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CHAPTER I

INTRODUCTION

In the seventeenth century it was held by some that inside a human sperm there was a minute human being—a homunculus—that was planted inside the womb. Development consisted of the miniature homunculus enlarging and passing through birth and on to maturity—just like inflating a balloon. There were others, going back to the early ideas of Aristotle and the many who followed him, who took the view that vast changes in shape occurred between egg and adult, for it could be plainly seen that the early stages of development of any animal bore no resemblance to what came later. These two views frame the point I want to make in this book. In the case of the homunculus, shape is totally unconnected to size; as size increases shape remains unaltered. In the other case—now totally accepted—as size increases from egg to adult, the shape must change; there is no alternative.

Let me put the matter in another way. If an engineer is commissioned to build two bridges, one across the Hudson River and the other across a brook no more than 30 feet wide, it is quite obvious that the two bridges will be very different in their appearance. Even more importantly, they will differ in their construction and materials. These differences will have nothing to do with the artistic whims of the engineer, at least for the larger bridge: they are absolute requirements. Any attempt to build the Hudson River bridge with wooden planks would collapse into the water long before it was finished. The elaborate steel trusses and the carefully designed architecture of the huge bridge are demanded by the width of the Hudson—it is dictated by its large size. As we shall see, this perfectly mirrors what happens in living organisms; they too cannot escape the conditions set by size; they have no choice.

With these thoughts in mind, let me state the main argument of this book. Changes in size are not a consequence of changes in shape, but the reverse: changes in size often require changes in shape. To put it another way, size is a supreme regulator of all matters biological. No living entity can evolve or develop without taking size into consideration. Much more than that, size is a prime mover in evolution. There is abundant evidence for the natural selection of size, for both increases and decreases. Those size changes have the remarkable effect that they guide and encourage novelties in the structure of all organisms. Size is not just a by-product of evolution, but a major player. Size increase requires changes in structure, in function, and, as we will see, in other familiar evolutionary innovations. It requires them because they are needed for the individual to exist. Life would be impossible without the appropriate size-related modifications.

The subject of size has not been ignored in the past. Quite to the contrary, and as will be clear in the pages to come, there is a great literature on matters of size, beginning with the Greeks and bursting into flower with Galileo. This is true for the West, and no doubt there are similar traditions in other cultures.

However, the subject is always to some degree fragmented because it is generally introduced as an adjunct to some other biological phenomenon or property. For instance, the topic might be running speed, or rate of metabolism, or one of many other possibilities, and in the discussion of each of these phenomena the crucial role of size would be included. Many of the themes treated in this book can be found elsewhere. Here I wish to look at them from a different point of view—from the other end of the telescope—and show that the biological world revolves around size.

The mindset that size is not a central issue is quite understandable. To say an elephant is big says nothing about all the things that make an elephant: its anatomy, its physiology, and even its behavior. These are the aspects that draw our attention and the matters we want to study. Yet size is an overarching issue. Its effect is something that no organism, from the smallest bacteria to the largest whale, can escape. It governs their shape and all their activities in a way that is of fundamental significance. Size dictates the characteristics of all living forms. It is the supreme and universal determinant of what any organism can be and can do. Therefore, why is it a subject that always resides in the wings rather than center stage?

The main reason is that organisms are material objects while size is a bloodless geometric construct. Any object, whether animate or inanimate, will have a size. Airplanes, boats, or musical string instruments vary in size just like animals and plants, and in all cases their size and their material construction are totally different matters even though they affect one another.

That the role of size has been to some degree neglected in biology may lie in its simplicity. Size may be a property that affects all of life, but it seems pallid compared to the matter which makes up life. Yet size is an aspect of the living that plays a remarkable, overreaching role that affects life's matter in all its aspects. It is a universal frame from which nothing escapes.

There are many things one wants to know about size, in particular those that concern its evolution. For instance, what is the evidence for my contention that size differences are a prime object of natural selection and are followed by changes in construction? What is the relation between size and internal complexity—that is, the division of labor—and, again, what is the evidence for which came first? What is the relation between size and the timing of all living activities such as the speed of movement of animals, or life span; and does size impose the timing, or the reverse? As we shall see, it is generally true that size is the prime mover: if size changes occur through the agency of natural selection, all those other matters must follow.

SIZE RULES

In the pages to come we will see many examples of where size rules life. They are supported by correlations in which various properties of organisms vary with size. It is these correlations that provide the foundation, the underpinning, for my contention that size rules life. The correlations can be stated in the form of five rules that will be briefly mentioned here and expanded and explained later. The rules are as follows:

RULE 1 Strength varies with size.

RULE 2 Surfaces that permit diffusion of oxygen, of food, and of heat in and out of the body, vary with size.

RULE 3 The division of labor (complexity) varies with size.

RULE 4 The rate of various living processes varies with size, such as metabolism, generation time, longevity, and the speed of locomotion.

RULE 5 The abundance of organisms in nature varies with their size.

Each of these rules will be put in its proper context. Some are physical or engineering principles; rules that apply for size differences occur in the inanimate as well as the animate. A central issue is the role of size in evolution, and this can be seen in numerous manifestations. Size also affects in many fundamental ways the physiology of animals, plants, and other organisms; in fact, this is true for all aspects of living things that involve time or rates of activity. And the human interest in the matter of size (including my own) will not be neglected.

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