and 1784, for example, each took from and fed upon the other in a remarkable series of intellectual rebounds that produced some of the most important general results in all of gravitational astronomy. Viewed from a historical distance, the *Celestial Mechanics* is clearly a response to the basic question generated by Newton's enunciation of the law of universal gravitation. Given the position and the movements of the members of the solar system at any set time, is it possible thereafter to deduce mathematically from the gravitation which mutually binds them their positions and motions at any other time? Of course such deductions would have to agree with actual observations. The resounding affirmative which Laplace's formulation gave, 100 years, almost to the moment, after the question was first posed as the essential, implicit query of the *Principia* taken as a whole is not only a measure of Laplace's own grasp of theoretical mechanics and his powers of mathematical analysis, but a final vindication (if such there need be) of the incredible richness of Isaac Newton's insight into the fundamental problems of matter and motion.

By setting the Newtonian problem in its most general form—a concern for the attraction between elements of mass, with the forces exerted between whole bodies considered as the sum of these forces properly adjusted for the larger shapes or conglomerates involved—Laplace derived a system of the world as close to fulfilling the mechanistic ideal of the scientific revolution of the 17th century as any which have ever been produced. The ten books (85 chapters) of the translated work move from a statement of the general law of equilibrium and motion (founded, of course, on the law of universal gravitation) through problems of the movement of and about centers of gravity, the figures of the heavenly bodies, and the theory of planetary motion as well as of satellites, especially the difficult problem of the moon, to a theory of comets, the oscillation of the sea and atmosphere, and almost in passing to comments on the stability of the solar system and the role of theory in science. If the great clock metaphor for the running of the universe thus found substance in Laplace, it was not without the casual dismissal of little irregularities. Discrepancies between observation and theory were there, but their incremental character, attributable to correctable errors of observation or calculation, did not ripple the calm scientific world of post-Laplacian mechanics. Laplace's own words, perhaps, spoke for them all:

> It is chiefly in the application of *analysis* to the system of the world, that we perceive the power of this wonderful instrument; without which, it would have been impossible to have discovered a mechanism which is so complicated in its effects, while it is so simple in its cause. The mathematician now includes in his formulas, the whole of the planetary system, and its successive variations; he looks back, in imagination, to the several states, which the system has passed through, in the most remote ages; and foretells what time will hereafter make known to observers [vol. 3, p. xiii].

About 20 years after the publication of the fourth volume, Laplace added a fifth. Actually this last volume, which appeared in parts (books XI and XII in 1823, XIII, XIV, and XV in 1824, and XVI in 1825), completed a program announced at the beginning of the treatise—to comment historically upon those whose labors had contributed to the content of the *Celestial Mechanics.* But having continued his research over the long years of its publication, Laplace took advantage of the occasion to add to the last volume a considerable amount of material that had either appeared elsewhere (in the *Mémoires de l'Institut de France* or the *Connaissance des Temps,* for example) or simply reflected his reexamination of certain problems. Thus the original French edition contains not only a historical *aperçu* but a return voyage. A Celestial Mechanics Revisited thus gives us a rare historical opportunity to notice what a great scientist chooses to add to an earlier masterpiece. Unfortunately, this is not made available to us in the present reprint, though it would have been simple enough to add the last volume either in the original language or in modern translation.

Nathaniel Bowditch, whose *New American Practical Navigator* in editions without end continues to be a useful text down to our own day, made the translation of the first four volumes between 1814 and 1817; but the late appearance of the fifth volume, other obligations, and finally death, prevented him from undertaking the final one, though there are extant notes for the task. The whole enterprise was obviously a labor of love, for this translation is much more than a linear shift from one language to another. It is armed with intelligent, clarifying commentary that brings light to dark passages and elucidates those intuitive transitions of the mathematician so frequently obscured by a dismissing reference to the obvious. In Laplace this nonrevealing process was nearly always announced by the phrase "Thus it plainly appears." The praise for Bowditch's achievement came from extraordinarily high places: Babbage, Bessel, but best of all, perhaps, was Legendre's comment:

> Your work is not merely a translation with a commentary; I regard it as a new edition, augmented and improved, and such a one as might have come from the hands of the author himself, if he had consulted his true interest, that is, if he had been solicitously studious of being clear.

There is much about Bowditch himself in a "Memoir of the translator" (including the interesting observation that he is supposed to have translated all or a part of Newton's *Principia*) that was part of volume 4 of the original edition. In transferring this biographical sketch in the present edition to volume 1, the publishers have neglected to indicate that it was written by his son, Nathaniel Ingersoll Bowditch. Worse yet, the last volume having appeared in 1839 and the first in 1829, some readers of the reprint (in spite of the publisher's inadequate warning) may worry about a posthumous biography preceding the decease of the subject.

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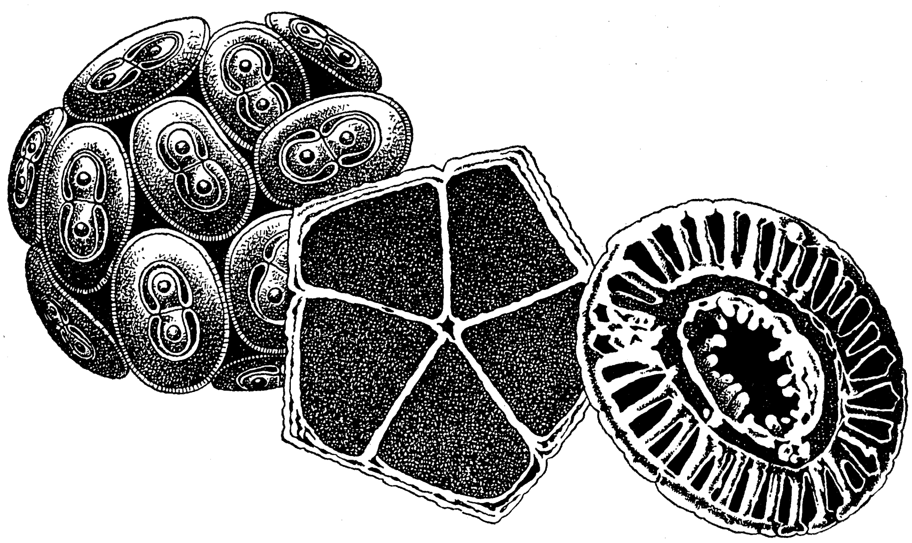
Huxley's Classic of Explanation

On a Piece of Chalk. THOMAS HENRY HUXLEY. With an introduction and notes by LOREN EISELEY and illustrations by Rudolph Freund. Scribner's, New York, 1967. 90 pp. $4.95.

During the 1868 meeting of the British Association for the Advancement of Science in Norwich, Thomas Henry Huxley delivered a lecture for the workingmen of the city. Building the lecture around a piece of chalk, he described



Coccoliths—remnants of unicellular algae. From a drawing in *On a Piece of Chalk*. [Copyright © 1967 by Rudolf Freund]

the age-long process by which chalk was laid down beneath the sea, the extent of the known chalk beds, up to 1000 feet thick and extending over most of Europe and into Africa and Asia, the fossil evidence found in and above these great beds of chalk, the current deposition of a new chalk bed in the Atlantic Ocean and the larger fossils embedded in it, and the conclusions one must draw from the weight of so much evidence concerning the majestic and continuing evolution of the earth and its inhabitants. It was his intent, he told his auditors, to demonstrate "that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches pocket, though ignorant of all other history, is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better conception of this wonderful universe and of man's relations to it than the most learned student who is deep-read in the records of humanity and ignorant of those of nature."

That the lessons of paleontology are now so much more widely appreciated than they were when Huxley drew them from a piece of carpenter's chalk is in good measure a tribute to Huxley's genius. We have much more factual knowledge than he had, but we have no better exemplar of the art of explaining in compelling and understandable terms what science is about, nor a more vigorous example of the scientist's obligation to practice that art.

Loren Eiseley's lucid introduction and explanatory notes and Rudolf Freund's illuminating drawings embellish a profound lecture told with charm and grace.

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Inventions of Antiquity

Ancient Greek Gadgets and Machines. ROBERT S. BRUMBAUGH. Crowell, New York, 1966. 166 pp., illus. $4.95.

The author, a professor of ancient Greek philosophy, went to Athens on a fellowship and found there that "an unexpected amount of gadgetry and machinery" had been in use in ancient Athens and Alexandria. So he began to explore this new field, partly to trace the relations between this technology and ancient philosophy, but also for its own sake, since he (like myself) enjoys a clever invention as others enjoy a piece of good music. This led him, together with Paul H. Sherrick, an inventor and equipment designer, to reconstruct one of Heron's instruments (*Pneumatica* 2:7, Teubner ed.), a model of the universe, made to illustrate the Stoic cosmological model. Since the experiment depends upon a ping-pong ball, an article unknown in Heron's time, it cannot explain the apparatus; but it is an admirable idea to try out an ancient instrument in practice.

The book, then, consists of comparisons of ancient cosmological speculations with the technical instruments of the time, but it also contains descriptions of technical marvels, mostly from Heron, for their own sake. It is easy to read and written with a most contagious enthusiasm; and I regret that I cannot recommend it. The author has spoilt what might have been a charming book by neglecting to test his statements and check his references. On page 77 we read that Archimedes "singlehanded, hauled a loaded warship along the sand"; on page 78 we learn, from Plutarch's own words, that it was a ship of burden. In the legend of the figure on page 54, we read that "as the screw turns it lowers the plate"; the figure shows that it lifts the plate. Heron's date is given on page 92 as the second century A.D.; O. Neugebauer, in 1938, determined his date at 62 A.D. by an eclipse of the moon described in his *Dioptra*. On page 95 we read that the Tower of the Winds at Athens was built by Andronikos of Rhodes in the first century A.D., and that he designed the clock; but the Tower was built about 100 B.C., by Andronikos Kyrestes, and the clock is the anaphoric clock, invented by Hipparchos about 150 B.C. On page 6 the same clock is suggested for a very primitive and somewhat doubtful waterclock built on the Agora about 360 B.C.; but the klepsydra with constant flow necessary for the anaphoric clock was invented by Ktesibios, who was alive in 270 B.C. These samples must suffice. A reader who knows about these matters will find the book painful reading; to give it to a novice would be rash. The layout of the book is bad. The unnumbered figures are scattered throughout the book, and no references are given from the text to the figures or from the figures to the text. There is an annotated bibliography and an index; the latter seems to have been written before the book was finally made up.

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Seven Biographical Essays

Late Eighteenth Century European Scientists. R. C. OLBY, Ed. Pergamon, New York, 1966. 217 pp., illus. Paper, $3.50.

This volume contains seven independent biographical sketches of Europeans defined as "late eighteenth-century scientists:" Jean Lamarck, 1744–1829, by