (Chap. 1). Chapter 2 starts with the Hess–Murray law, starting from its original form, and extending it to turbulent flow, non-Newtonian flows, etc. Flows in asymmetric branched systems, occlusion in tree flow networks, and the fractal description of optimized tree flow architectures are also included. Scaling relations have been observed to exist in geophysics and physiology. This chapter also contains a review of the studies that use optimized tree networks to provide a theoretical foundation for the existence of Kleiber’s law for metabolic rates and the scaling laws of river basins, but also for the number of bifurcations of the respiratory tree. Chapter 3 deals with particle transport through the respiratory tree. It starts with quantification and a size characterization of aerosol particles and their deposition mechanism within the airways. Then, equations that describe the motion of air and dilute particles are presented.

This chapter also contains a brief review of some of the pertinent numerical and experimental investigations regarding inhaled particles. Chapter 4 studies several shapes of extended surfaces, i.e., fins and an assembly of fins. The goal is to discover the best configuration for T-, Y-, T–Y-shaped and a complex assembly of fins. The constructal design method is introduced and will be used in this chapter and the subsequent chapters, associated with the exhaustive search method and/or genetic algorithm, to optimize the studied architectures. Chapter 5 shows that it is important to analyze not only the fins but also the shape of the body to which the fins are attached. Configurations with trapezoidal and circular bodies are optimized for several thermal conductivities and other parameters of interest. Inverted or negative fins, also known as cavities, are investigated in Chap. 6. Isothermal and convective elemental cavities are optimized. Later, additional configurations such as T-, Y-, X-, and H-shaped cavities are studied, and the performance evolution from elemental to H-shaped configuration (second construct) is shown. Chapter 7 gives a brief idea as to how to cool a heat generation body using high thermal conductivity material. The best configurations of the Y-shaped pathways are determined, through a procedure that can be extended to other configurations of pathways, or pathways with different thermal conductivities. Finally, additional topics are suggested for the continuation of this study, for example configurations in which the thermal contact resistance can be taken into account.

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