FOREWORD

This Was a Man

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From Falstaff to the *Ring of the Nibelungen*, great constructions and great works of art have paid a price for amplitude beyond usual standards. D'Arcy Wentworth Thompson (1860–1948), Professor of Zoology at Scotland's University of St. Andrews, and perhaps the greatest polymath of our century, was scarcely *homo unius libri* (a man of one book). He composed two volumes of commentaries on all birds and fishes mentioned in classic Greek texts; he prepared the standard translation of Aristotle's *Historia animalium*; he labored for years over statistics for the Fishery Board of Scotland; and he wrote the section on pycnogonids (a small but fascinating group of arthropods) for the *Cambridge Natural History* series. But his enduring (indeed evergrowing) fame rests upon a glorious (and very long) book that served more as the active project of a lifetime than a stage of ontogeny—*On Growth and Form* (first edition of 793 pages in 1917, second edition enlarged to 1116 pages in 1942).

Much as it must pain any scholar and publisher of integrity to abridge such a work (for such an act does resemble the dissection of a body), one must not, as Jesus told us, light a candle and then place it invisibly under a bushel (Matthew 5:14–17). *On Growth and Form* is one of the great lights of science (and of English prose); it must be available at an affordable price and a totable heft: "Let your light so shine before men, that they may see your good works."

D'Arcy Thompson, according to a legend that could have been true, was offered his choice of professorships in three apparently disparate disciplines: classics, mathematics, and zoology. The greatness of *On Growth and Form* lies in its genuine integration (not just ostentatious show) of these three foci.

1. Classics and the humanities. *On Growth and Form* is the greatest work of prose in twentieth-century science. Consider the judgment of two preeminent scientific humanists: P. B. Medawar

called it "beyond comparison the finest work of literature in all the annals of science that have been recorded in the English tongue." G. E. Hutchinson regarded it as "one of the very few books on a scientific matter written in this century which will, one may be confident, last as long as our too fragile culture." D'Arcy Thompson's prose is like a Wagnerian opera: it flows on and on in waves of sumptuous sound, with occasional cadences at climactic moments. I can, for example, quote by heart the lovely last line of chapter 2, "On Magnitude," as the author descends from the ordinary gravitational world of our own species, through the realm of surface forces inhabited by insects, to the utterly unfamiliar domain of the bacterium: "We have come to the edge of a world of which we have no experience, and where all our preconceptions must be recast."

But D'Arcy Thompson can also become a victim of his own erudition, not so lightly worn. Few people today have his literary and linguistic background; even fewer will grasp the classical allusions (not to mention the untranslated lines of Greek and Latin) that are not mere adornments, but intrinsic parts of the text. The very beginning of the book can be quite daunting, with its Kantian statement in German (translated at least), followed by an unannotated Latin line from Roger Bacon and a similarly untranslated Italian footnote from Leonardo--all before the first paragraph even reaches its halfway point!

2. Mathematics. D'Arcy Thompson states his primary purpose in the epilogue: "to show that a certain mathematical aspect of morphology . . . [is] helpful, nay essential, to [the] proper study and comprehension of Growth and Form." (The 2-page epilogue then continues with two untranslated quotes in Latin, one in Greek and two in French, including the closing line.) The application of mathematics to organic form may sound like a highly modern enterprise, but D'Arcy Thompson's examples contain blessedly little of the apparatus usually employed in such efforts: theoretical modelling with differential equations or empirical treatment with sophisticated statistics. D'Arcy Thompson knew these fields, but he approached *Growth and Form* as a classical scholar, in particular as a Pythagorean geometer boosted with a knowledge of Newtonian mechanics. This book dwells in the Miraldi angle, the Fibonacci series, the logarithmic spiral and the golden ratio.

3. Zoology. D'Arcy Thompson was an invertebrate zoologist by

primary choice. He used his classical and mathematical training to full and integrative advantage in *On Growth and Form*, but his great treatise is still, primarily, a biological theory. The theory is easily lost amidst D'Arcy Thompson's elaborations and elegant examples—and also readily missed because the theory is so iconoclastic that we can't quite believe he is really saying such a thing. I have been astonished at how many people can read the book, enjoy the sweep of the prose and all the ingenious examples, and then thoroughly miss the coordinating theory!

This hybrid theory of Pythagoras and Newton argues that physical forces shape organisms directly (with "internal" and genetic forces responsible only for producing raw material, admittedly in gradients and programmed timings, for construction under principles of physics)—and that the ideal geometries beloved by classical Athens pervade organic form because natural law favors such simplicity as an optimal representation of forces. I do not know D'Arcy Thompson's religious views, but we may certainly say that his God was a geometer, just as Einstein's did not play dice with the universe. D'Arcy Thompson tells us in the epilogue:

> For the harmony of the world is made manifest in Form and Number, and the heart and soul and all the poetry of Natural Philosophy are embodied in the concept of mathematical beauty . . . A greater than Milton had magnified the theme and glorified Him 'that sitteth upon the circle of the earth', saying: He hath measured the waters in the hollow of his hand, and meted out heaven with the span.

As usual, D'Arcy Thompson does not give us the explicit reference (and doesn't even include quotation marks to alert us), but the source of the last phrase is Isaiah 40:12, and the actor is Jehovah himself.

The sequence of chapters, and the logic of the entire book, focus upon this theme. We first have an introduction on mathematical approaches to form, followed by the crucial chapter "On Magnitude," with its central argument that surface/volume ratios must decline as organisms grow in size, and that large and small therefore inhabit different realms of forces. If physical forces shape organisms directly, then small creatures should be the product of surface forces, large creatures of gravitational (volumetric) forces. The next several chapters move up this continuum: small creatures are shaped by surface forces (protozoans as Plateau's surfaces of revolution, for example); intermediate sizes express a balance (jellyfishes like viscous drops, held up by surface

tension, but oozing down by gravity); large creatures are ruled by gravity (the famous diagram comparing forces on a leg bone with the loading of a crane).

D'Arcy Thompson does not try to extend the argument to all nuances of form in complex creatures: the disparity between a hippo and an oak tree does not simply lie in differing external forces acting upon their growth. Two strategies for bringing complex forms into the general theory structure the remaining chapters of *Growth and Form*. (1) Parts or wholes, even when not shaped directly by physical forces, take optimal forms of ideal geometry as solutions to problems of morphology (the equiangular spirals of mollusks, ram horns and paths of moths flying to light as the only way to coil and maintain the same shape as size increases; alternating spirals of the Fibonacci series in phyllotaxis as a consequence of optimal space filling in systems adding new units at a pole). (2) Even if complex prototypes must be accepted as genetic givens, at least their transformations to related forms may be expressed as simple physical deformations of entire systems—the theory of transformed coordinates. (This theory, subject of the last and most widely influential chapter, is often misunderstood as a coda unrelated to the rest of the book. But when we realize that simplicity in geometry of the transformation grid, not complexity of the underlying prototype, expressed D'Arcy Thompson's main concern, then we can grasp the stunning unit of the entire book.)

We may view *Growth and Form* as a coherent triumph today, but D'Arcy Thompson suffered for his iconoclasm during life. He did not intend to spend his career at a small and isolated Scottish University; he had applied for key jobs at Oxford, Cambridge, and London, and had lost out every time. He received many accolades late in life, including an honorary degree from Oxford in 1945, but marginality was his fate throughout the central years of his professional life.

I wrote one of my earliest articles about D'Arcy Thompson in 1971, when I was still in my twenties—and I misread him (or grasped him only partially) as a consequence of my misplaced romanticism. I saw him as a noble Canute holding back the tides of modernistic philistinism—a Greek geometer more than two thousand years from his time of flourishing. This timelessness is, indeed, part of the man—as when, in explaining the tests of foraminifera (single celled protozoans), he rejects the contingency of genealogy, and speaks of geometric permanence, unaltered by mere time.

But D'Arcy Thompson was also a man of his own age, and I missed this theme. His doubts about Darwinism (combined with confidence about the fact of evolution) reflect a common view of 1917 (date of the first edition), though they had become passé by the second edition of 1942. His two major criticisms are exactly those highlighted by his more conventional contemporary, William Bateson, though D'Arcy Thompson gave a personal twist to each standard doubt: (1) Do not make up speculative stories about natural selection just because a gradual transition can be observed (for D'Arcy Thompson, such transitions might only reflect a changing set of external forces acting on unaltered biological material). (2) Some changes must be saltational rather than gradual (just as some geometries can only transform into others through a discontinuity).

Will the real D'Arcy Thompson stand up? Classicist? Prose stylist? Compiler of elegant examples? Iconoclastic morphologist? Contemporary critic of Darwinism? Greek geometer? He was all this and much more. Shakespeare may as well have the last word: ". . . the elements so mixed in him that Nature might stand up and say to all the world, 'this was a man!'"

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