Chapter 1
The Constructal Law in Nature and Society
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1.1. The Constructal Law

Society with all its layers and features of organization is a flow system. It is a “live” system, perhaps the most complex and puzzling we know. It is the most difficult to comprehend because we, the individuals who try to make sense of it, are inside the flow system. Each of us is like an alveolus in the lung, an eddy in a turbulent river, or a leaf on a tree branch. From such a position of singularity, which is identical in rank to the positions of enormous numbers of individuals, it is a formidable task to see and describe the big picture—the lung, the river basin, and the forest.

Nature impresses us with shape, structure, configuration, pattern, rhythm, and similarity. This was our stroke of luck. From it, science was born and developed to the present day, where it is responsible for our physical and intellectual well-being. The puzzling architecture and history of society has many things in common with the architecture and evolution of other complex (but simpler) flow systems: blood vascularization, river basins and deltas, animal movement, respiration, dendritic solidification, etc. Coincidences that occur in the billions are loud hints that a universal phenomenon is in play. Is there a single physics principle from which the phenomenon of configuration and rhythm can be deduced without recourse to empiricism?

There is such a principle, and it is based on the common (universal) observation that if a flow system (e.g., river basin, blood vessel) is endowed with sufficient freedom to change its configuration, the system exhibits configurations that provide progressively better access routes for the currents that flow. Observations of this kind come in billions, and they mean one thing: a time arrow is associated with the sequence of flow configurations that constitutes the existence of the system. Existing drawings are replaced by easier-flowing drawings.

* Here, the meaning of position is geometric. The individual is a particular point of view in space. That point is occupied by this individual (his or her view of the world) and not by anybody else.
I formulated this principle in 1996 as the *constructal law* of the generation of flow configuration (Bejan 1996, 1997a–c):

For a finite size flow system to persist in time (to survive) its configuration must evolve in such a way that it provides easier and easier access to the currents that flow through it.

This law is the basis for the *constructal theory* of organization in nature, which was first summarized in book form in Bejan (1997c). Today this body of work represents a new extension of physics: the thermodynamics of flow systems with configuration (Bejan and Lorente 2004, 2005).

To see why the constructal law is a law of physics, ask why the constructal law is different than (i.e., distinct from, or complementary to) the other laws of thermodynamics. Think of an isolated thermodynamic system that is initially in a state of internal nonuniformity (e.g., regions of higher and lower pressures or temperature, separated by internal partitions that suddenly break). The first and second laws account for billions of observations that describe a tendency in time, a time arrow: if enough time passes, the isolated system settles into a state of equilibrium (no internal flows, maximum entropy at constant energy, etc.). The first and second laws speak of a black box. They say nothing about the configurations (the drawings) of the things that flow. Classical thermodynamics was not concerned with the configurations of its nonequilibrium (flow) systems.

This tendency, this time sequence of drawings that the flow system exhibits as it evolves, is the phenomenon covered by the constructal law: not the drawings per se, but the time direction in which they morph if given freedom. No drawing in nature is “predetermined” or “destined” to be or to become a particular image. The actual evolution or lack of evolution (rigidity) of the drawing depends on many factors, which are mostly random. One cannot count on having the freedom to morph in peace (undisturbed).

Once again, the juxtaposition of the constructal law with the laws of classical thermodynamics can be useful. No isolated system in nature is predetermined or destined to end up in a state of mathematically uniform intensive properties so that all future flows are ruled out. One cannot count on the removal of all the internal constraints. One can count even less on anything being left in peace, in isolation.

As a thought, the second law proclaims the existence of a “final” state: the concept of equilibrium in an isolated system, at sufficiently long times. Similarly, the constructal law proclaims the existence of a concept: the equilibrium flow architecture, when all possibilities of increasing morphing freedom have been exhausted.

Constructal theory is now a fast-growing field with contributions from many sources, which have been reviewed on several occasions (Poirier 2003; Lewins 2003; Rosa et al. 2004; Torres 2004; Upham and Wolo 2004; Bejan and Lorentz 2006; Reis 2006). The basic idea, however, is that constructal theory is the 1996 law cited at the start of this section.