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Book review

Shape and Structure, from Engineering to Nature, A. Bejan, Cambridge University Press, Cambridge, 2000, 344 pp, hbk $110.00/£70.00 (ISBN 0-521-79049-2), pbk $39.95/£24.95 (ISBN 0-521-79388-2)

Written in a refined style, with lucidity in every aspect that it covers, this delightful read conducts the reader through the marvelous world of optimal systems. It describes how the most simple of the optimization concepts used in engineering can also be adopted to explain many facts and phenomena in nature.

With basic college mathematics – indeed, only algebraic and very few calculus operations are used throughout the book, after scale and orders of magnitude analyses –, the author utilizes results from optimally engineered assemblies to discover a primary principle for the geometric formation and operation in natural systems. A Constructal Theory (from the Latin verb *construere*, meaning to build) is thus established that explains how certain basic elements, individually and collectively optimized to form an arrangement, are employed to construct more complex natural systems, within the specific constrains imposed by the physics in every case.

According to Constructal Theory, the principle according to which the geometric form of natural systems can be *deduced* is the optimized shape and structure obtained from engineering analysis. It is a predictive theory of the geometry and rhythm of nature, as opposed to the descriptive techniques of fractal geometry, where a repeating sequence of operations is *assumed* to generate an image that resembles a natural tree network.

The author elucidates many facts in nature, pertaining to both, the inanimate as well as to the living world of plants and animals. He uses concepts and methods from optimized engineering constructs like the shape and dimensions of cantilever beams, the distribution of heat dissipation elements in electronic arrangements, the branching of flow networks, the allocation of heat exchanger in power systems, the defrosting periods of modern refrigerators, the costs of travel time in transportation, etc. With these tools, he unfolds the observed river morphology, the dendritic formation in ice systems, the drying of wet pieces of land, the flying features of birds and flocks, the breath and heart rhythms of large and small species, and many other examples.

The most valuable aspect of this book is that the core analysis and synthesis methods of Constructal Theory are totally based on the author's own research experience during many years, previously published in specialized journals and books, and supported by many observed facts and results, fully documented in the open literature.

Chapter 1 presents the basic ideas and questions behind the theory developed in the remaining parts of the book. Chapter 2 reviews shape and structure that are present in optimized mechanical systems. Chapter 3 deals with thermal structures: parting from the cooling of electronic components, the optimal arrangements for ventilating convection flows are presented. In Chapters 4 and 5, these results are extended to explain how natural tree shapes emerge: the heat- and fluid-tree concepts, that configure the volume-to-point paths with minimal resistance. In Chapter 6 an explanation of river cross-sections is given, together with an elegant account of river basin morphology. Chapter 7 reviews some concepts about turbulent flow structure and similar unstable flow formation. Chapter 8 resumes the concept of optimal trees, but this time as applied to convective heat systems. In Chapter 9, a summary of optimal structures in power systems is presented, including flying machines and animals. The very surprising results for breathing and heart beating of animals is analyzed in Chapter 10. An unexpected but welcome analysis of transportation and economics structure is presented in Chapter 11. Finally, Chapter 12 gives a recapitulation of the book, with concluding and suggestive remarks.

In summary, this is an outstanding book, highly recommended not only for physicists and engineers, but also for life scientists, physicians, architects, economists and in general, for any person interested in how natural and man-made systems are composed and perform the way they do. Reading the book is a joyful experience that further stimulates the reader's mind and contributes to the creative observation of our natural and ingenuous world.

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