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THE ONLY PRESENTATION COPY KNOWN, IN A SPECIAL GIFT BINDING

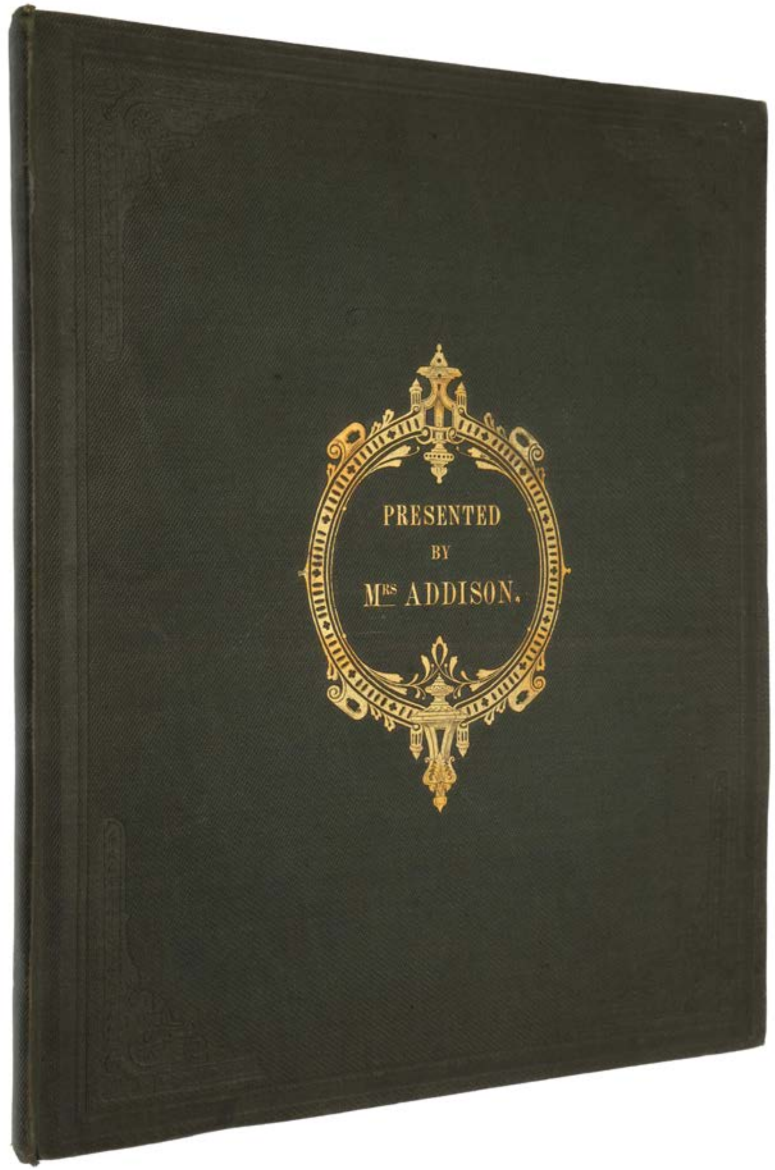
Grolier/Norman, *One Hundred Books Famous in Medicine* 60c

ADDISON, Thomas. *On the Constitutional and Local Effects of Disease of the Supra-Renal Capsules.* London: Samuel Highley, 1855.

$45,000

4to (323 x 249 mm). viii, 43, [1]pp. 11 hand-colored lithograph plates by W. Hurst and M. and N. Hanhart after drawings by W. Hurst and John Tupper. Original green cloth stamped in gilt and blind, very slight wear at extremities. Fine, clean copy, presented by Addison's widow to Addison's friend Henry Lonsdale (1816-76), with a unique binding with the gilt-stamped ornament on the front cover reading "Presented by Mrs. Addison," instead of the usual title lettering, and inscription on the front free endpaper, presumably in the hand of Mrs. Addison, reading: "To Dr. Lonsdale one of the Author's best & kind friends." A very fine copy, preserved in a custom leather box.

First edition, the only known presentation copy, presented by Addison's widow to Addison's friend Henry Lonsdale (1816-76), with a unique binding with the gilt-stamped ornament on the front cover reading "Presented by Mrs. Addison," instead of the usual title lettering, and inscription on the front free endpaper, presumably in the hand of Mrs. Addison, reading: "To Dr. Lonsdale one of the Author's best & kind friends." Addison's monograph inaugurated the study of diseases of the ductless glands and the disturbances in chemical equilibrium known as pluriglandular syndromes; it also marks the beginning of modern



endocrinology. Addison chanced upon adrenal disease while searching for the causes of pernicious anemia; his initial report on the subject, a short paper entitled "On anemia: Disease of the suprarenal capsules" (1849), attempted to link the two diseases. The present monograph focuses on diseases of the suprarenal capsules and contains the classic description of the endocrine disturbance now known as "Addison's disease," and also includes his superb account of pernicious anemia ("Addison's anemia"), in which he suggested that the existence of anemia together with supra-renal disease was not coincidental. Addison was the first to suggest that the adrenal glands are essential for life, and his monograph inspired a burst of experimental research that led, among other things, to Vulpian's discovery of adrenalin in 1856.

Addison "was born in April 1793, at Long Benton, Newcastle-upon-Tyne and died on June 29 1860, at 15 Wellington Villas, Brighton. The son of Sarah and Joseph Addison, a grocer and flour dealer in Long Benton, Addison was first sent to school in a roadside cottage where his teacher was John Rutter, the parish clerk, who years later also taught Robert Stephenson.

"He proceeded to the Royal Free Grammar School, Newcastle-upon-Tyne, and learned Latin so well that he made notes in that language. This explains his lifelong precision in language. His father endeavoured to provide an education and a social status much higher than his own. In 1812 Thomas became a medical student at the University of Edinburgh and in August 1815 gained an MD with a thesis 'Concerning Syphilis and Mercury' (now in the Wellcome Library, London). In that year he moved to Skinner Street, Snow Hill, London, to become house surgeon at the Lock Hospital, and entered as pupil to the Public Dispensary. Thomas Bateman (1778-1821), an acclaimed dermatologist, instilled in him a lasting interest in skin diseases. He progressed rapidly: the 1817 Guy's Hospital records show:

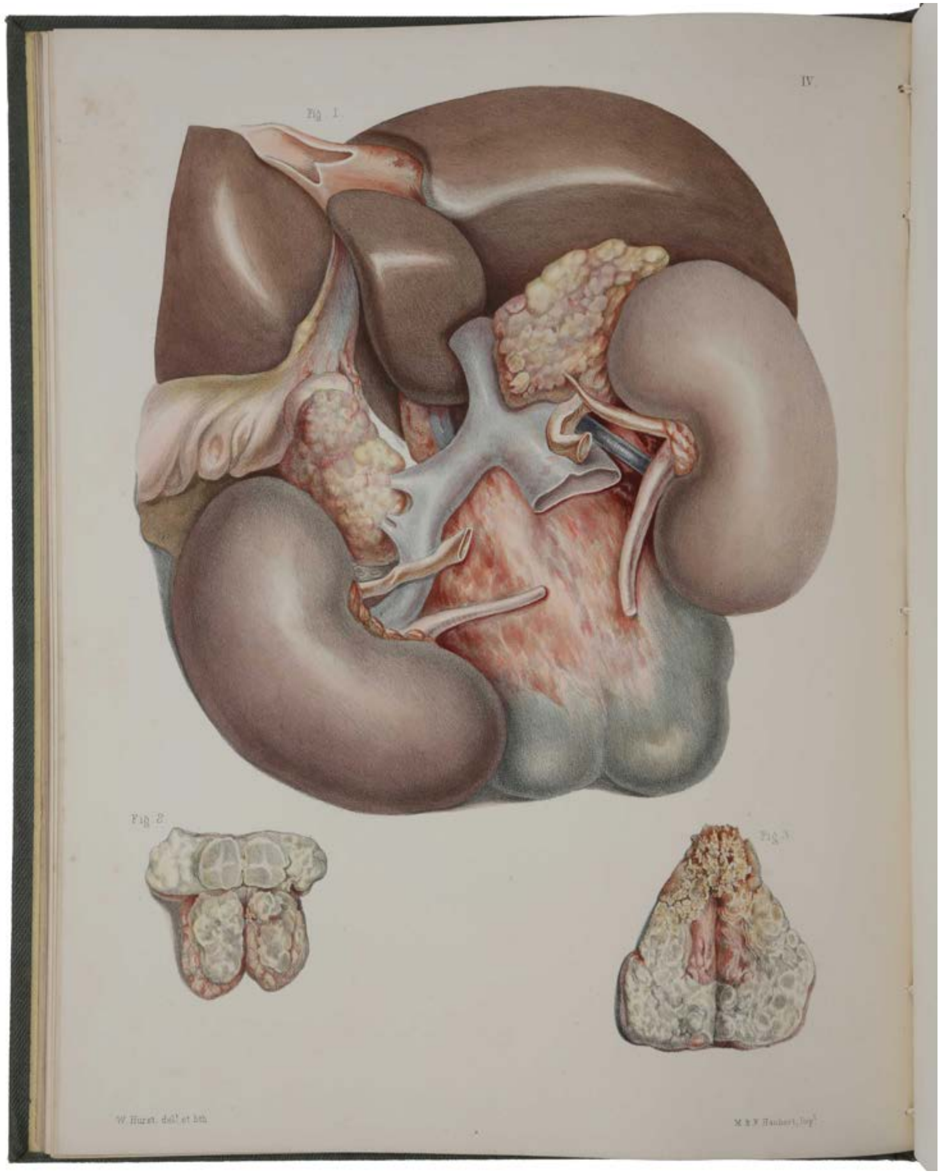
'Dec. 13, 1817, from Edinburgh, T. Addison, M.D., paid pounds 22-1s to be a perpetual Physician's pupil.'

"He obtained his LRCP in December 1819, was promoted to assistant physician and in 1827 became lecturer in *materia medica*. His lectures were so popular that his lecture-fees were assessed at £700 or £800 a year. In 1835 Addison with Richard Bright gave lectures on practical medicine, and in 1837 Addison became full physician to Guy's Hospital. Unlike the charming and cheerful Bright with wealthy parentage and broad education, Addison concealed nervousness and timidity beneath a proud and haughty exterior. In the words of Samuel Wilks:

'a quick hasty and impassioned manner of expression is not unfrequently the result of a deficient controlling power. We know … that, although wearing the outward garb of resolution, he was beyond most other men, most liable to sink under trial.'

"Probably for these reasons his professional preferment came late in life. For example, not until 1838 was he elected a Fellow of the Royal College of Physicians. His shyness and occasional severity stood in the way of a large private practice; nevertheless, his diagnostic brilliance and his lucid and forceful teaching were appreciated at Guy's, where he showed devotion to patients and students alike. His enquiring mind and scientific curiosity were apparent, for in a biographical prefix to his published writings he was described as

'Possessing unusually vigorous perceptive powers, being shrewd and sagacious beyond the average of men, the patient before him was scanned with a penetrating glance from which few diseases could escape detection... [he] would remain at the bedside with a dogged determination to track out the disease to its very source for a period which often wearied his class and his attendant friends.'



"The story of 'Addison's disease' begins with the adrenal glands, first described by Eustachius in 1714. Addison first wrote a short article in the *London Medical Gazette* (1849): 'Anaemia—disease of the suprarenal capsules in which the disease is not distinctly separated from a new form of anaemia'. Then, in 1855, came his monograph, one of the unsurpassed medical works of the nineteenth century. Addison describes here for the first time two chronic diseases which he could not clearly separate—'On the Constitutional and Local Effects of Disease of the Suprarenal Capsule'. The entity he related was doubted by Hughes Bennett (1812-1875) in Edinburgh but confirmed by Trousseau (1801-1867) in Paris, who recognized suprarenal failure and named it Addison's disease. The monograph describes how, when investigating a peculiar form of anaemia, he found pathological changes in both suprarenal glands that appeared to be independent of the anaemia. He had with Samuel Wilks collected 11 patients.

"He described the symptoms of 11 cases:

'The discoloration pervades the whole surface of the body, but is commonly most strongly manifested on the face, neck, superior extremities, penis, scrotom, and in the flexures of the axillae and around the navel... The leading and characteristic features of the morbid state to which I would direct your attention are, anaemia, general languor and debility, remarkable feebleness of the heart's action, irritability of the stomach, and a peculiar change of the colour in the skin, occurring in connection with a diseased condition of the suprarenal capsules.'

"One patient had been treated by Bright, who had noted typical clinical features but failed to incriminate the adrenals. Indeed Addison critically commented:

'It did not appear that Dr. Bright either entertained a suspicion of the disease of the capsules before death, or was led at any period to associate the colour of the skin with the diseased condition of the organs, although his well-known sagacity induced him to suggest the probable existence of some internal malignant disease. In this as in most other cases, we have the same remarkable prostration, the usual gastric symptoms, the same absence of any very obvious and adequate cause of the patient's actual condition together with a discoloration of the skin, sufficiently striking to have arrested Dr. Bright's attention even during the life of the patient.'

"Interestingly, to his pupils his essay on suprarenal failure ranked far below his elucidation of phthisis and his impressive teaching.

"In most cases of Addison's disease today the pathogenesis is autoimmune, as exemplified by the polyglandular autoimmune syndromes where it is evident in two-thirds of type 1 and almost all cases of type 2. Tuberculosis now accounts for about 20% of primary adrenal insufficiency in developed countries, whereas in Addison's day it was found at autopsy in 70-90% of cases.

"The description of 'Addison's anaemia' came in 1849, in a lecture to the South London Medical Society. But in 1822 James Scarth Combe, in the *Transactions of the Medico-Surgical Society of Edinburgh*, had described 'idiopathic anaemia' and never sought priority for this new disease—pernicious anaemia. In the *Medical Times and Gazette* of London in 1874, Biermer of Zurich wrote of a new 'idiopathic anaemia' not yet described in England. Within a week, Samuel Wilks refuted this claim in the *British Medical Journal*, stating that the disease was well known in England since Addison had lectured on it in 1843. Addison observed its insidious onset in either sex, usually in middle life. He related:

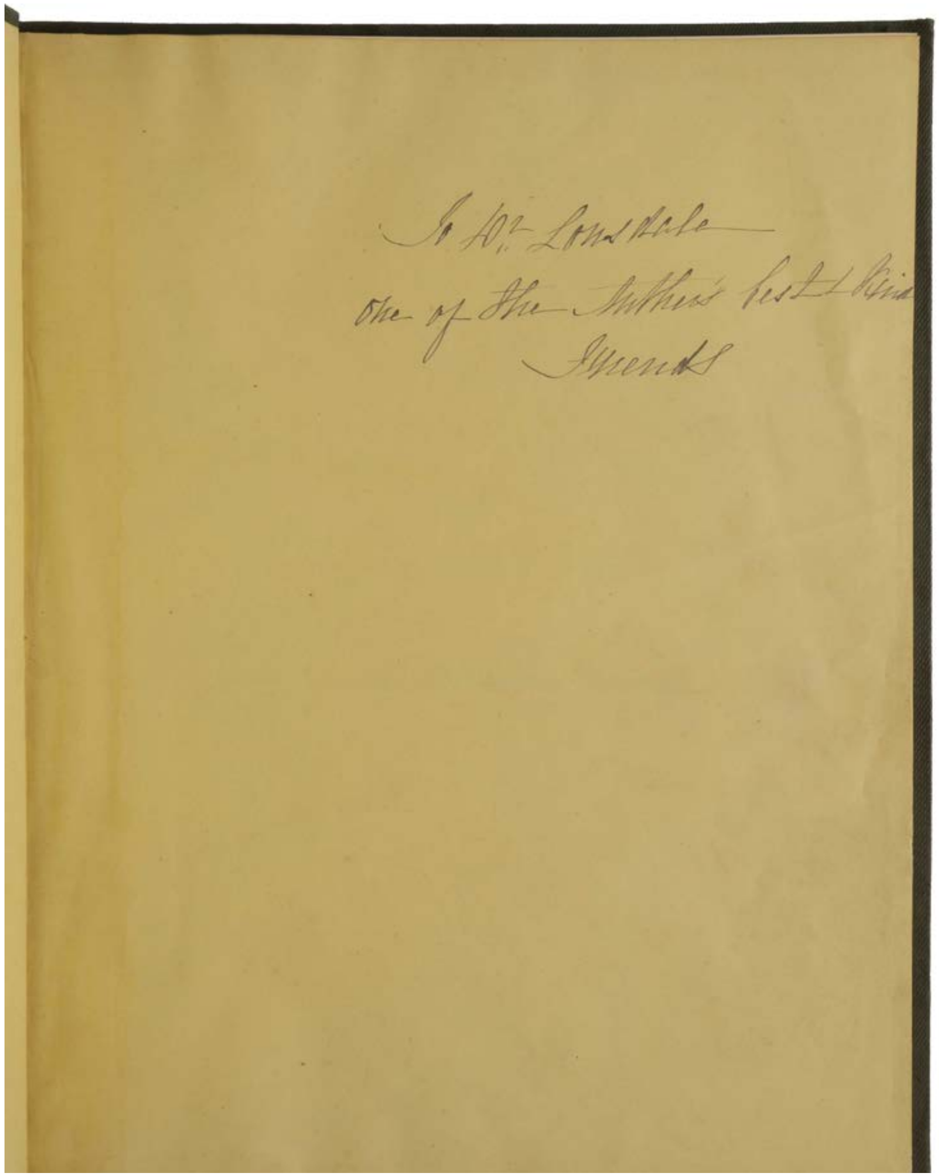
'the countenance gets pale, the whites of the eyes become pearly, the general frame flabby rather than wasted... the whole surface of the body presents a blanched, smooth and waxy appearance; the lips, gums, and tongue seem bloodless...

extreme languor and faintness supervene, breathlessness and palpitations being produced by the most trifling exertion or emotion; some slight oedema is probably perceived in the ankles; the debility becomes extreme… the disease… resisted all remedial efforts and sooner or later terminated fatally… On examining the bodies I have failed to discover any organic lesion that could properly or reasonably be assigned as an adequate cause…'

"The condition became known as pernicious anaemia—usually caused by loss of the 'intrinsic factor' required for absorption of cyanocobalamin.

"Addison made other signal contributions. He wrote volume 1 of *Elements of the Practice of Medicine* (1839), but the planned two further volumes with Bright never emerged. It contained an early and comprehensive account of 'Inflammation of the caecum and appendix vermiformis'. He also gave an identifiable account of biliary cirrhosis, previously described by Pierre-François-Olive Rayer in *Traité théorique et pratique des maladies de la peau* (1826-1827), Paris, 1835. In 1824 Addison founded the Department of Dermatology at Guy's, which still possesses a collection of wax models of skin disorders prepared under his supervision. 'On a certain affection of the skin, vitilogoidea plana tuberosa', presents a seminal account of *xanthoma planum et tuberosum*, a common sequel to hypercholesterolaemia. Addison with Sir William Gull (1816-1890) described *xanthoma diabeticorum*, and he also depicted circumscribed scleroderma (morphoea). In 1843 he correctly described the pathology of pneumonia, which until that time was thought to be an interstitial pneumonitis. He had traced the bronchial branches to their alveolar termination where he discovered 'pneumonic deposits in the air cells'" (Pearce).

Addison suffered from several bouts of severe depression during his lifetime, and eventually committed suicide in 1860. It would seem that Addison's mental



instability precluded him from giving any copies of his *Disease of the Supra-Renal Capsules* to his friends, as we know of no other presentation copies of this work apart from this one from his widow. It is in a very special original binding, that was undoubtedly bound specially for the purpose, in which the normal lettering within the gilt cartouche on the upper cover ("On Disease of the Supra Renal Capsules by Thomas Addison, M.D.") is replaced by the words "Presented by Mrs. Addison." The work was inscribed to Dr. Henry Lonsdale, who was physician to the Cumberland Infirmary in Carlisle; he was also the author of *The Worthies of Cumberland* (1873), which contains a 12-page memoir of Addison. This copy is the only nineteenth century medical or scientific work in a cloth presentation binding of this type we have seen.

Grolier, *One Hundred Books Famous in Medicine* 60c; *Heirs of Hippocrates* 1502; Norman 8; Garrison-Morton.com 3864 ; Goldschmid, p. 194; McCann, pp. 87-89; Medvei, pp. 225-230.; Pearce, 'Thomas Addison (1793-§860),' Journal of the Royal Society of Medicine 97 (2004), pp. 297-300.

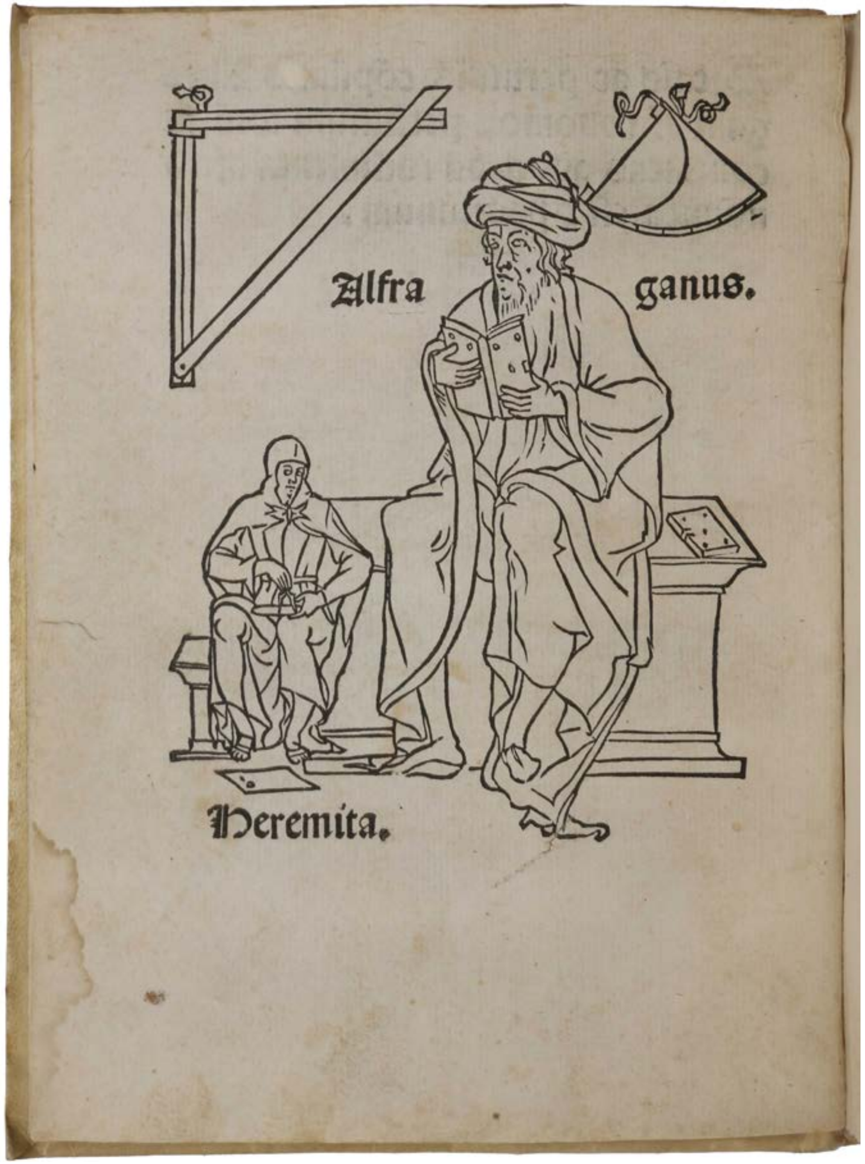
THE FOUNDATIONWORK OF EARLY MODERN ASTRONOMY

AL-FARGHĀNĪ, Ahmad ibn Muhammad ibn Kathīr [ALFRAGANUS]. *Brevis ac perutilis co[m]pilatio Alfragani astronomo[rum] pertissimi totu[m] id continens quo ad rudimenta astronomica est opportunum [Compilatio introductoria in astronomiam. Translated by John of Spain].* Ferrara: Andreas Belfortis, Gallus, 3 September, 1493.

$185,000

4to (197 x 147 mm), ff. 30, 35 lines, outstanding full-page woodcut on verso of first leaf, representing the beturbaned author reading a book and at his side a smaller figure of an 'heremita' using a compass, eight woodcut diagrams in text (small marginal light damp-stain to first gatherings, two tiny clean tears to margins of title-page). Contemporary limp vellum.

First edition, extremely rare, of this foundation work of early modern astronomy, the *Kitāb fī Jawāmi Ilm al-Nujūm*, now usually known in the West as the *Elements of Astronomy*. This is an exceptional copy, in an untouched contemporary binding, with numerous annotations and calculations in a contemporary hand. "This book marks the beginning of the period during which Arab astronomers introduced new elements into the science of astronomy, and exhibited an attitude of healthy scepticism and caution toward the contents of Ptolemy's works" (Sezgin, p. v). "The influence of the *Elements* on medieval Europe is clearly attested by the existence of numerous Latin manuscripts in European libraries. References to it in medieval writers are many, and there is no doubt that it was greatly responsible



for spreading knowledge of Ptolemaic astronomy, at least until this role was taken over by Sacrobosco's *Sphere*. But even then, the *Elements* of al-Farghānī continued to be used, and Sacrobosco's *Sphere* was clearly indebted to it" (DSB). The great French historian of science Pierre Duhem summarized the influence of al-Farghānī's treatise as follows (quoted from Sezgin, p. vi). "Everything which Robert Grosseteste, a leading figure in the thirteenth-century Aristotelian school of Paris, attributed to Ptolemy in his *Summa Philosophiae*, was in fact taken from al-Farghānī. We note further that the Italian astronomers from the thirteenth until the beginning of the fourteenth century depended completely upon the book of al-Farghānī when they referred to Ptolemy … Similar facts are known concerning the influence of al-Farghānī upon the famous Italian poet Dante Alighieri, who also obtained all the Ptolemaic astronomical ideas in his *Il convivo* from the book of al-Farghānī. Finally, I mention that Regiomontanus, the famous Renaissance scholar, delivered lectures in Padua in 1464 based on al-Farghānī's book." On his first voyage to find the Indies, Christopher Columbus used the data on the measurement of the earth in al-Farghānī's work. "In a Latin marginal note to Pierre d'Ailly's *Imago Mundi*, Columbus wrote: 'Note that from Lisbon south to Guinea I frequently observed the course carefully and afterwards I many times took the Sun's altitude with the quadrant and other instruments, and I found agreement with al-Farghānī, that is, that 56⅔ miles equalled one degree'" (Glick, p. 132); Ptolemy had given the less accurate value of 50.3 miles. (Columbus' calculations were badly wrong, however, as al-Farghānī used a longer mile than the one used in fifteenth century Spain). No other copy in auction records, and we are aware of only one other copy having appeared on the market in several decades (and that in a nineteenth-century binding – W. P. Watson, Cat. 8 (1997), n. 1, £25,000). OCLC lists four copies in US (Columbia, Harvard, Morgan and Smithsonian).

Provenance: Extensively annotated with interesting marginalia and calculations in a contemporary hand (a little shaved to outer margins); Charles William Dyson-Perrins (1864-1958), English bibliophile, businessman and philanthropist (bookplate on front paste-down) – his sale, Sotheby & Co., 17 June, 1946, lot 11. "Perrins was a collector of the vintage and calibre of Yates Thompson, Fairfax Murray and Pierpont Morgan" (*The Book Collector*, Winter 1958, p. 354); Robert B. Honeyman (1897-1987), American bibliophile and metallurgical engineer – his sale, Sotheby's, October 30, 1978, lot 70.

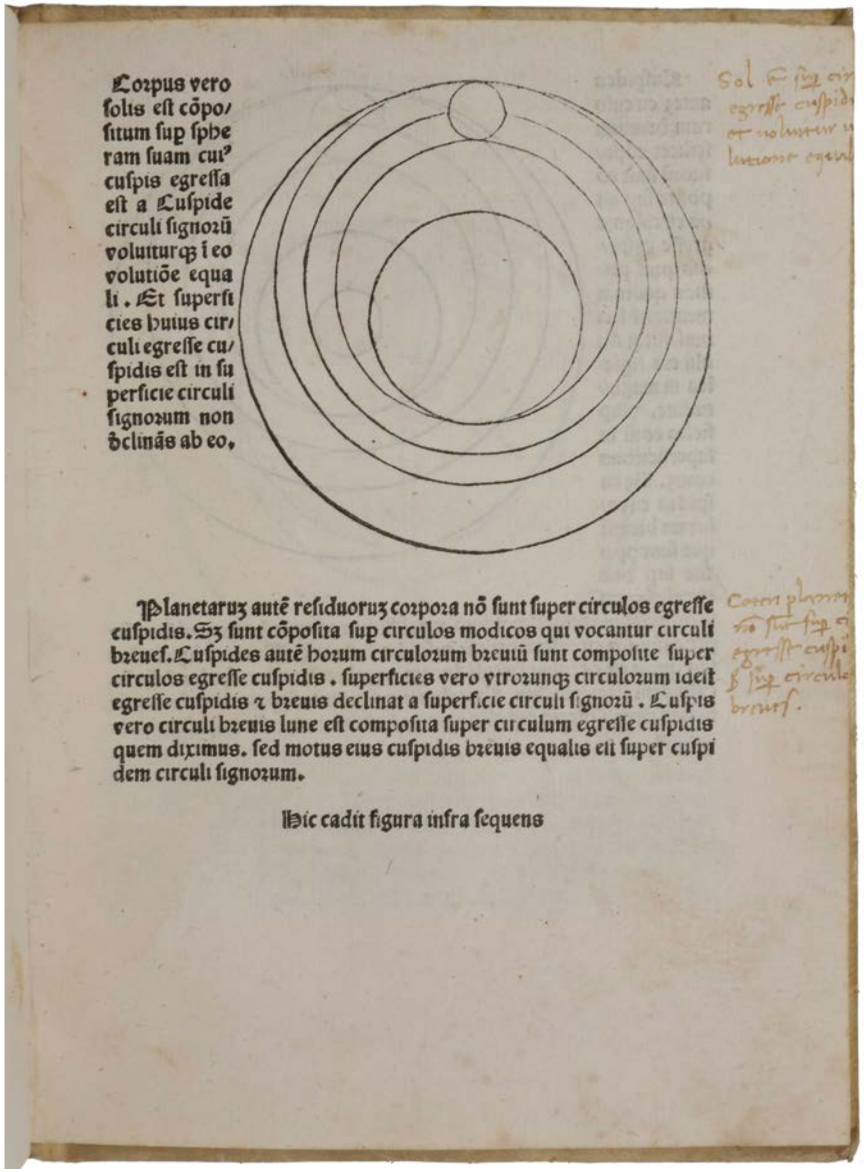
The foundations of Islamic science in general and of astronomy in particular were laid two centuries after the emigration of the prophet Muhammad from Mecca to Medina in AD 622. Then the new Abbasid dynasty, which had taken over the caliphate in 750 and founded Baghdad as the capital in 762, began to sponsor translations of Greek texts. In just a few decades the major scientific works of antiquity – including those of Galen, Aristotle, Euclid, Ptolemy, Archimedes and Apollonius – were translated into Arabic. The most vigorous patron of this effort was Caliph al-Ma'mūn, who acceded to power in 813, and founded an academy called the House of Wisdom. The Academy's principal translator of mathematical and astronomical works was a pagan named Thābit ibn Qurra (836-901). He wrote more than 100 scientific treatises, including a commentary on the *Almagest*. The most important astronomers of the Academy were al-Farghānī (b. 797 or 798) and his successor al-Bāttanī (858-929).

Written after the death of al-Maʻmūn in 833 but before 857, the *Elements* was al-Farghānī's best-known and most influential work. It gives a comprehensive account of the elements of Ptolemaic astronomy that is entirely descriptive and nonmathematical. These features, together with the admirably clear and well-organized manner of presentation, must have been responsible for the popularity this book enjoyed.

The *Elements* comprises thirty chapters. Chapter 1, to which nothing corresponds in the *Almagest*, describes the years of the Arabs, the Syrians, the Romans, the Persians, and the Egyptians, giving the names of their months and days and the differences between their calendars.

Chapters 2–5 expound the basic concepts of *Almagest* I.2–8: the sphericity of the heavens and their rotation (Chapter 2); the sphericity of the earth (Chapter 3), which al-Farghānī justifies on the evidence that the sun, the moon and the stars rise and set at different times in different parts of the world; the central position of the earth in the heavens, which he justifies on the evidence that each part of the earth is visible from the sky at exactly the same distance (Chapter 4). He also states that the size of the earth in relation to the heavens is as the point in a circle. Chapter 5 discusses the two primary movements of the heavens: the universal movement of everything from east to west and the movement of the stars (sun, moon and planets) from west to east. He explains that the zodiac is divided into 12 equal parts, and he gives their names, and that each sign of the zodiac is divided into 30 degrees and therefore the circle consist of 360 degrees. Al-Farghānī gives the Ptolemaic value for the inclination of the ecliptic as 23° 51´, and reports the (more accurate) value determined at the time of al-Ma‘mūn as 23° 35´.

Chapters 6–9 give a description of the inhabited quarter of the earth and list the seven climes and the names of well-known lands and cities. In Chapter 6 al-Farghānī describes the Equator, which divides the earth into two parts, and the North and South poles. He then discusses the inhabited part of the earth, the horizon, meridian, and differences between summer and winter and between day and night. Chapter 7 describes the appearance of the sun in different places on the earth, notably the places where the sun rises for several months without setting and those where it sets for several months without rising. In Chapter 8, al-Farghānī details the measurements of the earth and the seven ‘climes’ into which he divided the inhabited part of the earth (divisions by latitude). He gives


Corpus vero solis est cõpositum sup sphe ram suam cui9 cuspis egressa est a Cuspide circuli signorũ voluiturq; i eo volutiõe equa li. Et superfi cies huius cir culi egresse cu spidis est in su perficie circuli signorum non dclinãs ab eo,

Planetaruz autẽ residuoruz corpora nõ sunt super circulos egresse cuspidis. Sz sunt cõposita sup circulos modicos qui vocantur circuli breuef. Cuspides autẽ horum circulorum breuiũ sunt composite super circulos egresse cuspidis. superficies vero vtrorunq; circulorum ideit egresse cuspidis ꝛ breuis declinat a superficie circuli signorũ. Cuspis vero circuli breuis lune est composita super circulum egresse cuspidis quem diximus. sed motus eius cuspidis breuis equalis est super cuspi dem circuli signorum.

Hic cadit figura infra sequens

the Maʿmūnic measurements of the circumference and the diameter of the earth: 20,400 miles and approximately 6,500 miles, respectively. Chapter 9 explains latitude and longitude and gives the names and geographical locations of several cities in each clime.

Chapters 10 and 11 discuss ascensions of the signs of the zodiac in the direct spheres, horizons of the equator, and oblique spheres, horizons of the climes, and equal and unequal temporal hours. Chapter 12 describes the spheres of each of the planets and their distances from the earth, listing the distances between the spheres of each planet in the following order: the smallest and nearest to the earth is the sphere of the moon, followed by the spheres of Mercury, Venus, the sun, Mars, Jupiter, Saturn, and finally the sphere of the fixed stars. He also explains such astronomical terms as 'belt of the sphere of the zodiac,' 'epicycles,' 'eccentrics,' 'apogee' and 'perigee.' Chapters 13 and 14 deal with the movement of the sun, moon, planets and fixed stars in their spheres from west to east, called 'longitude movement.' He also explains why the fixed stars are regarded as being fixed. Chapter 15 describes the retrograde motions of the 'wandering planets', Mercury, Venus, Mars, Jupiter and Saturn. Chapter 16 gives the magnitudes of the eccentricities of the sun, the moon and the planets, and of the epicycles, and Chapter 17 gives the approximate values of the periods of revolution of the planets in their orbits. Al-Farghānī asserts that the slow eastward motion of the sphere of the fixed stars about the poles of the ecliptic through one degree every 100 years (the Ptolemaic value) is shared by the spheres (the apogees) of the sun, as well as of those of the moon and the five planets. Chapter 18 describes the movement of the fixed and moving stars in a north-south direction, or 'latitude movement'.

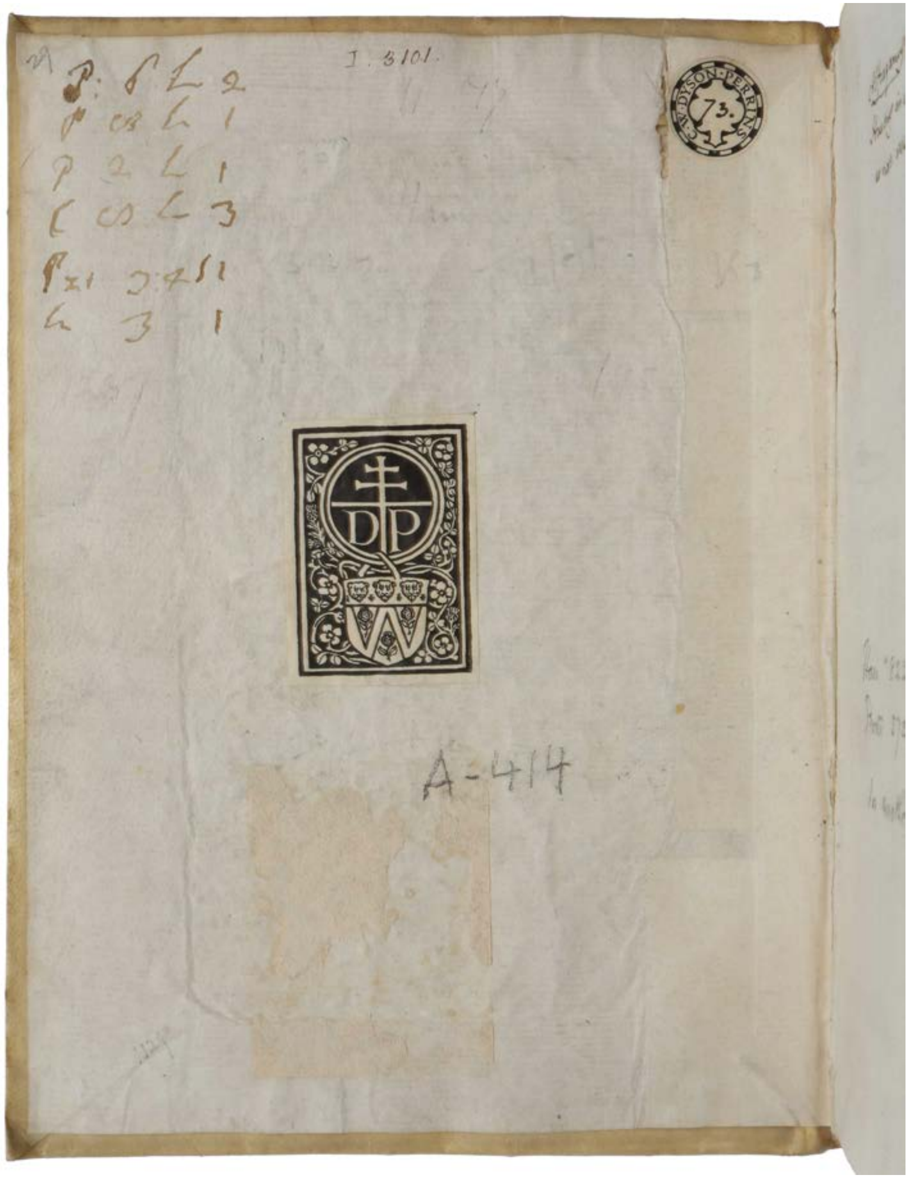
Chapter 19 is on the number of the fixed stars, their classification according to their magnitude, and the positions of the most remarkable among them. Of the 1022 measured stars, 15 are of the first magnitude, 45 of the second, 208 of the third, 474 of the fourth and 217 of the fifth. Al-Farghānī lists the 15 stars of the first magnitude and provides detailed information about their location. Chapter 20 describes the 'lunar mansions,' the 28 segments of the ecliptic (often called stations or houses) through which the Moon passes in its orbit around Earth, and the particular stars located in each. Chapter 21 gives the distances of the planets from the earth (Ptolemy had stated only the distances of the sun and the moon), and Chapter 22 the magnitudes of the planets compared with the magnitude of the earth ("Ptolemy only showed the magnitude of the sun and of the moon, but not that of the other planets; it is, however, easy to know the latter by analogy with what he did for the sun and the moon"); according to al-Farghānī the magnitude sequence is as follows: the biggest is the sun, followed by 15 fixed stars, then Jupiter, Saturn, other fixed stars, Mars, earth, Venus, the moon, and finally Mercury.

Chapter 23 is on the rising and setting of the sun, moon and planets, Chapter 24 on their ascension, descension, and occultation, Chapter 25 the phases of the moon and the five planets, Chapter 26 the ascent of the five planets, Chapter 27 the parallax of the moon and planets, and Chapters 28–30 solar and lunar eclipses and their intervals. According to al-Farghānī, a solar eclipse occurs when the moon reaches a point between the sun and the earth, and a lunar eclipse occurs when the earth's shadow falls on the moon's surface. He states that intervals between solar and lunar eclipses must be at least six lunar months, and he explains several cases in which the interval may be greater.

Although the *Elements* are based on the *Almagest*, al-Farghānī differs from Ptolemy in many details. Al-Farghānī agrees with Ptolemy's theory of precession, but whereas Ptolemy believed precession only affects the planets al-Farghānī believes it also affects the sun's apogee, so that there are two movements of the sun, the movement in the eccentric and the movement of its apogee. In addition, some of the data given by al-Farghānī differ from Ptolemy's: as already noted, al-Farghānī gives the greatest inclination between the equator and the ecliptic as 23° 35´, compared to Ptolemy's value of 23° 51´; he gives the length of a degree at the equator as 56⅔ nautical miles, while Ptolemy's value is 50.3 miles; and there are further differences between the two astronomers on the eccentricity and diameter of the epicycle of the moon, the elongations of Mars and Venus, and the anomalistic motion of Saturn. In most cases al-Farghānī's values were more accurate than Ptolemy's.

Two Latin translations of the *Elements* were made in the twelfth century, one by John of Spain (John of Seville) about 1137 under the title *Differentie scientie astrorum*, and the other by Gerard of Cremona before 1175 titled *Liber de aggregationibus scientiae stellarum et principiis celestium motuum*. Printed editions of the first translation appeared in 1493 [offered here], at Nüremberg in 1537 (*Continentur in hoc libro Rudimenta astronomica*, with the commentary of Regiomontanus), and at Paris in 1546 (*Alfragania astronomorum pertissimi compendium*) – this was the first edition to include the name of the translator in print. Gerard's translation was not published until 1910. Jacob Anatoli made a Hebrew translation of the book in 1231, *Quizzur almagesti*, that served as the basis for a third Latin translation by Jacob Christmann (*Muhamedis Alfragani Arabis Chronologica et astronomica elementa*), which appeared at Frankfurt in 1590. Jacob Golius published the Arabic text, based on a manuscript at Leiden (MS. Or. 8418/5, ff. 17-33), at Amsterdam in 1669 (*Muhammedis Fil. Ketiri Ferganensis, qui vulgo Alfraganus dicitur, Elementa Astronomica, Arabice & Latine*), but Golius' new Latin translation and notes covered only the first nine chapters of al-Farghānī's work.

This first edition was printed by Andreas Belfortis, the first and most important printer in Ferrara, who printed 55 titles between 1471 and 1493. This is the only



one of his works to contain illustrations, and appears to be the first illustrated book printed at Ferrara. Belfortis' career was interrupted twice by political upheavals and war: in his final phase, from 1481 to 1493, he printed scientific and medical works, including commentaries on Avicenna and Mesue. The charming full-page illustration on the verso of the title-page, a portrait of al-Farghānī and of an 'heremita', probably a member of the Eremita family of Ferrara, is in the style of the Ferrara master Cosimo Tura and has attracted the attention of art historians. "The editor of this tract appears to have been a member of the Ferrarese family of Eremita, not an Augustinian, although he is so represented in the cut" (Cicognara, quoted in the BM Catalogue). The portrait is much reproduced even today (e.g., by the Library of Congress).

Little is known with certainty about al-Farghānī's life. Although known today as an astronomer, it is in connection with his engineering activities that we have some information about him. Al-Farghānī supervised the construction of the New Nilometer at Old Cairo, completed in 861, the year in which caliph al-Mutawakkil, who ordered the construction, died. Al-Mutawakkil had also charged the two sons of Mūsā ibn Shākir, Muhammad and Ahmad, with supervising the digging of a canal running through the new city of al-Ja'fariyya, which al-Mutawakkil had built near Sāmarrā on the Tigris and named after himself. They delegated the work to al-Farghānī, but unfortunately he made a serious error, making the beginning of the canal deeper than the rest, so that water which entered the mouth of the canal would not flow properly through its other parts. When al-Mutawakkil learned of this, he threatened to crucify Muhammad and Ahmad, but they were saved by Sanad ibn 'Alī who vouched for the correctness of al-Farghānī's calculations, and said that if there had been an error it would be visible in four months' time when the level of the water would decline. However, as had been predicted by astrologers, al-Mutawakkil was murdered shortly before the error became apparent. Al-Farghānī wrote a number of other works on astronomy, including a commentary on the astronomical tables of al-Khwārizmī, the founder of algebra, as well as treatises on the astrolabe and on sundials. The crater *Alfraganus* on the Moon is named after him.

BMC VI, 605; Carmody, p. 144; Goff A-460; GW 1268; HC *822; Honeyman 70 (this copy); Houzeau & Lancaster 1112; IGI 351; Klebs 51.1. Lippmann, p. 153; Pellechet 513; Proctor 5753; Sander 279; Stillwell 13; the Crawford Library copy is the only one recorded by Grassi. Abdukhalimov, 'Ahmad Al-Farghani and his Compendium of Astronomy,' *Journal of Islamic Studies*, Vol. 10 (1999),

pp. 142-58. Glick *et al* (eds.), *Medieval Science, Technology, and Medicine*: *An Encyclopedia*, 2005. Sezgin (ed.), *Jawāmi ilm al-nujūm wa-usūl al-harakāt al-samāwīya [von] Ahmad ibn Muhammad ibn Kathīr al-Farghānī; herausgegeben als Elementa astronomica mit lateinischer Übersetzung von Jacob Golius; Nachdruck der Ausgabe Amsterdam, 1669*, 1986. Shaw, 'Andreas Belfortis, First Printer in Ferrara: A Revised Chronology of his Output, 1471–1478,' *La Bibliofilia* 105 (2003), pp. 3-25. For the relation between the *Elements* and Sacrobosco's *Sphere*, see Thorndike, *The Sphere of Sacrobosco and its Commentators* (1949), pp. 15-18.

THE 'PRINCIPIA' OF ELECTRODYNAMICS

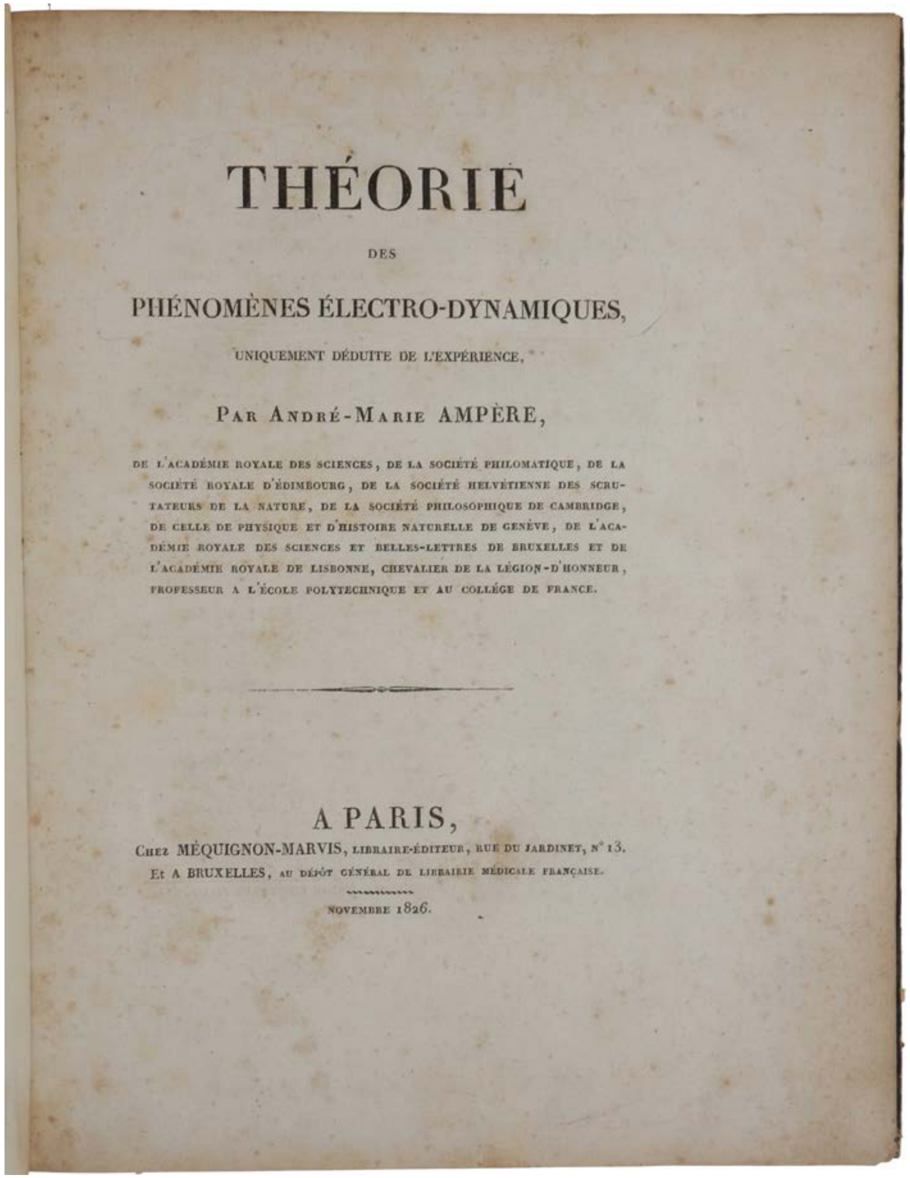
Grolier/Horblit, *One Hundred Books Famous in Science* 3a

AMPÈRE, André-Marie. *Théorie des phénomènes électro-dynamiques, uniquement déduite de l'expérience.* Paris: Firmin Didot for Mequignon-Marvis; Depot General de Librairie Medicale Francaise, 1826.

$15,000

4to (265 x 210 mm), pp. [3], 4-226. [1, errata], with two folding engraved plates. Contemporary half calf over marbled boards, spine gilt, some light wear to extremeties, internally with some spotting to the first and final leave.

First edition of the "*Principia* of electrodynamics" (DSB), offprint issue (published before the journal issue). "Having established a noumenal foundation for electrodynamic phenomena, Ampère's next steps were to discover the relationships between the phenomena and to devise a theory from which these relationships could be mathematically deduced. This double task was undertaken in the years 1821-1825, and his success was reported in his greatest work ... In this work, the *Principia* of electrodynamics, Ampère first described the laws of action of electric currents" (DSB). "The experimental investigation by which Ampère established the laws of the mechanical action between electric currents is one of the most brilliant achievements in science. The whole, theory and experiment, seems as if it had leaped, full grown and full armed, from the brain of the 'Newton of electricity.' It is perfect in form, and unassailable in accuracy, and it is summed up in a formula from which all the phenomena may be deduced, and which must always remain the cardinal formula of electro-dynamics" (James Clerk Maxwell, *Treatise on Electricity and Magnetism*, Vol. II (1873), p. 162).



THÉORIE

DES

PHÉNOMÈNES ÉLECTRO-DYNAMIQUES,

UNIQUEMENT DÉDUITE DE L'EXPÉRIENCE,

PAR ANDRÉ-MARIE AMPÈRE,

DE L'ACADÉMIE ROYALE DES SCIENCES, DE LA SOCIÉTÉ PHILOMATIQUE, DE LA SOCIÉTÉ ROYALE D'ÉDIMBOURG, DE LA SOCIÉTÉ HELVÉTIENNE DES SCRUTATEURS DE LA NATURE, DE LA SOCIÉTÉ PHILOSOPHIQUE DE CAMBRIDGE, DE CELLE DE PHYSIQUE ET D'HISTOIRE NATURELLE DE GENÈVE, DE L'ACADÉMIE ROYALE DES SCIENCES ET BELLES-LETTRES DE BRUXELLES ET DE L'ACADÉMIE ROYALE DE LISBONNE, CHEVALIER DE LA LÉGION-D'HONNEUR, PROFESSEUR A L'ÉCOLE POLYTECHNIQUE ET AU COLLÉGE DE FRANCE.

A PARIS,

CHEZ MÉQUIGNON-MARVIS, LIBRAIRE-ÉDITEUR, RUE DU JARDINET, N° 13.

ET A BRUXELLES, AU DÉPÔT GÉNÉRAL DE LIBRAIRIE MÉDICALE FRANÇAISE.

NOVEMBRE 1826.

"By that time, early 1823, Ampère's electrodynamics had reached maturity. With the perfected Ampère law, the Ampèrean currents, and proper analytical tools, one could calculate every known magnetic or electromagnetic effect. However, a systematic account of the theory was still wanting. This Ampère gave in 1826 with his masterful 'Mémoire sur la théorie des phénomènes électro-dynamiques, uniquement déduite de l'expérience.'

"Imitating the rhetorics of Newton's *Principia* or Fourier's *Théorie Analytique de la Chaleur,* Ampère presented his results as the plain expression of experimental truths: 'I have solely consulted experiment to establish the laws of these phenomena, and I have deduced the only formula that can represent the forces to which they are due.' Later commentators have had no difficulty detecting a few unwarranted hypotheses in Ampère's theory, for example the central character of elementary forces, the absence of elementary torque, and the Ampèrean currents. There is no reason, however, to doubt Ampère's sincerity. As was mentioned, the concept of *physical* current elements, on which the character of the action between current elements depended, seemed to be materialized in his apparatus. The currents in magnets were not a hypothesis, as far as they were the only consistent way to unify magnetism and electromagnetism: 'The proofs on which I base [my theory] mostly result from the fact that they reduce to a single principle three sorts of actions which all phenomena prove to depend on a common cause, and which cannot be reduced in a different manner.

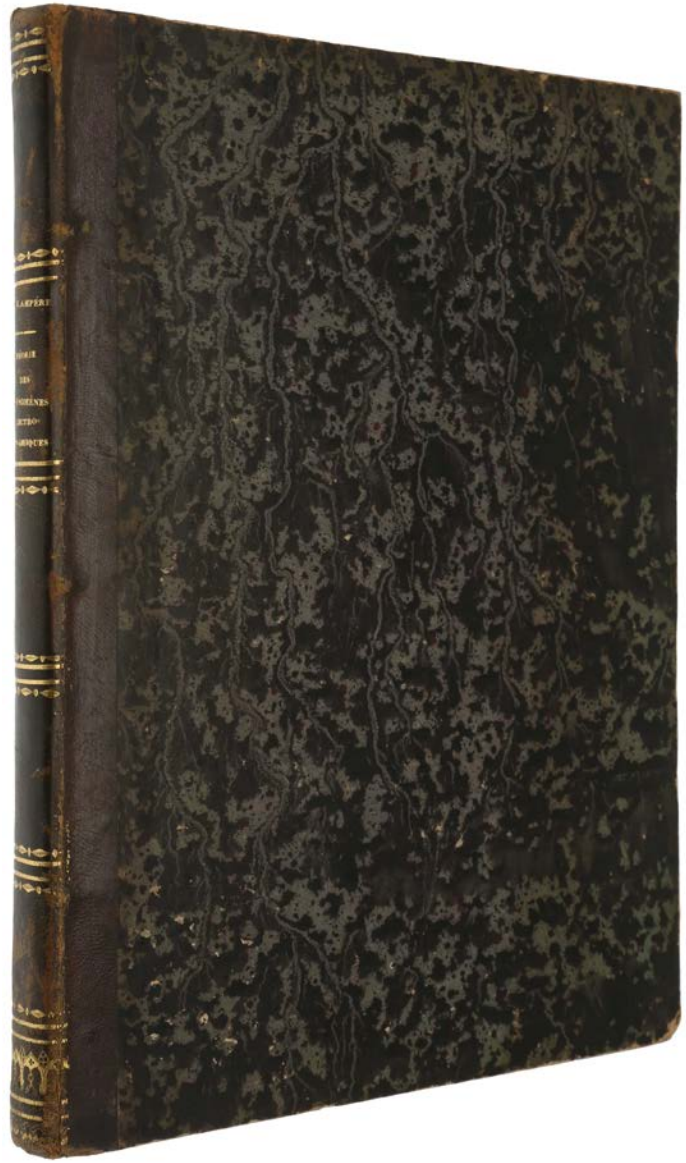
"Most important, Ampère's formula for the force between two current elements did not depend on any assumption regarding the nature of the electric current and connected mechanisms: 'Whatever be the physical cause to which we may wish to relate the phenomena produced by this action, the formula obtained will always remain the expression of facts.' As we shall see, this turned out to be largely true, since Ampère's formula (at least its consequences for closed currents) remained an essential basis for the construction of all later theories of electrodynamics. Ampère again compared himself to Fourier, whose equations for heat propagation had survived Fresnel's wave theory of light and heat. Extending the parallel, Ampère did not exclude the search for physical causes. He himself speculated on various mechanisms for the production of electrodynamic forces, as will be seen in a moment. But he required a clean separation between laws and causes. For the determination of the force between two current elements, Ampère offered a polished version of the null method, which was 'more direct, simpler, and susceptible of great precision.' The first equilibrium case concerned the lack of action of two contiguous opposite currents. The second established the equivalence of rectilinear and sinuous currents, in the manner of 1821. The third replaced the no-rotation devices of 1822 and proved that the force acting from a closed circuit on a current element was perpendicular to the element. The fourth established the scale invariance of the electrodynamic action … The complete expression of the force still involved obvious factors: the lengths of the elements and the intensities of the currents. In Ampère's mind the latter factor constituted a quantitative *definition* of the intensity of a current, including a definite current unit as soon as the unit of force was defined. The experiments and reasonings of the null method had an air of great systematism. A closer look at them, however, reveals serious flaws. Ampère did not quantify the precision of his apparatus, as if measuring a zero quantity required zero efforts at error analysis. Even worse, his third case of equilibrium was utterly unstable and hardly observable, and the apparatus for the fourth one was never built, on Ampère's own admission. Could it be that Ampère's law rested on paper evidence? Certainly not … For the sake of a reductionist rhetoric, however, he preferred an ideal justification of his formula that would not depend on the complicated physics of magnets.

"In the bulk of his memoir, Ampère developed the consequences of his formula for closed currents, Savary's solenoids, and magnets. The diversity of his mathematical techniques must be emphasized …

"As a special case of a closed current, Ampère considered a single infinitesimal loop of current, and showed that it was equivalent to a magnetic dipole. A finite closed current, he went on, could be replaced by a net of infinitesimal current loops, and was therefore mathematically equivalent to a double sheet of boreal and austral fluid. The ingenious equivalence played little role in Ampère's deductions, save for a proof that the continuous rotations were impossible for closed rigid circuits. Yet it could be very helpful to anyone who, unlike Ampère, wished to derive the law of electrodynamics from those of magnetism.

"Toward the end of his memoir, Ampère relaxed his severe attitude and indulged In speculations on the cause and nature of electric motions. In his previous researches he had repeatedly tried to understand electrodynamic forces in terms of a propagated action in a medium. In his youth he condemned 'the supposition of an action between bodies that do not touch each other.' In the early 1820s, the success of Fresnel's optical ether revived his desire to reduce all physics to the local motions of a medium. When he discovered the equivalence of rectilinear and sinuous current, he imagined a corresponding superposition of ether motions. Later, the equivalence between a closed circuit and a net of infinitesimal current loops suggested to him a rotary motion in the medium. In each case, the fact preceded the intuition, and Ampère remained very discreet about his ether.

"Ampère was more open about his conception of the electric current. In 1821, he gave up Volta's idea of an electric motion of which the substratum of the conductor was the only obstacle. He adopted instead Oersted's idea of a series of



compositions and decompositions of the two electricities starting in the battery and propagating along the conductor. In lengthy speculations, he combined this view with the atomistic conception of matter to explain contact tension and electrolysis. More succinctly, he imagined an ether made of the neutral fluid resulting from the combination of negative and positive electricity.

"In the memoir of 1826 Ampère expounded his view of the electric current, and mentioned the related conception of the ether. He briefly suggested a propagation of electromagnetic actions through this ether, but favored a more conservative approach in which Coulomb's electrostatic law remained basic. The idea was to take the average of the Coulomb forces between the separated fluids in the interacting currents. Since the separation was a temporary, spatially directed process, the angular dependence of the net forces could perhaps emerge in this manner.

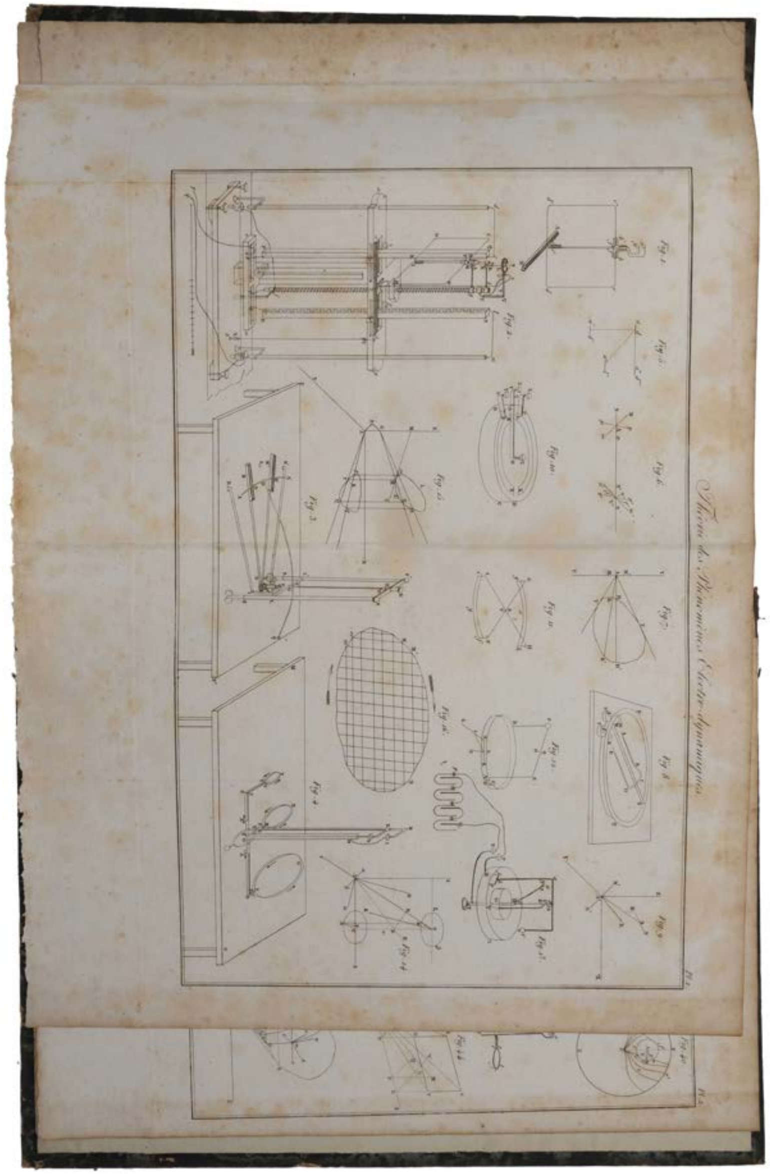
"In sum, Ampère's influential memoir of 1826 was not just the reunion of the equilibrium cases, the Ampère formula, and the Ampèrean currents in magnets. It also involved a store of mathematical techniques from which successors could borrow, and it prefigured two ways of deepening our understanding of electrodynamic forces: by reducing them to motions in the ether or by summing the direct actions of the electric fluids running in conductors. The magnificent architecture of the memoir rested on a fictitious three-stage history. In the first stage, fundamental experiments established general properties of electrodynamic forces. In the second, a general force formula was inferred from these properties. In the third, all known phenomena of electrodynamics and magnetism were deduced from the force law and the assumption of Ampèrean currents. This architecture helped clarify the subject and convince Ampère's readers. At the same time, it obscured the dynamical interplay of experiment, mathematical techniques, and theoretical ideas in the actual genesis of electrodynamics.

"Oersted's new effect, Newtonian analogy, and the principle of unity were the sources of Ampère's initial theoretical convictions. Then Ampère conceived, ordered, and used apparatus intended to support these convictions. The infinitesimal analysis of the theory conditioned the structure of the apparatus. Reciprocally, this structure suggested the notion of a physical current element as a separable entity with regard to the principles of mechanics. In general, the experiments confirmed the original intuitions. However, the few failed experiments played a crucial role. They removed previous indeterminations of the theory, they redirected Ampère toward the null method, and they prompted the development of new mathematical techniques. In turn, these techniques permitted a confirmation of the more qualitative components of Ampère's theory, and suggested more fundamental explanations of electrodynamic forces.

"This complex history and Ampère's simple reconstruction of electrodynamics share a common trait: the mathematics is rigorous and adaptable, while the experiments lack precision and flexibility. This asymmetry, later regarded as a basic defect of the otherwise impressive French physics, has a natural explanation: the experiments were intended to found the theory at the simplest level of analysis, for which effects are small and geometrical configurations highly constrained. There were two obvious ways of avoiding the difficulty: to deny the control of mathematical theory over experiment, as Faraday did, or to relocate the control at the level of more complex, but still computable systems, as Weber later did" (Darrigol).

"Ampère presented the work to the Académie des Sciences in 1823, and it was first printed, under the title 'Mémoire sur la théorie mathématique des phénomènes électro-dynamiques,' on pp. 177-387 of Vol. VI of the Mémoires de l'Académie des Sciences" (Norman). "As Vol. VI was the volume for 1823 this date appears on the first page of each signature as an identifying mark for the printer; the whole volume, however, was not published until late in 1827 … In the meantime the author's separate was prepared; the last twelve pages were reset and extended to eighteen; the work was repaginated and re-signed; and the '1823' was removed from lower margins (except on sig. 21 where it remained on all copies and on sig. 12 where, together with the original periodical pagination, it remained in a few copies, but was corrected during printing). The separate was issued in November 1826; thus although printed second it was published first" (Honeyman). It is often said (e.g., in Norman) that there is an earlier issue with pages 85-92 retaining their journal pagination 257-264, but we have never seen such a copy (or seen one described), and this mispagination is not mentioned in any copy listed on OCLC, KVK or COPAC.

Grolier/Horblit 3a; *En Français dans le Texte* 240; ; Honeyman 85; Norman 50.



EXTENSIVELY ANNOTATED

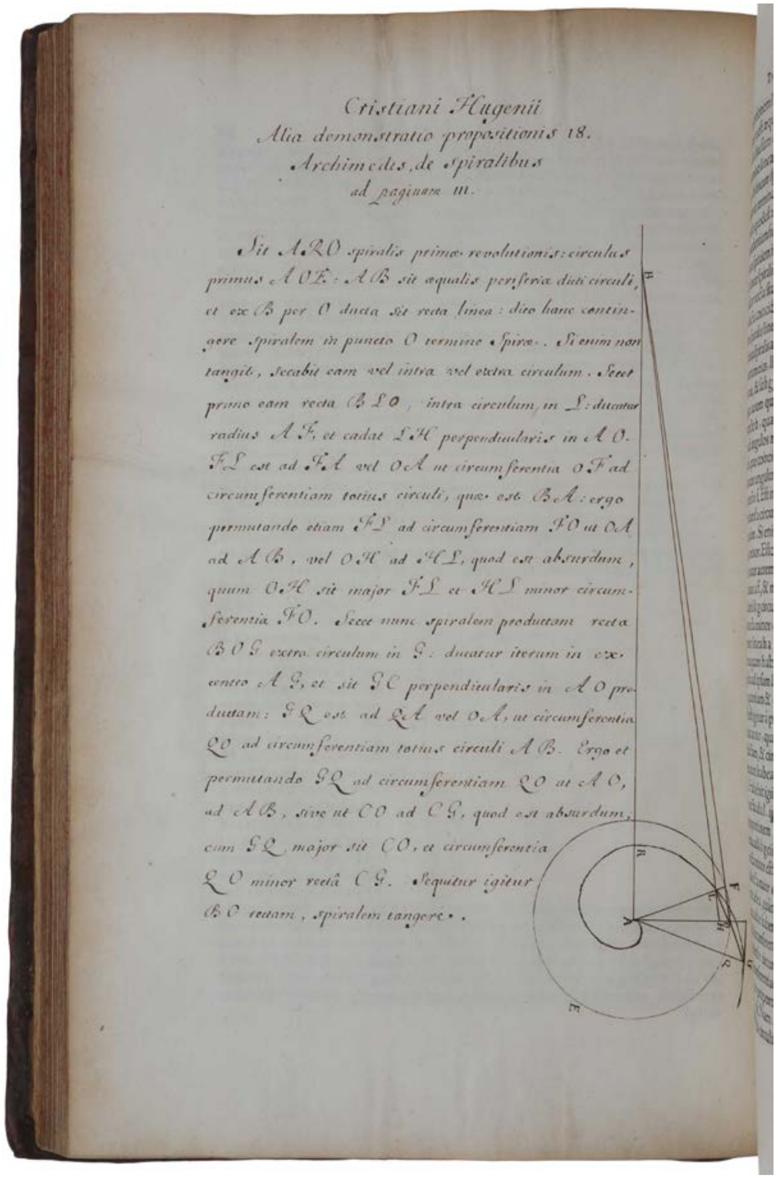
PMM 72; Dibner 137; Grolier/Horblit, *One Hundred Books Famous in Science* 5

ARCHIMEDES. *Opera, quae quidem extant, omnia ... nuncque primum & Graece Latine in lucem edita ... adiecta quoque sunt Eutocii Ascalonitae in eosdem Archimedis libros commentaria item Graece & Latine, nunquam antea excusa.* Basle: Joannes Hervagius, 1544.

$75,000

Folio (310 x 205 mm), pp. [8], 1-139, [1], [8], [1], 2-163, [1], [4], 1-65, [1], 1-68, [1, colophon]. Numerous woodcut diagrams and initials, text in Greek and Latin. Seventeenth-century (Dutch?) calf with gilt-stamped armorial on covers (rebacked retaining the original endpapers), red speckled edges.

First edition of one of the key scientific books of the Renaissance, representing a decisive step forward in the history of mathematics, containing the first printings of the majority of the surviving works of the greatest mathematician, physicist and engineer of antiquity. This is a fascinating copy with numerous contemporary annotations by a well-informed reader, both in the margins and in the text itself (in a minuscule neat hand that does not obscure the original text). In addition, there is a full-page manuscript entitled 'Cristiani Hugenii / Alia demonstratio propositionis 18 / Archimedis de spiralibus / ad paginam 111,' and including a large geometrical diagram, which provides Huygens' alternative proof to a proposition about Archimedes' spiral demonstrated on the facing page of text. This suggests that the annotator was probably a member of Huygens' circle. This book constitutes "the first printing of the original Greek text of seven Archimedean



mathematical texts, accompanied by Jacopo de Cremona's Latin translation from a manuscript corrected by Regiomontanus, and the commentaries (in both Greek and Latin) of the sixth-century mathematician Eutocius of Ascalon" (Norman). "Archimedes – together with Newton and Gauss – is generally regarded as one of the greatest mathematicians the world has ever known, and if his influence had not been overshadowed at first by Aristotle, Euclid and Plato, the progress of modern mathematics might have been much faster. As it was, his influence began to take full effect only after this first printed edition which enabled Descartes, Galileo, and Newton in particular to build on what he had begun" (PMM). The seven treatises included in the present work are: *On the Sphere & Cylinder*; *On the Measurement of the Circle*; *On Conoids & Spheroids*; *On Spirals*; *On the Equilibrium of Planes* (and *Centres of Gravity*); *The Arenarius*, or *Sand-Reckoner*; and *On the Quadrature of the Parabola*. "Publication of this *editio princeps* inspired a multiplication of texts on Archimedes and his methods, which exerted a strong influence on the development of mathematics during the sixteenth and seventeenth centuries. One of the important effects of that influence can be seen in Kepler's *Astronomia nova* (1609), in which Archimedes' so-called 'exhaustion procedure' was applied to the measurement of time elapsed between any two points if Mars's orbit" (Norman). "Apart from one small tract published in 1503 and an imperfect edition by Tartaglia in 1543, [this] is the first complete edition of Archimedes' works" (PMM). This volume also includes for the first time the description of the heliocentric system of Aristarchus, who had conceived this theory centuries before Copernicus.

"The principal results in *On the Sphere and Cylinder* (in two books) are that the surface area S of any sphere of radius r is four times that of its greatest circle (in modern notation, $S = 4\pi r^2$) and that the volume V of a sphere is two-thirds that of the cylinder in which it is inscribed (leading immediately to the formula for the volume, $V = 4/3\pi r^3$). Archimedes was proud enough of the latter discovery to leave instructions for his tomb to be marked with a sphere inscribed in a cylinder. Marcus Tullius Cicero (106–43 BC) found the tomb, overgrown with vegetation, a century and a half after Archimedes' death.

"*Measurement of the Circle* is a fragment of a longer work in which π, the ratio of the circumference to the diameter of a circle, is shown to lie between the limits of 3 10/71 and 3 1/7. Archimedes' approach to determining π, which consists of inscribing and circumscribing regular polygons with a large number of sides, was followed by everyone until the development of infinite series expansions in India during the 15th century and in Europe during the 17th century. That work also contains accurate approximations (expressed as ratios of integers) to the square roots of 3 and several large numbers.

"*On Conoids and Spheroids* deals with determining the volumes of the segments of solids formed by the revolution of a conic section (circle, ellipse, parabola, or hyperbola) about its axis. In modern terms, those are problems of integration.

"*On Spirals* develops many properties of tangents to, and areas associated with, the spiral of Archimedes—i.e., the locus of a point moving with uniform speed along a straight line that itself is rotating with uniform speed about a fixed point. It was one of only a few curves beyond the straight line and the conic sections known in antiquity.

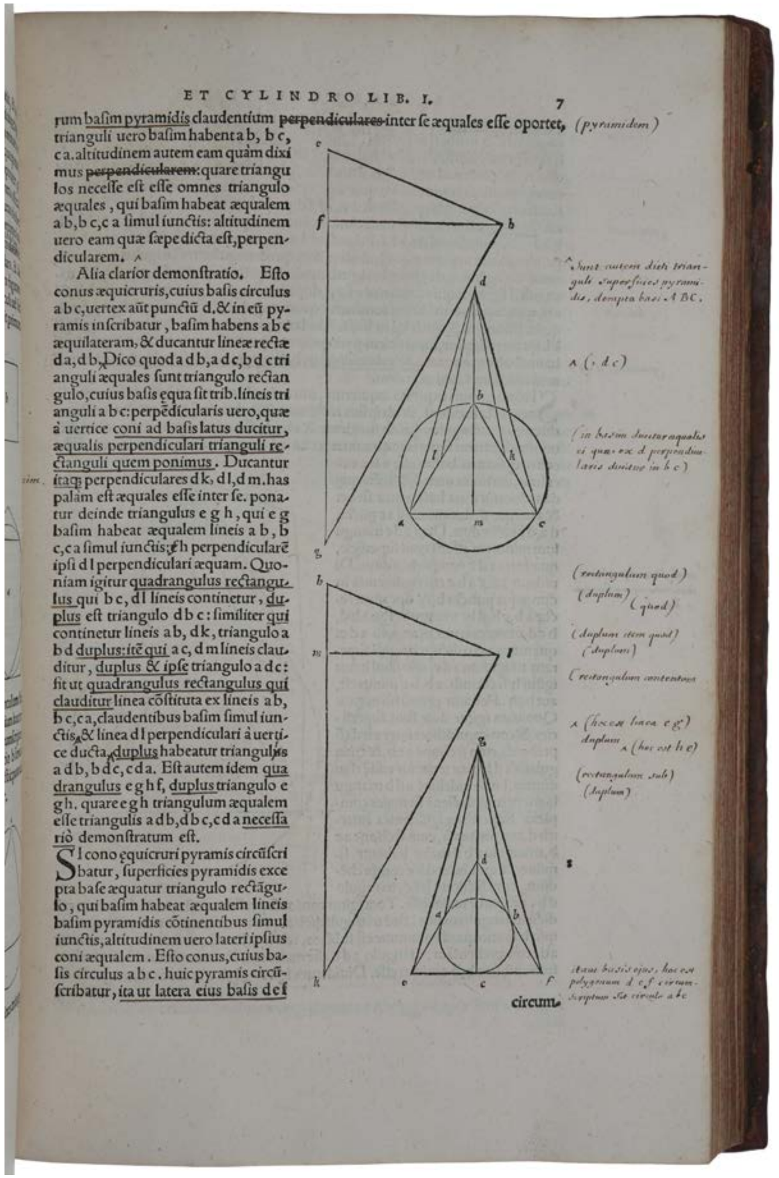
"*On the Equilibrium of Planes* (or *Centres of Gravity of Planes*; in two books) is mainly concerned with establishing the centres of gravity of various rectilinear plane figures and segments of the parabola and the paraboloid. The first book purports to establish the 'law of the lever' (magnitudes balance at distances from the fulcrum in inverse ratio to their weights), and it is mainly on the basis of that treatise that Archimedes has been called the founder of theoretical mechanics.

Much of that book, however, is undoubtedly not authentic, consisting as it does of inept later additions or reworkings, and it seems likely that the basic principle of the law of the lever and—possibly—the concept of the centre of gravity were established on a mathematical basis by scholars earlier than Archimedes. His contribution was rather to extend those concepts to conic sections.

"*Quadrature of the Parabola* demonstrates, first by 'mechanical' means and then by conventional geometric methods, that the area of any segment of a parabola is 4/3 of the area of the triangle having the same base and height as that segment.

"*The Sand-Reckoner* is a small treatise that is a jeu d'esprit written for the layman—it is addressed to Gelon, son of Hieron [see below]—that nevertheless contains some profoundly original mathematics. Its object is to remedy the inadequacies of the Greek numerical notation system by showing how to express a huge number—the number of grains of sand that it would take to fill the whole of the universe. What Archimedes does, in effect, is to create a place-value system of notation, with a base of 100,000,000. (That was apparently a completely original idea, since he had no knowledge of the contemporary Babylonian place-value system with base 60.) The work is also of interest because it gives the most detailed surviving description of the heliocentric system of Aristarchus of Samos (c. 310–230 BC) and because it contains an account of an ingenious procedure that Archimedes used to determine the Sun's apparent diameter by observation with an instrument …

"Archimedes' mathematical proofs and presentation exhibit great boldness and originality of thought on the one hand and extreme rigour on the other, meeting the highest standards of contemporary geometry. While he arrived at the formulas for the surface area and volume of a sphere by 'mechanical' reasoning involving infinitesimals, in his actual proofs of the results in *Sphere and Cylinder*



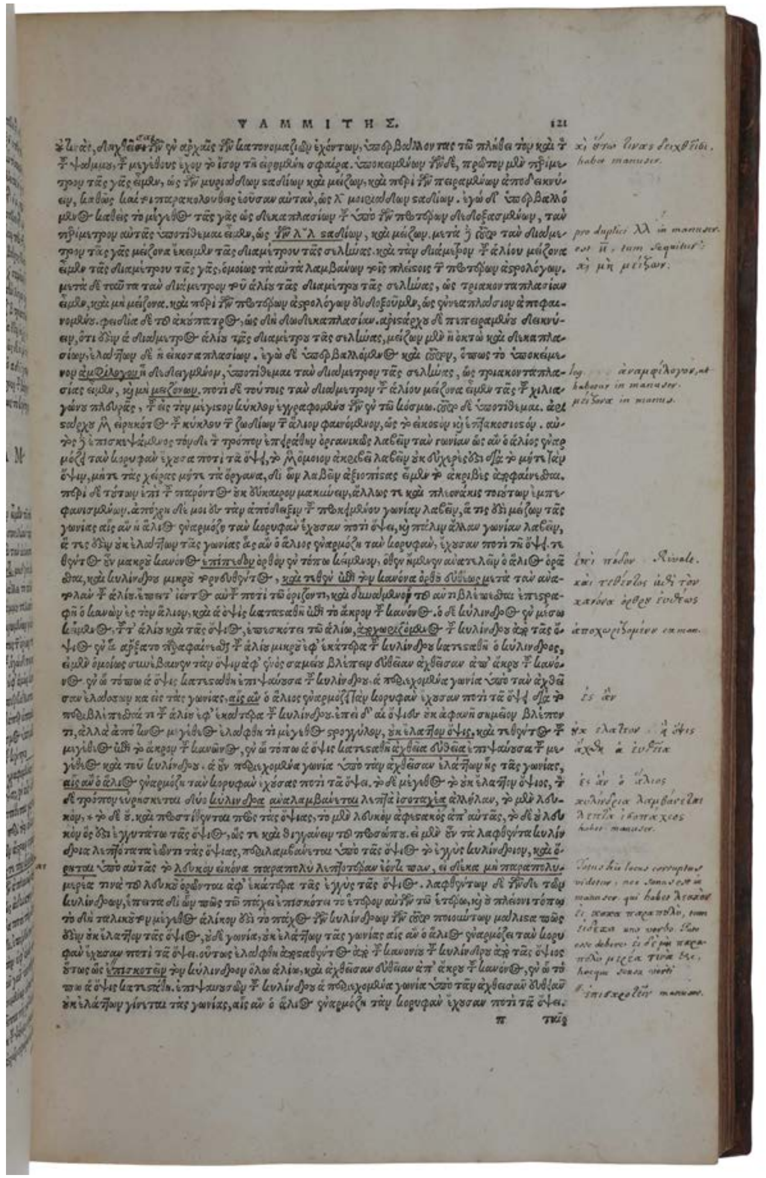
he uses only the rigorous methods of successive finite approximation that had been invented by Eudoxus of Cnidus in the 4th century BC. These methods, of which Archimedes was a master, are the standard procedure in all his works on higher geometry that deal with proving results about areas and volumes. Their mathematical rigour stands in strong contrast to the 'proofs' of the first practitioners of integral calculus in the 17th century, when infinitesimals were reintroduced into mathematics. Yet Archimedes' results are no less impressive than theirs. The same freedom from conventional ways of thinking is apparent in the arithmetical field in *Sand-Reckoner*, which shows a deep understanding of the nature of the numerical system" (Britannica).

Although Eutocius (480-540) was not an original thinker, his commentaries contain much historical information which might otherwise have been lost. It is to Eutocius that we owe the Archimedean solution of a cubic by means of intersecting conics, referred to in *On the Sphere & Cylinder* (Book II.4) but not otherwise extant except through his commentary. Eutocius also records the solution of the original problem of II.4 by Diocles (c. 240 – c. 180 BC), avoiding the use of the cubic, and the solution by Dionysodorus (c. 250 – c. 190 BC) of the auxiliary cubic. It is thought that Eutocius did not know of the four remaining works, *On Conoids & Spheroids*, *On Spirals*; *The Sand-Reckoner*, and *On the Quadrature of the Parabola*.

"In contrast to Euclid's *Elements*, the writings of Archimedes were not widely known in antiquity. Survival of their texts was due to interest in Archimedes' writings at the Byzantine capital of Constantinople from the sixth through the tenth centuries. "It is true that before that time individual works of Archimedes were obviously studied at Alexandria, since Archimedes was often quoted by three eminent mathematicians of Alexandria: Hero, Pappus, and Theon. But it is with the activity of Eutocius of Ascalon, who was born toward the end of the fifth century and studied at Alexandria, that the textual history of a collected edition of Archimedes properly begins. Eutocius composed commentaries on three of Archimedes' works: *On the Sphere and the Cylinder*, *On the Measurement of the Circle*, and *On the Equilibrium of Planes*. These were no doubt the most popular of Archimedes' works at that time … The works of Archimedes and the commentaries of Eutocius were studied and taught by Isidore of Miletus (442-537) and Anthemius of Tralles (474-534), Justinian's architects of Hagia Sophia in Constantinople. It was apparently Isidore who was responsible for the first collected edition of at least the three works commented on by Eutocius as well as the commentaries. Later Byzantine authors seem gradually to have added other works to this first collected edition until the ninth century when the educational reformer Leon of Thessalonica produced the compilation represented by Greek manuscript A (adopting the designation used by the editor, J. L. Heiberg [*Opera omnia, cum commentariis Eutocii*, 3 vols., Leipzig, 1880-1]). Manuscript A contained all of the Greek works now known excepting *On Floating Bodies*, *On the Method*, *Stomachion*, and *The Cattle Problem*. This was one of the two manuscripts available to William of Moerbeke (1215-86) when he made his Latin translations in 1269. It was the source, directly or indirectly, of all of the Renaissance copies of Archimedes. A second Byzantine manuscript, designated as B, included only the mechanical works: *On the Equilibrium of Planes*, *On the Quadrature of the Parabola* and *On Floating Bodies* (and possibly *On Spirals*). It too was available to Moerbeke, but it disappears after an early fourteenth-century reference. Finally we can mention a third Byzantine manuscript, C, a palimpsest whose Archimedean parts are in a hand of the tenth century. It was not available to the Latin West in the Middle Ages, or indeed in modern times until its identification by Heiberg in 1906 at Constantinople (where it had been brought from Jerusalem).

"In the fifteenth century, knowledge of Archimedes in Europe began to expand. A new Latin translation was made by James of Cremona (1400-56) in about 1450 by order of Pope Nicholas V. Since this translation was made exclusively from manuscript A, the translation failed to include *On Floating Bodies*, but it did include the two treatises in A omitted by Moerbeke, namely *The Sand Reckoner* and Eutocius' *Commentary on the Measurement of the Circle*. It appears that this new translation was made with an eye on Moerbeke's translation. . . . There are at least nine extant manuscripts of this translation, one of which was corrected by Regiomontanus and brought to Germany about 1468 … Greek manuscript A itself was copied a number of times. Cardinal Bessarion had one copy prepared between 1449 and 1468 (MS E). Another (MS D) was made from A when it was in the possession of the well-known humanist George [Giorgio] Valla (1447-99). The fate of A and its various copies has been traced skilfully by J. L. Heiberg in his edition of Archimedes' *Opera*. The last known use of manuscript A occurred in 1544, after which time it seems to have disappeared.

"The first printed Archimedean materials were in fact merely Latin excerpts that appeared in George Valla's *De expetendis et fugiendis rebus opus* (Venice, 1501) and were based on his reading of manuscript A. But the earliest actual printed texts of Archimedes were the Moerbeke translations of *On the Measurement of the Circle* and *On the Quadrature of the Parabola* (*Teragonismus, id est circuli quadratura* etc.) published from the Madrid manuscript by L[uca] Gaurico (Venice, 1503). In 1543 also at Venice N[iccolo] Tartaglia republished the same two translations directly from Gaurico's work, and in addition, from the same Madrid manuscript, the Moerbeke translations of *On the Equilbrium of Planes* and Book I of *On Floating Bodes* (leaving the erroneous impression that he had made these translations from a Greek manuscript, which he had not since he merely repeated the texts of the Madrid manuscript, with virtually all their errors) … The



key event, however, in the further spread of Archimedes was the aforementioned *editio princeps* of the Greek text with the accompanying Latin translation of James of Cremona at Basel in 1544" (Marshall Clagett in DSB).

For this *editio princeps* the editor Thomas Gechauff, called Venatorius (d. 1551), was able to use the above-mentioned manuscript of James of Cremona's Latin translation corrected by Regiomontanus, which included the commentaries of Eutocius. For the Greek text Gechauff used a manuscript which had been acquired in Rome by humanist Willibald Pirckheimer (1470-1530), and is preserved today in Nuremberg City Library. Gechauf, Nuremberg scholar and theologian, was born about 1490 and was a pupil of Johannes Schöner (1477-1547) and a friend of Pirckheimer. He wrote in both Latin and German, published an edition of Aristophanes 'Plutus' (1531), and his name is found in some works in conjunction with that of Andreas Osiander (1498-1552), who famously added the preface to Copernicus.

Manuscripts A and B are now lost. However, after disappearing into a European private collection in the early twentieth century, the third key record of Archimedes' texts discussed above, the tenth century Byzantine manuscript C, known as the Archimedes Palimpsest, re-appeared at a Christie's auction in New York on October 28, 1998, where it was purchased by a private collector in the United States. Since then it has been made widely available to scholars, and has been the subject of much research. It contains the only extant manuscript of Archimedes' *Method Concerning Mechanical Theorems*, which describes how he used a 'mechanical' method to arrive at some of his key discoveries, including the area of a parabolic segment and the surface area and volume of a sphere. The technique consists of dividing each of two figures into an infinite but equal number of infinitesimally thin strips, then 'weighing' each corresponding pair of these strips against each other on a notional balance to obtain the ratio of the two original figures. Archimedes emphasizes that this procedure, though useful as a heuristic method, does not constitute a rigorous proof. Nevertheless, his method is a clear precursor of Cavalieri's method of indivisibles (1635), and of the integral calculus of Newton and Leibniz.

Archimedes (c. 287 – 212/211 BC) "probably spent some time in Egypt early in his career, but he resided for most of his life in Syracuse, the principal Greek city-state in Sicily, where he was on intimate terms with its king, Hieron II. Archimedes published his works in the form of correspondence with the principal mathematicians of his time, including the Alexandrian scholars Conon of Samos and Eratosthenes of Cyrene. He played an important role in the defence of Syracuse against the siege laid by the Romans in 213 BC by constructing war machines so effective that they long delayed the capture of the city. When Syracuse eventually fell to the Roman general Marcus Claudius Marcellus in the autumn of 212 or spring of 211 BC, Archimedes was killed in the sack of the city.

"Far more details survive about the life of Archimedes than about any other ancient scientist, but they are largely anecdotal, reflecting the impression that his mechanical genius made on the popular imagination. Thus, he is credited with inventing the Archimedes screw, and he is supposed to have made two 'spheres' that Marcellus took back to Rome—one a star globe and the other a device (the details of which are uncertain) for mechanically representing the motions of the Sun, the Moon, and the planets. The story that he determined the proportion of gold and silver in a wreath made for Hieron by weighing it in water is probably true, but the version that has him leaping from the bath in which he supposedly got the idea and running naked through the streets shouting 'Heurēka!' ("I have found it!") is popular embellishment. Equally apocryphal are the stories that he used a huge array of mirrors to burn the Roman ships besieging Syracuse; that he said, 'Give me a place to stand and I will move the Earth'; and that a Roman soldier killed him because he refused to leave his mathematical diagrams—although all are popular reflections of his real interest in catoptrics (the branch of optics dealing with the reflection of light from mirrors, plane or curved), mechanics, and pure mathematics" (Britannica).

Active in the early 6th century, Eutocius apparently was a pupil of the Neo-Platonist Ammonius Saccas (175-242), and perhaps a colleague of Anthemius of Tralles. If so, he was trained as a Neo-Platonist philosopher. In this tradition, it was customary to pay attention to the mathematical sciences and even to write some commentaries on them, but Eutocius is the only Neo-Platonist we know to concentrate uniquely on mathematical commentary. In addition to his commentaries on Archimedes, he also wrote an important commentary on the first four books of the *Conics* of Apollonius (c. 262 BC – c. 190 BC).

PMM 72; Adams A1531; Dibner 137; Grolier/Horblit 5; Hoffman I, 228; Macclesfield 179 & 180; Norman 61.

COMPLETLEY UNTOUCHED IN ITS ORIGINAL STATE

BARONIO, Giuseppe. *Degli innesti animali.* Milan: Fonderia del Genio, 1804.

$6,500

Large 8vo (243 x 153 mm, uncut), publisher's original boards with printed paper spine label, stiple-engraved frontispiece by F. Bordiga, pp. [1-2] 3-78 [79:index] [1:blank] and 2 engraved plates (one folding), printed on thick paper. Spine with some wear. A completley untouched copy in its original state.

First edition of this very important work on transplantation and experimental surgery in animals. "The publication of *Degli Innesti Animali* (On grafting in Animals) by Giuseppe Baronio (1759-1811) in 1804, the first account of experimental autologous skin transplantation in a ram, marks the beginning of a new era for plastic surgery – the demonstration that skin transfer in the same individual is possible and successful" (Mazzola). His early skin grafts on sheep are among the first closely controlled medical experiments using animals, and according to Garrison-Morton "He successfully carried out full-thickness skin grafts after detachment from the body, and the first purely scientific research in the history of plastic surgery." Baronio laid the foundation for human skin grafting, which was only successfully done for the first time 13 years later, in 1817. There are chapters on the Indian method for restoration of the nose, and the revival of this method by Carpue, on the surgery of Tagliacozzi, on teeth graft in man, and on skin grafts in animals. "It is a landmark in the development of plastic surgery procedure after two centuries of neglect" (Hagstromer Library). "It was Giuseppe

Baronio, physician and naturalist of Milan, who first demonstrated on sheep that full-thickness skin grafts could be successfully transplanted after detachment from the body. In three experiments which he describes in 1804, Baronio removed from the back of a sheep patches of skin which he transplanted to new sites on the same sheep, one immediately, a second after eighteen minutes, and a third after one hour of detachment. All became successfully adherent to the new bed . . . Baronio's significant findings went unnoticed, . . . and it was not until more than fifty years later that free whole-thickness skin grafts came into general use … The basic principle of free transplantation . . . constituted, when fully understood and applied, the greatest single advance [in plastic surgery] of the nineteenth century" (Gnudi & Webster, p 328). "Baronio carried out trials on a total of 27 animals (rams, goats, dogs, and even a mare and a cow), always with the same positive results. These studies were of immense significance, serving first and foremost to demonstrate that grafts could be transferred and survive, a fact up to then had not been scientifically proven. Indeed, this possibility was dismissed by leading surgeons including Alfred Armand Velpeau who… asserted that "this strange operation will never be practiced." Furthermore, by comparing the results of grafts carried out under different conditions and different time intervals, Baronio succeeded in clarifying many of the biological aspects of the grafting and healing processes" (Santoni-Rugiu & Sykes, p. 123). Rare in such fine condition.

"*Degli Innesti Animali*, the most important work of Baronio, is a 78-page book, printed on thick paper, issued in 1804 in Milan by Tipografia del Genio. The book is rare and seldom appears on the market. It is divided into seven parts and includes three engraved illustrations. The first one shows the portrait of the Count Carlo Anguissola, to whom the work is dedicated, who sponsored the publication, although this is not mentioned, and provided animals and stables for making Baronio's experiments possible.

"In parts one and two, Baronio traces the origin of nasal reconstruction by quoting the Brancas of Sicily, Tagliacozzi, and the Maratha surgeons from India. Tagliacozzi's arm flap technique is extensively described, whereas the Indian forehead flap procedure is also illustrated by an engraved plate. Part three is devoted to transplantation of teeth in human beings, a procedure first reported by John Hunter; whereas part four explains the grafting of spur and "other animal parts into the cock's comb." In part five, Baronio reports the method of healing severed skin parts by using certain balms, as proposed by some charlatans. Part six, the most important section of the book, deals with the original Baronio studies on skin graft in a ram. He carried out three types of experiments on the farm of the estate of the Count Anguissola at Albignano, in the surroundings of Milan. In doing this, Baronio was supported by two Milanese surgeons G.B. Monteggia (1762-1815) and G.B. Palletta (1748-1832).

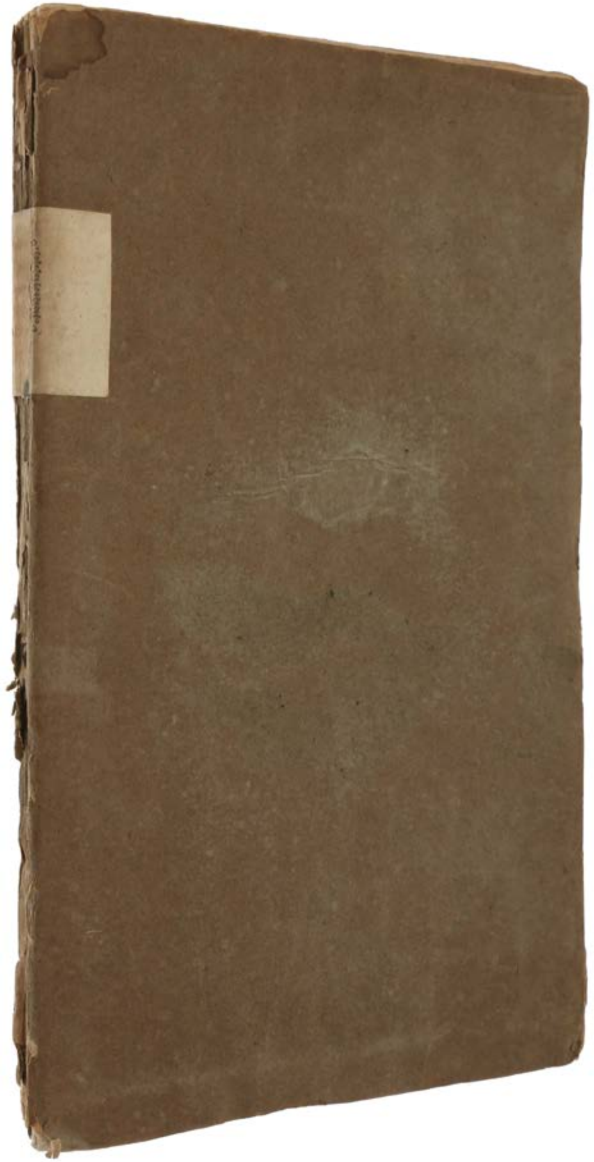
"In the first experiment, he excised a piece of skin from the dorsum of a ram and grafted it immediately on the opposite side without suturing it, but attaching it with an adhesive. After eight days the graft took perfectly. In the second experiment, on the same ram, the time lapse was 18 minutes. Baronio noticed that the graft had some difficulties in taking (Author's note: probably superficial necrosis at it occurs in full thickness skin grafts). In the third experiment, always on the same ram, the time lapse was longer and the graft did not take. He concluded that the shorter the time for transplantation the better in terms of survival rate. A beautiful engraved illustration of a ram with skin grafts positioned along its dorsum accompanies the text. Regrettably, Baronio was not aware that the thickness of the skin was the most important factor for skin graft survival. Very possibly in the third experiment he harvested the skin with the underlying adipose tissue, thus jeopardizing the graft take.

"In the last part of the book, part seven, he created wounds on different animals (goat, dog, sheep) and covered them with aluminum paste to isolate wounds from the air to avoid potential contamination. He noticed that this method facilitated wound healing.

"How did Baronio come to this great idea? In explaining the rationale for his investigations, he affirms "I want to verify tissue regeneration and healing process in wounds." Certainly a legacy of the period he spent at Pavia University with his teacher Lazzaro Spallanzani, who dedicated an entire life to studying regeneration and reproduction of animal parts …

"*Degli Innesti Animali*, has to be considered an epoch-marking work for several reasons. It is the only treatise on plastic surgery written two centuries after Tagliacozzi's *De Curtorum Chirurgia* (1597). It is the first experimental account on a successful autologous skin graft in an animal with a detailed report. It is the first example of purely scientific research in the history of plastic surgery. For this reason, the founding members of the Plastic Surgery Research Council established the image of the Baronio ram with skin graft over its dorsum as the emblem of the organization …

"Giuseppe Baronio was born in Milan (Northern Italy) in 1759. He studied Medicine at Pavia University, a historical city 20 miles south of Milan, as Milan had no University at that time. One of his teachers was Lazzaro Spallanzani (1729-99), Professor of Natural History, well known for his studies on regeneration and reproduction of animal parts. In 1780, Baronio graduated in Medicine and Philosophy with a thesis on regeneration of limbs in warm and cold-blooded animals and this may have had an influence on his future researches. The following year he became an intern physician at Ospedale Maggiore of Milan.



Due to his lack of interest in politics and particularly for the French government, which was dominating Milan in that period, he did not advance in his career. Although he tried numerous times to obtain a better position, he never succeeded. His applications were constantly rejected. The only duty he could obtain was an appointment as Physician of the Prisons.

"In 1807, he was affected by gout and his physical conditions deteriorated slowly. The following year he could have had the opportunity to apply for a professorship in physics at Bologna University, but he was advised by some of his friends and colleagues against submitting the application, due to his poor health. Three years later, in 1811, Baronio died aged 52, completely forgotten. He never married.

"Baronio had numerous scientific interests and published his observations extensively. His works were recognized for their scientific value, so it was possible for him to become a member of various scientific societies. He wrote on the treatment of rabid dog bites, on the regeneration of bone and brain in fowl, on the regeneration of the Achilles tendon in the human being, on the superiority of the San Pellegrino spring waters, on electricity. He was a close friend of Alessandro Volta (1745-1827), Professor of Natural Philosophy at Pavia University, with whom he conducted some experiments on electrical phenomena. He described a new galvanic pile composed of vegetable materials only, capable of producing contractions in a frog" (Mazzola).

Garrison-Morton 5736; Gnudi & Webster, *The Life and Times of Gaspare Tagliacozzi*, p. 328; Zeis Index 301 & 422; Maltz, Evolution of Plastic Surgery, p 221; Bankoff, *The Story of Plastic Surgery*, p. 42; Belloni, 'Dalle "Riproduzioni animali" di L. Spallanzani agli "Innesti animali" di G. Baronio' in *Physis*, III, 1961, pp. 37-48; Hirsch, I, 243. Mazzola, 'Giuseppe Baronio and the origins of skin grafting,' International Society of Aesthetic Plastic Surgery (isaps.org/blog/2013/10/30/giuseppe-baronio-origins-free-skin-grafting). Santoni-Rugiu & Sykes, *A History of Plastic Surgery*, 2007. Waller 686. Wellcome II, 103.

INSCRIBED PRESENTATION COPY

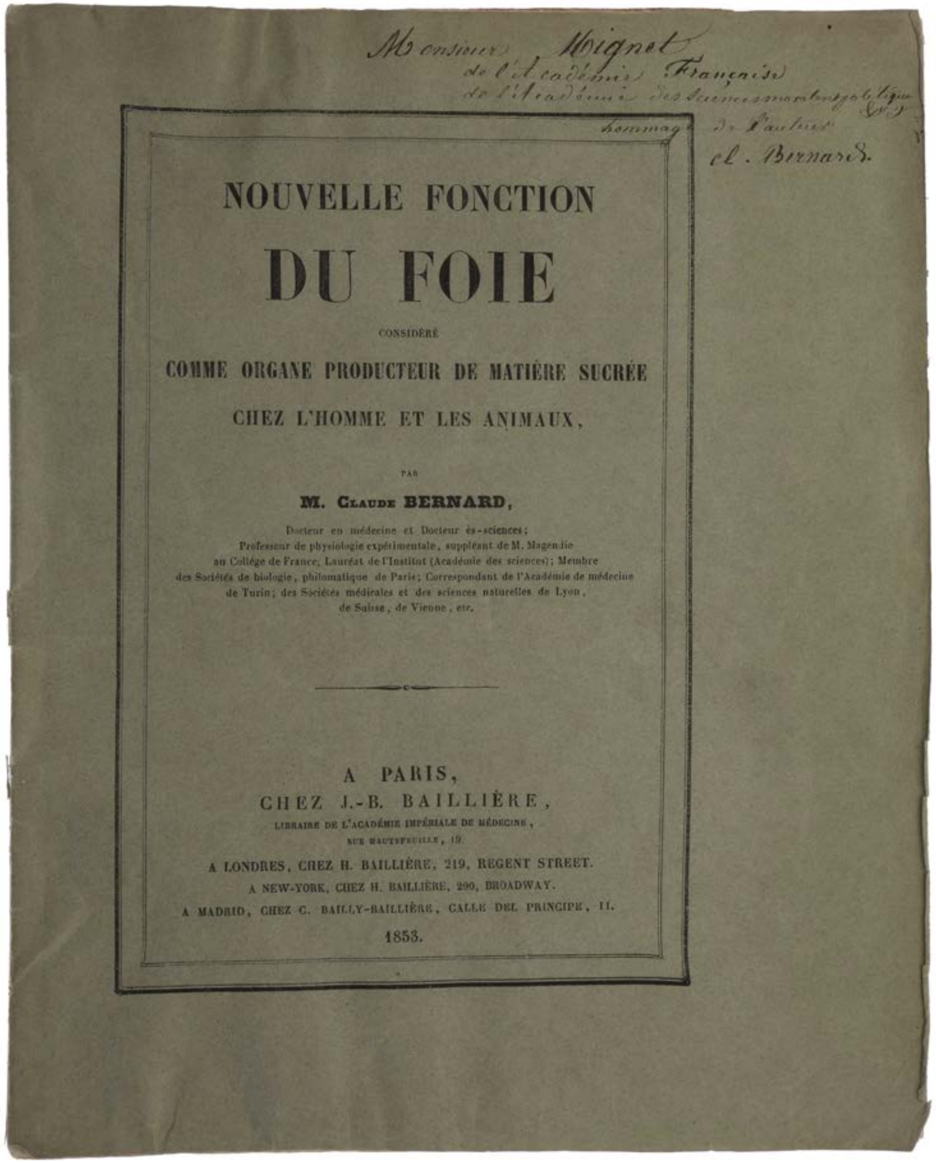
Grolier/Horblit, *One Hundred Books Famous in Science*, 11a.

BERNARD, Claude. *Nouvelle fonction du foie, considerée comme organe producteur de matière sucrée chez l'homme et les animaux.* Paris: J.-B. Baillière, 1853.

$25,000

4to (277 x 223 mm) 92, [2]pp. Wood-engraved text illustration. Original gray-green printed wrappers, spine a little worn; boxed. Light foxing but a fine and totally unrestored copy in its original condition. Presentation copy, inscribed by Bernard to François-Auguste Mignet (1796-1884) on the front wrapper: "Monsieur Mignet de l'Académie Française de l'Académie des Sciences morales et politiques &c. &c. homage de l'auteur Cl. Bernard."

First edition, monograph issue, of Bernard's doctoral thesis, a "remarkable exposition of the glycogenic function of the liver" (Horblit – referring to this issue). This is an outstanding presentation copy, inscribed by Bernard to François-Auguste Mignet (1796-1884) on the front wrapper: "Monsieur Mignet de l'Académie Française de l'Académie des Sciences morales et politiques &c. &c. homage de l'auteur Cl. Bernard." "As much through concrete discoveries as through the creation of new concepts, the work of Claude Bernard constitutes the founding of modern experimental physiology. His scientific career started with two series of precise and well delimited researches: on the one hand, the chemical and physiological study of gastric digestion, and on the other, experimental sections of nerves" (DSB). Bernard's doctoral thesis on the gastric juice published the first results of his experiments on the artificial ingestion of food substances. It linked two important discoveries: first,



that when sucrose (a complex sugar) is injected into the bloodstream, it is eliminated in the urine, while injected glucose (a simple sugar) is retained in the organism; and second, that gastric juice transforms sucrose into physiologically usable sugar; i.e., one that, when injected, is not eliminated. This led to the realization that glucose and the other monosaccharides represent the only physiologically useful sugars in the animal organism, and that gastric juice changes all other forms of carbohydrate into assimilable physiological sugar" (Norman).

Provenance: Bernard elegantly inscribed this copy of his thesis to François-Auguste Mignet, a noted French liberal journalist, playwright and historian. As Bernard's beautifully penned inscription states, Mignet was a member of both the Académie Française, France's most august and exclusive learned society, and the Académie des Sciences Morales et Politiques, another of the five academies of the Institut de France. The Académie Française consists of forty members, known as immortels (immortals). New members are elected by the members of the Académie itself. Académicians hold office for life. As a member of both societies, Mignet represented the pinnacle of the French establishment in the arts, letters, and science. Bernard, who had initially aspired to a literary career, and retained a strong literary bent in his writings, was himself eventually appointed to the Académie Française, taking his seat along with other luminaries, including Mignet, in 1868. This is an extremely rare honor for a physician, and perhaps the highest academic honor that France offers.

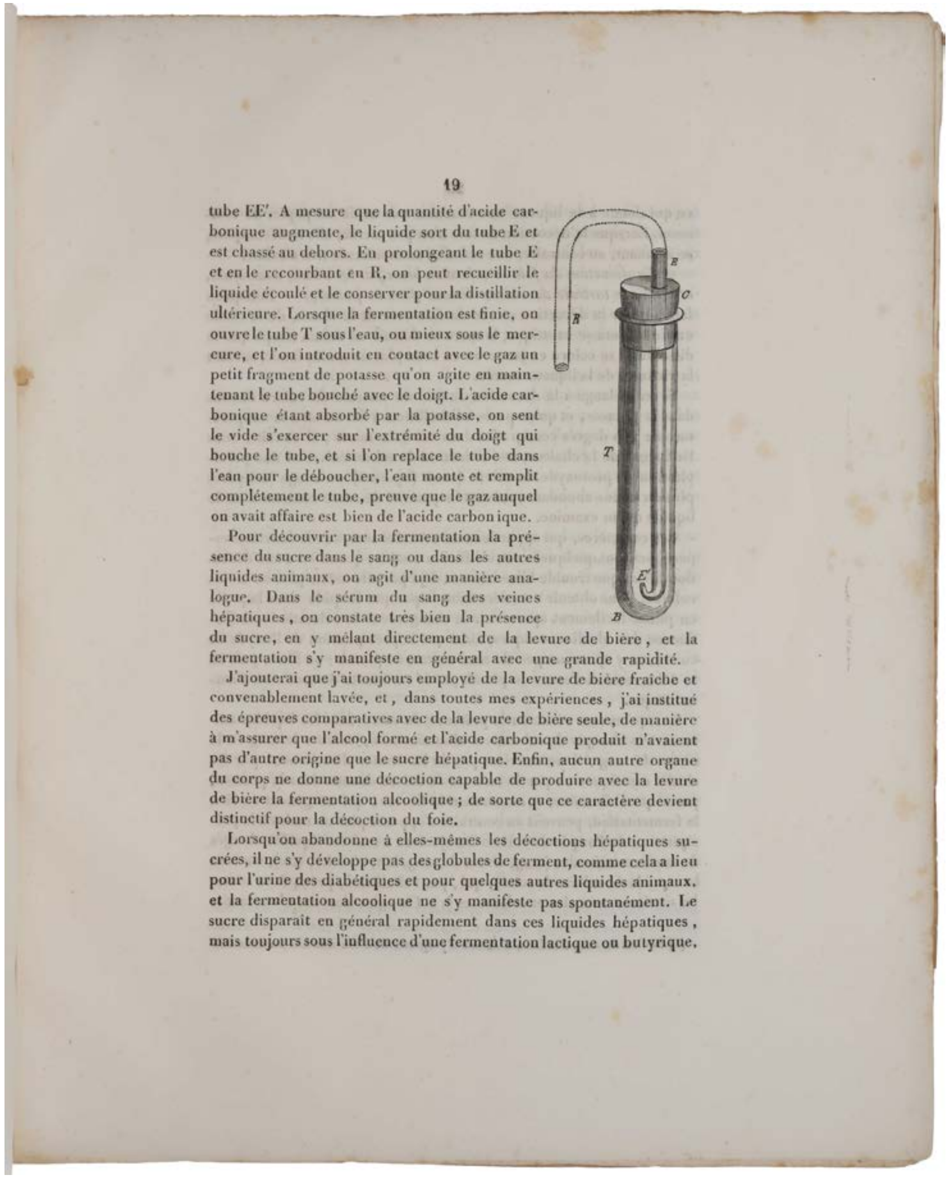
"Bernard's most impressive discoveries in the field of digestion proper concern the functions of the pancreas, especially the importance of pancreatic juice in the digestion and absorption of fats. Two observations showed him the road to follow. First, he had noted that the urine of herbivores is alkaline, while that of carnivores is acid. Bernard showed that fasting brought about acidity of the urine in herbivores (they lived off their body fat) and that man and carnivorous animals put on a vegetarian diet excreted alkaline urine (1846). Bernard then applied himself to the comparative study of the phenomena of digestion in both carnivores and herbivores. He initiated experiments by which to follow the changes in the chyle in the various parts of the intestinal tract of a dog and a rabbit. Thereby he noted that the absorption of fat by the chyliferous vessels occurred at a rather considerable distance from the pylorus in the rabbit and immediately at the beginning of the duodenum in the dog. Bernard discovered that this difference coincided with an anatomical difference at the point of discharge of the pancreatic juice into the intestine. Thus the role of the pancreas in the first phase of fat metabolism was demonstrated ("Du sucpancreéatique et de son rôle dans les phénomènes dela digestion," 1849). In order to collect pancreatic juice in its pure state and to study the regulation of its secretion, Bernard conceived and made the temporary pancreatic fistula, later improved by Pavlov. Bernard found that pancreatic juice acted on fats by a saponification process.

"In studying the digestive properties of the gastric and pancreatic Juices. Bernard did not intend to restrict himself to a narrow view of the problem of local digestion alone, or of the decomposition of food in the gastrointestinal tract. Although he studied intensively the chemical changes in food exposed, both in *vivo* and *in vitro*, to saliva, gastric Juice, or pancreatic juice, this was to him only one, fragmentary aspect of a vast research subject. What interested him above all was what happened to the food in the animal organism, from its entry until its total assimilation or excretion. Thus the horizon of Bernard's research kept widening and, by going beyond the limits of simple "digestion," it made its true object "nutrition" (or, in modern terminology, "metabolism").

"Never wavering, Bernard was to advance beyond the then prevailing notions of "animal statics" and to set up the first milestones on the road to the understanding of intermediate metabolism. To begin with, Bernard accepted the theory of his teachers that animals are incapable of synthesizing sugar, fat, and albumin. These three substances would always originate in plants, and their percentage in the blood would vary and would depend essentially on the food consumed. Nutrition would consist of three stages: digestion, transport of digested substances, and chemical in corporation or combustion.

"Then he discovered that the alleged transport of absorbed substances is an extremely complicated process, more chemical than physical, more a series of transformations than a series of displacements. He also understood that nutrition is a phenomenon of synthesis as much as it is an analytical process. If food intake is an intermittent process, "nutrition" (in the sense of metabolism) is continuous and is stopped only by death. "Nutrition" is also indirect: prior to being integrated into the tissues, the organic alimentary substances must be broken down to a certain degree and then recombined. In formulating and demonstrating these ideas, Bernard was able to talk with pride of his work on nutrition: "I am the first one to have studied the intermediary stage. The two extremes were known and the rest was accomplished by means of the physiology of probability."

"In his thesis on gastric juice (1853), Bernard published, marginally to the principal subject, the first results of his experiments on the ingestion of food substances by other than natural means. His thesis relates two important discoveries: (1) if so-called "type I" sugar (sucrose) is injected directly into the blood, it is eliminated by the kidneys, while the so-called "type 2" sugar (glucose) is retained in the organism; (2) gastric juice transforms sucrose into assimilable sugar, that is, sucrose exposed to the action of gastric juice and then injected into the blood no longer appears in the urine. "Type 2" sugars (in modern terminology, sugars of the monosaccharide group) represent the only "physiological" form of carbohydrates in the animal organism. Gastric juice changes all other forms of carbohydrates into assimilable physiological sugar" (DSB).


19

tube EE'. A mesure que la quantité d'acide carbonique augmente, le liquide sort du tube E et est chassé au dehors. En prolongeant le tube E et en le recourbant en R, on peut recueillir le liquide écoulé et le conserver pour la distillation ultérieure. Lorsque la fermentation est finie, on ouvre le tube T sous l'eau, ou mieux sous le mercure, et l'on introduit en contact avec le gaz un petit fragment de potasse qu'on agite en maintenant le tube bouché avec le doigt. L'acide carbonique étant absorbé par la potasse, on sent le vide s'exercer sur l'extrémité du doigt qui bouche le tube, et si l'on replace le tube dans l'eau pour le déboucher, l'eau monte et remplit complétement le tube, preuve que le gaz auquel on avait affaire est bien de l'acide carbonique.

Pour découvrir par la fermentation la présence du sucre dans le sang ou dans les autres liquides animaux, on agit d'une manière analogue. Dans le sérum du sang des veines hépatiques, on constate très bien la présence du sucre, en y mêlant directement de la levure de bière, et la fermentation s'y manifeste en général avec une grande rapidité.

J'ajouterai que j'ai toujours employé de la levure de bière fraiche et convenablement lavée, et, dans toutes mes expériences, j'ai institué des épreuves comparatives avec de la levure de bière seule, de manière à m'assurer que l'alcool formé et l'acide carbonique produit n'avaient pas d'autre origine que le sucre hépatique. Enfin, aucun autre organe du corps ne donne une décoction capable de produire avec la levure de bière la fermentation alcoolique ; de sorte que ce caractère devient distinctif pour la décoction du foie.

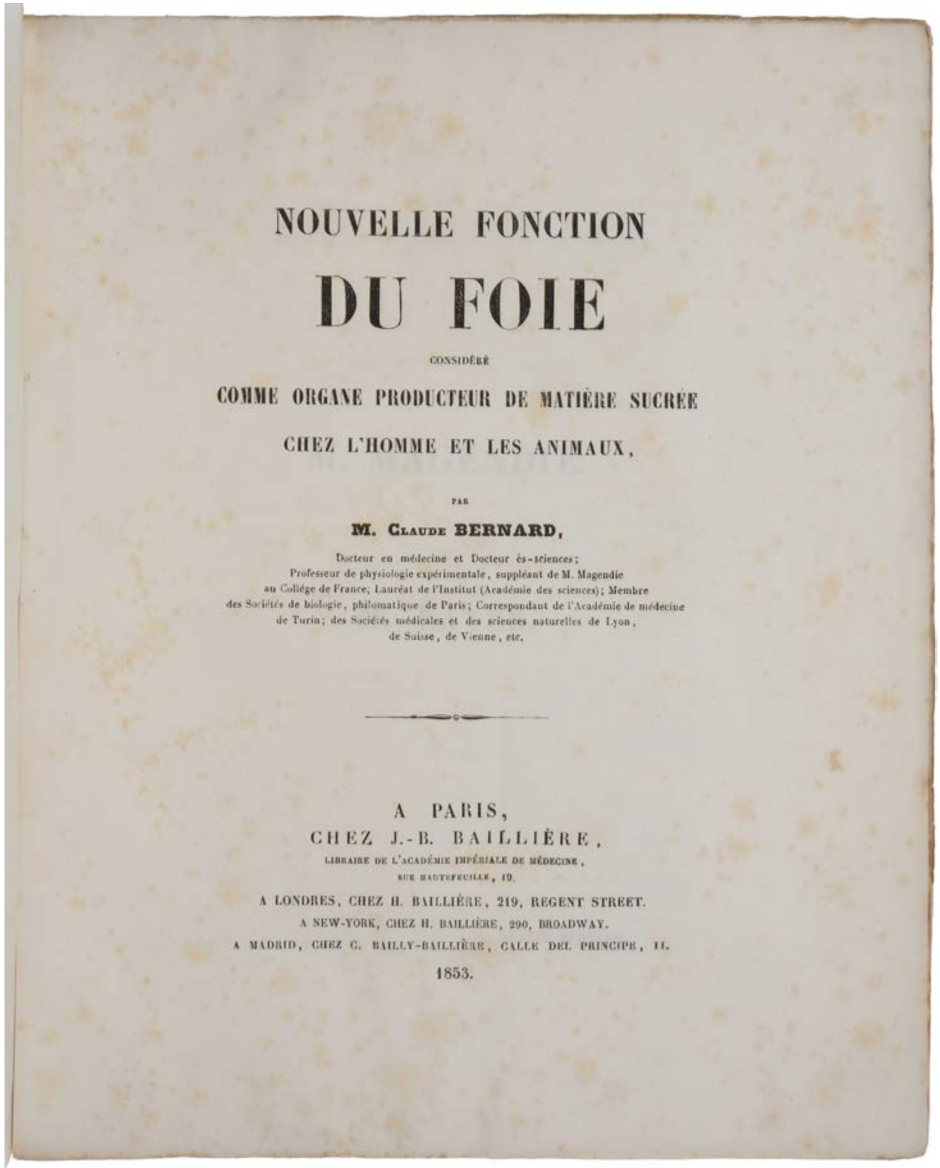
Lorsqu'on abandonne à elles-mêmes les décoctions hépatiques sucrées, il ne s'y développe pas des globules de ferment, comme cela a lieu pour l'urine des diabétiques et pour quelques autres liquides animaux, et la fermentation alcoolique ne s'y manifeste pas spontanément. Le sucre disparait en général rapidement dans ces liquides hépatiques, mais toujours sous l'influence d'une fermentation lactique ou butyrique.

"Claude Bernard (1813-78) is regarded as the most important contributor to experimental physiology in the nineteenth century. Born in St. Julien, a village in the wine country of Beaujolais, Bernard's early education was humanistic rather than scientific. He at one time aspired to be a playwright, but when his efforts met with discouragement from the critic Saint Mare-Girardin, he entered the Faculté de Médecine in Paris in 1834. While still a student, Bernard came under the influence of the famous physiologist François Magendie, working as Magendie's assistant from 1841 to 1844 and learning from him the use of animal vivisection for physiological experimentation. It was under Magendie's influence that Bernard performed some of his most important researches into the physiology of digestion and nerves.

"Bernard's contributions are so important and so numerous that it is difficult to select one work to represent them. His major physiological discoveries included the role of the pancreas in digestion, the glycogenic function of the liver, the vasomotor innovation, and the effects of curare on neuromuscular transmission. He also introduced seminal theoretical concepts, such as that of 'internal secretion,' and was the author of the landmark medico-philosophical work, *Introduction à l'étude de la médecine expérimentale*, in which he analyzed the philosophical basis of the scientific method and its application to the study of living beings" (Grolier-Horblit).

Bernard's doctoral thesis was also issued, by Martinet, probably a few months earlier than the monograph issue, to meet the formal requirements of the degree. The Martinet issue is extremely rare.

Norman 200; Grolier, *One Hundred Books Famous in Medicine*, 67A; Horblit, *One Hundred Books Famous in Science*, 11A.


NOUVELLE FONCTION

DU FOIE

CONSIDÉRÉ

COMME ORGANE PRODUCTEUR DE MATIÈRE SUCRÉE

CHEZ L'HOMME ET LES ANIMAUX,

PAR

M. CLAUDE BERNARD,

Docteur en médecine et Docteur ès-sciences;
Professeur de physiologie expérimentale, suppléant de M. Magendie
au Collége de France; Lauréat de l'Institut (Académie des sciences); Membre
des Sociétés de biologie, philomatique de Paris; Correspondant de l'Académie de médecine
de Turin; des Sociétés médicales et des sciences naturelles de Lyon,
de Suisse, de Vienne, etc.

A PARIS,
CHEZ J.-B. BAILLIÈRE,
LIBRAIRE DE L'ACADÉMIE IMPÉRIALE DE MÉDECINE,
RUE HAUTEFEUILLE, 19.
A LONDRES, CHEZ H. BAILLIÈRE, 219, REGENT STREET.
A NEW-YORK, CHEZ H. BAILLIÈRE, 290, BROADWAY.
A MADRID, CHEZ C. BAILLY-BAILLIÈRE, CALLE DEL PRINCIPE, 11.
1853.

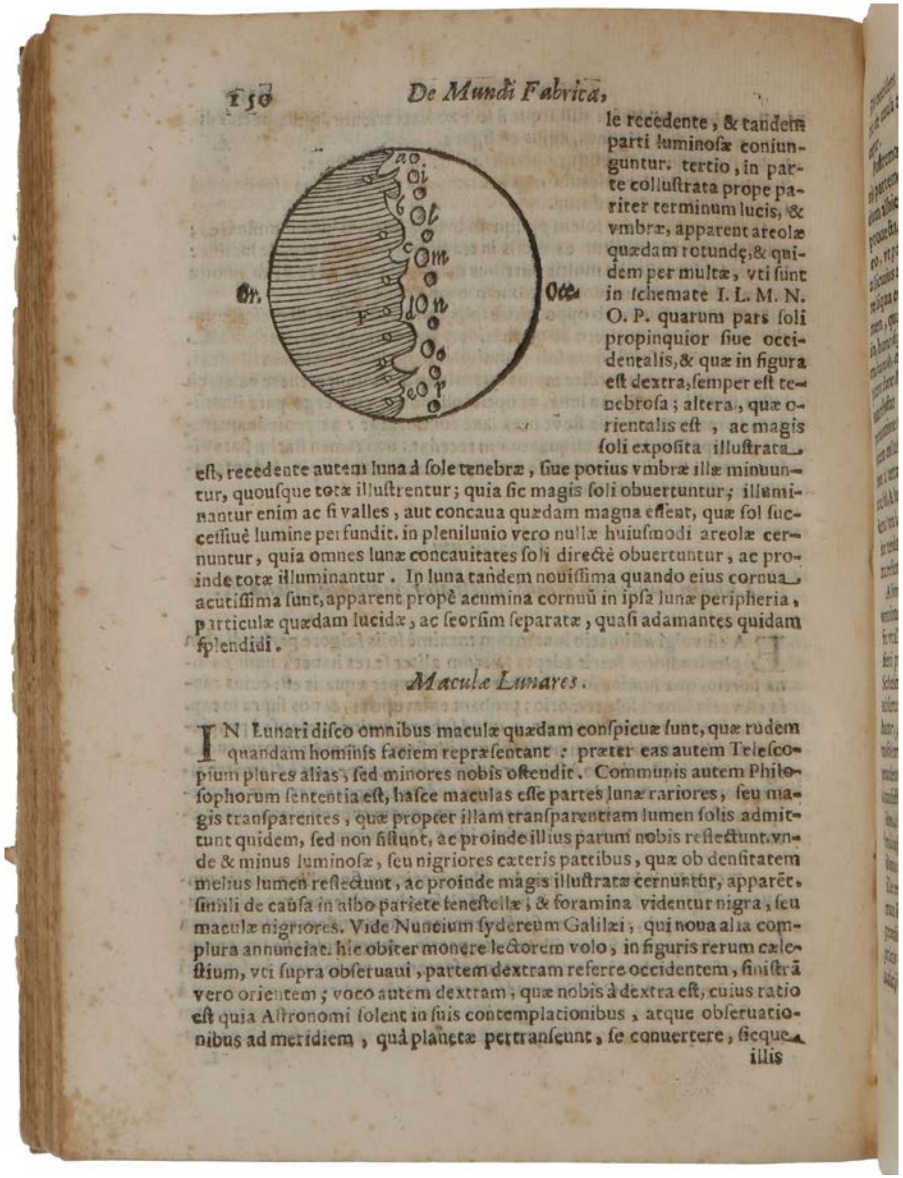
THE DISCOVERIES OF TYCHO BRAHE, KEPLER, GALILEO, COPERNICUS

BIANCANI, Giuseppe [Josephus BLANCANUS]. *Sphaera mundi seu Cosmographia, demonstrativa ac facili methodo tradita, in qua totius mundi fabrica, una cum novis Tychonis, Kepleri, Galilaei, aliorumque astronomorum adinventis continetur. Accessere: I. Brevis introductio ad Geographiam. II. Apparatus ad mathematicarum studium. III. Echometria, id est Geometrica traditio de Echo.* Bologna: Sebastiano Bonomi for Geronimo Tamburini, 1620.

$17,500

4to (220 x 160 mm), pp. [xxiv], 445, [1], with volvelle at p. 227 and one large folding plate. Title printed in red and black, numerous woodcut diagrams in text. Contemporary vellum, manuscript title along spine, remains of ties. Inner front hinge starting, light spotting throughout. In all very fine and completely untouched copy.

First edition of Biancani's rare Jesuit treatise on astronomy which "brought Clavius's *Sphaera* up to date, incorporating in it the discoveries of Galileo, Kepler, and others, and enthusiastically endorsed the advances being made in astronomy … [Biancani] defended Galileo's stand regarding mountains on the moon—which elicited a long letter from Galileo to another Jesuit astronomer, Christopher Grienberger, in which Galileo states that he is "infinitely obliged" to Biancani. Unfortunately this student of Clavius got too enthusiastic in Galileo's cause, and his remaining writings were never passed for publication by the censors of his Order" (Wallace 2003, pp. 108-9). "In 1620 there appeared an important treatise on astronomy which consistently and repeatedly used the word *telescope*. This was the *Sphaera mundi* of Josephus Blancanus, or Giuseppe



150 *De Mundi Fabrica,*

le recedente, & tandem parti luminosæ coniunguntur. tertio, in parte collustrata prope pariter terminum lucis, & vmbræ, apparent areolæ quædam rotundę, & quidem per multæ, vti sunt in schemate I. L. M. N. O. P. quarum pars soli propinquior siue occidentalis, & quæ in figura est dextra, semper est tenebrosa; altera, quæ orientalis est, ac magis soli exposita illustrata est, recedente autem luna à sole tenebræ, siue potius vmbræ illæ minuuntur, quousque totæ illustrentur; quia sic magis soli obuertuntur; illuminantur enim ac si valles, aut concaua quædam magna essent, quæ sol successiuè lumine perfundit. in plenilunio vero nullæ huiusmodi areolæ cernuntur, quia omnes lunæ concauitates soli directè obuertuntur, ac proinde totæ illuminantur. In luna tandem nouissima quando eius cornua acutissima sunt, apparent propè acumina cornuũ in ipsa lunæ peripheria, particulæ quædam lucidæ, ac seorsim separatæ, quasi adamantes quidam splendidi.

Maculæ Lunares.

IN Lunari disco omnibus maculæ quædam conspicuæ sunt, quæ rudem quandam hominis faciem repræsentant: præter eas autem Telescopium plures alias, sed minores nobis ostendit. Communis autem Philosophorum sententia est, hasce maculas esse partes lunæ rariores, seu magis transparentes, quæ propter illam transparentiam lumen solis admittunt quidem, sed non sistunt, ac proinde illius parum nobis reflectunt. vnde & minus luminosæ, seu nigriores cæteris partibus, quæ ob densitatem melius lumen reflectunt, ac proinde magis illustratæ cernuntur, apparẽt, simili de causa in albo pariete fenestellæ, & foramina videntur nigra, seu maculæ nigriores. Vide Nuncium sydereum Galilæi, qui noua alia complura annunciat. hic obiter monere lectorem volo, in figuris rerum cælestium, vti supra obseruaui, partem dextram referre occidentem, sinistrã vero orientem; voco autem dextram, quæ nobis à dextra est, cuius ratio est quia Astronomi solent in suis contemplationibus, atque obseruationibus ad meridiem, quà planetæ pertranseunt, se conuertere, sicque illis

Biancani … [He] was the first to employ exclusively and repeatedly the term 'telescope' in an extended treatise. More importantly, however, is the fact that his example and influence undoubtedly hastened general acceptance and use of the term" (McColley, pp. 364-5). "In present-day literature [Biancani] is sometimes depicted as an opponent of Galileo and the new science, but his exchanges in the unpublished sources with several Jesuit censors over his two main books show that quite the opposite was the case. These documents clearly reveal a split within the Jesuits at that time between the philosophers of orthodox Aristotelian persuasion and a group of mathematicians and astronomers, including Biancani, who advocated the autonomy of astronomy and mathematics and a more quantitative and descriptive approach, which resulted in some quite anti-Aristotelian views. Thus although he disputed some of Galileo's calculations, Biancani agreed that the surface of the Moon was mountainous and not a smooth sphere; he also maintained that the heavens were composed of fluid matter, not solid spheres, another anti-Aristotelian view" (Blackwell, pp. 148-9). Blackwell even sees Biancani's book as precipitating, via Grienberger's support, "the beginning of the end of classical Jesuit science" (p. 152). Biancani was perhaps the first to suggest, in this book, that comets may return (Thorndike VII, p. 51). The third appendix of the book, *Echometria*, is devoted to the study of acoustics. "Giuseppe Biancani can be considered as the founder of geometrical acoustics (1620), a theory that – from the time of Athanasius Kircher until at least the end of the 18th century – was traditionally used to explain how speaking- and hearing-trumpets worked" (Barbieri, p. 156). Pages 387-414 contain a very interesting bibliography of books in the mathematical sciences (in their widest sense) including astronomy, physics, perspective, music, mechanics, etc. ABPC/RBH list just one copy (and that with a defective title page).

"Giuseppe Biancani, the author of the *Sphaera mundi* (1620), tied his book to Clavius' farewell injunction: 'in view of what Galileo diligently and accurately set forth in his *Nuncius sidereus*, astronomers should see how the celestial orbs are to be constituted so that these phenomena can be accounted for.' Biancani's solution, worked out partly in correspondence with Grienberger, was to adopt Tycho's system and justify it and other statements about the constitution of the world by appeal to 'the best astronomers' or 'the common opinion of astronomers.' The closer to physics, the more diffident the statements. Are the stars carried by a rigid firmament, like rivets in steel? Probably. Do the planets move through the heavens like fish in the sea or birds in the air? '*Incompertum mihi est*', I do not know.' Under this cover, Biancani delivered a very good textbook, filled with information indifferent to the choice of world systems (calendars, eclipses) and descriptions of the new phenomena – the mountainous moon, spotted sun, horned Venus, companions of Jupiter, bumps of Saturn. The sun sits in the middle of the other planets, except for the moon, as if their Lord, "according to the common opinion of astronomers.' Copernicus, Tycho, and Kepler all teach that the planets circle the sun as the moon does the earth. The statement was strictly true and patently false, a perfect, even a Jesuitical equivocation, since the earth is a planet to Copernicus and a unique something else to Tycho. Biancani ended his celestial survey with comets. Again he follows Tycho in placing them in solar orbit above the moon. The arrangement agreed with observations by Jesuit astronomers in many parts of Germany and Italy of the brilliant comet first seen in late November 1618" (Heilbron, p. 232).

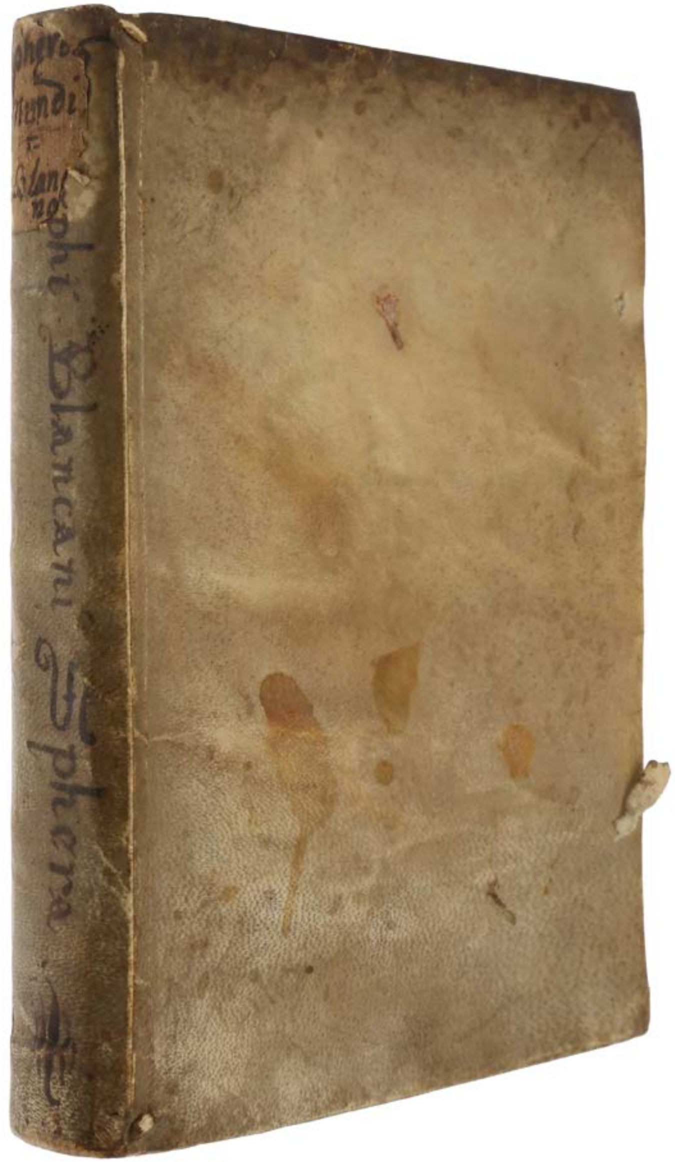
Biancani had been censured by the Jesuits for his astronomical teachings even before the condemnation of Copernicanism in March 1616. The initial area of dispute with the censors occurred over Biancani's *Aristotelis loca mathematica* (1615), a systematic and highly critical analysis of the passages in Aristotle pertaining to mathematics and its use in the sciences. "In the meantime Biancani had written another book for which he is more famous and which was directly devoted to astronomy, his *Sphaera mundi, seu cosmographia*. This book must have been completed in penultimate draft form sometime late in 1615, and then submitted to the censors as usual.

"Of the numerous reports from the censors on this book, by far the most significant was writtem by Grienberger, a close friend of Biancani, and who, judging from his comments, must have been personally in agreement with him and also anguishing over the same problems of intellectual freedom. On the second page of his long and undated censure appear the following most significant remarks.

'He [Biancani] says on page 91b, line 14, that astronomers, whom he names, and especially Copernicus, use diagrams in determining and explaining celestial motions, and they call them hypotheses. But in other places Copernicus does not speak hypothetically, but definitely tries to prove that the system of the world is such as he has imagined it to be, and as a result he tries to refute arguments which assert the contrary. This is the main reason why his book has by recent decree been prohibited until corrected, which I understand has been done although it has not yet been promulgated …'

"Grienberger's discomfort with this dramatic turn of events [the decree against Copernicus] and his sympathy for Biancani's dilemma become more evident as his report continues. He points out that Aristotle's view that the heavens are inalterable is refuted by many changes observed in the heavens in recent years … At the end he adds a plea for intellectual freedom written at a moment of great pressure, but which unfortunately was fated to go unheard.

'A new *Cosmographia* seems to be necessary because the old one has been changed a great deal in our day and many embellishments have been added to it. But the question has been raised as to whether it is proper for us Jesuits to do this. It seems to me that the time has now come for a greater degree of freedom of thought to be



given to both mathematicians and philosophers on this matter, for the liquidity and corruptibility of the heavens are not absolutely contrary to theology or to philosophy and even much less to mathematics … It seems that he [Biancani] has not exercised his talents sufficiently in writing the *Cosmographia*. But I am quite willing to excuse him about this. For up to now his hands have been tied, as have ours. Thus he has digressed into many less important topics when he was not allowed to think freely about what is required.'

"This unheeded plea may well be the beginning of the end of classical Jesuit science. Although Grienberger, the successor to Clavius, was a major player in the scientific circles of his day, he never wrote a major treatise on science. One wonders whether this was the reason. Biancani's book waited four years before it would be published. The language was softened, but all the new ideas and theories were still reported for the reader's information, although in a neutral vein. When Biancani reached the critical section of his book, 'On the Motion of the Earth,' he reviewed all the available theories, ancient and modern. Referring specifically to the heliocentric views of Copernicus, Kepler, and Gilbert, he comments:

'By this hypothesis they not only save all the appearances but also think that they have easily answered the arguments of all the adversaries. That this opinion is false and should be rejected (even though it is established by better proofs and arguments) has nevertheless become much more certain in our day when it has been condemned by the authority of the Church as contrary to Sacred Scripture.'

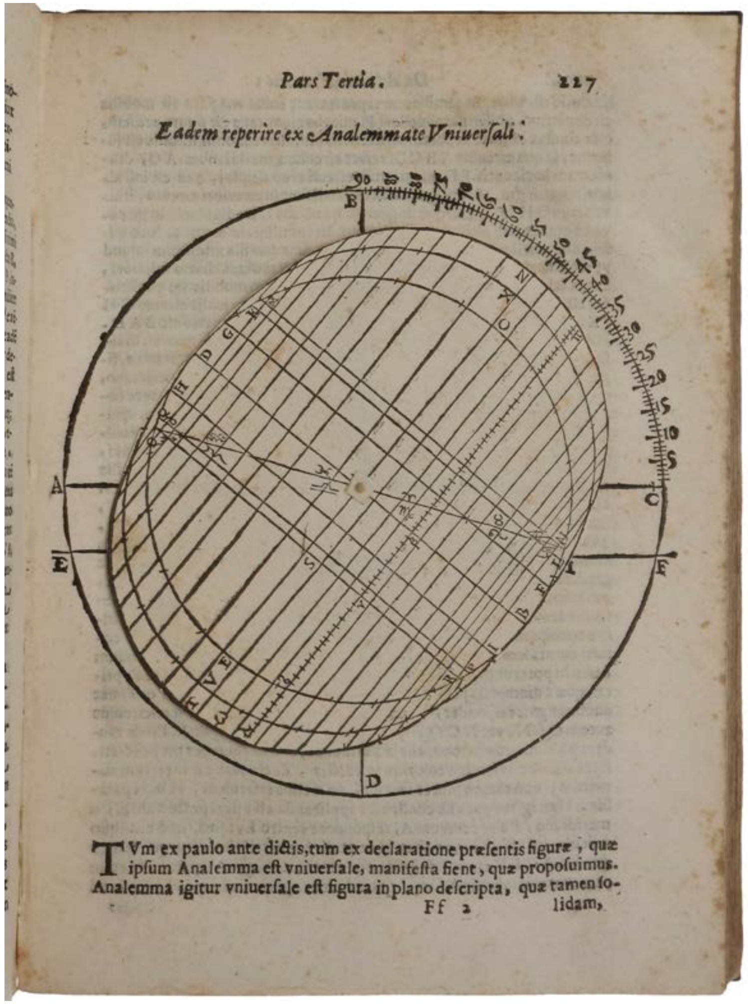
"The dilemma of the Jesuit scientists could hardly be more explicit: truth or obedience. Copernicanism is to be rejected on grounds of religious authority, even though it is "established by better proofs and arguments" than its rivals … But despite Biancani's struggles for precisely the opposite results, it has been his fate in history to be identified as an enemy of Galileo and the new science. He deserved much better treatment from both sides" (Blackwell, pp. 151-3).

Biancani's Sphaera is completed by three appendices on topics only loosely related to cosmology. The discussion of the origin of mountains in the first of these appendices influenced Bernhardus Varenius in his *Geographia generalis* (1650), the founding work of geography as a branch of applied mathematics (later revised by Isaac Newton). "In his lengthy treatment of the original earth, Varenius followed the *Sphaera mundi* (1620) of Joseph Blancanus, though he also introduced ideas that had come into thinking during the intervening decades. Few writers had been as consistent as Blancanus in their belief in the symmetry and proportion God had given the earth, in which the highest mountain exactly corresponded to the lowest depth of the sea. The original earth had emerged on the third day as a smooth sphere. Had it been affected only by natural law, it would have remained in that form, but the miraculous hand of God had scooped out the channel of the sea and created the Alps and other mountains. If left to its own nature, the world would perish as it had begun, in water. But God would not permit such natural metamorphosis: the world would perish by fire. Following Blancanus, but improving upon him in various ways, Varenius found the origin of terrestrial mountains in water. To the general reader, particularly the poet, the most impressive parts of the *Geographia generalis* were sections in which Varenius sent his imagination over the globe, calling a catalogue of the ranges and peaks in every continent, as they rise, sometimes in majesty, sometimes in terror. Theology still clouded Varenius' eyes to some extent in his mountain-passages, though even the three decades since Blancanus had made him basically more scientific" (*Dictionary of the History of Ideas*, Vol. 3, pp. 256-7).

The second appendix, *Apparatus ad mathematicarum stadium*, that is, a preparation for learning and advancing the mathematical disciplines, is clearly addressed to Biancani's students. In this he indicates that mathematics, like other sciences, can be divided into branches that are speculative and practical, pure and intermediate. The speculative branches are six in number, two of which – geometry and arithmetic – are pure, and the remainder of which, *perspectiva* or *optica* (including *catoptrica* and *dioptrica*), *mechanica*, *musica*, and *astronomia* – are intermediate. Biancani incudes a bibliography of works in each of these areas. This is followed by a discussion of the nature of mathematical proofs. Biancani "characterizes mathematical resolution not as a general method applicable to all the sciences and arts, but rather as a special method that assists one in finding geometrical demonstrations quickly and easily. Earlier he had pointed out that geometers use basically two methods in their proofs, one direct, that of ostensive demonstration, the other indirect, that of reduction to the impossible; at this point he turns to explaining how resolution and composition are useful for uncovering either … He then explains what Euclid means by them … Blancanus concludes his explanation with the remark that it is easier to see this method in use than it is to describe precepts for its use, and refers the reader to Euclid, Apollonius, Archimedes, and Pappus for clear exemplifications of it" (Wallace 1992).

In the third appendix, *Echometria*, Biancani initiates the science of acoustics. "Towards the end of the 16th century, with the rediscovery of conic sections and burning glasses of Archimedes, the propagations of sound was associated – for the first time – with that of light rays. According to the Jesuit Giuseppe Biancani (1620), Ettore Ausonio, a doctor and mathematician working in Venice in the second half of the 16th century, was the first to hypothesize the existence – in burning glasses – of a dualism between light and sound … However, none of Ausonio's writings on the subject have survived …

"These speculations on the sound-light dualism, however, lay forgotten until 1620 when they were taken up and amplified in the *Echometria* of Biancani, who connections and their influence on his science,' pp. 99-126 in Feingold (ed.), *Jesuit Science and the Republic of Letters*, 2003.

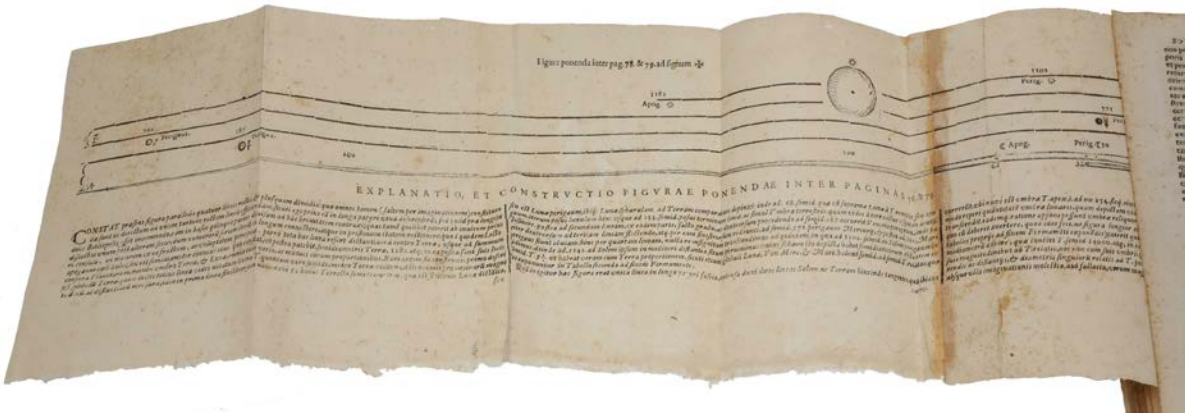


can therefore be considered the founder of geometrical acoustics. In fact, it was this work that inspired the first applications founded on this schematization: applications that above all involved architectural acoustics and certain windpipes. Biancani himself defines his *Echometria* as a 'new part of the mathematical sciences', or more precisely, one could add, of the *mathesis mixta*. In fact, this short treatise can be considered the first to be entirely devoted to this new discipline. Moreover, it was precisely from this schematization that the discipline subsequently developed until it assumed the name of 'acoustics'" (Barbieri, pp. 161-2).

Giuseppe Biancani (1566-1624) entered the novitiate of the Society of Jesus on 4 October 1592. He studied mathematics under Christopher Clavius at the Collegio Romano in Rome; between 1596 and 1599, he was studying at the Jesuit College in Padua. Galileo had been appointed professor of mathematics at the University of Padua in 1592. In a letter he wrote on 14 June 1611, Biancani referred to his friendship with Galileo: 'I love and admire Galileo, not only for his rare learning and invention, but also for the old friendship that I had with him in Padua, where I was overcome by his courtesy and affection, which bound me to him.' In the early 1600s Biancani, having completed the long training period for the Jesuit order, went to the Jesuit College in Parma where he taught mathematics for the remainder of his career. During his final four years at Parma, from 1620 to 1624, Biancani taught Giovanni Battista Riccioli who mentions him with gratitude and admiration and later named a lunar crater after him.

Copies of this work are described in bibliographies as having one, two or even three plates. The present copy, with one folding plate is complete. Three plates were originally printed on two folded sheets. On the sheet with two plates, one plate was intended to be cut out and mounted as a volvelle on p. 227; the other was to be joined with the plate on the other sheet to make one large folded plate, which was too long to be printed on a single sheet. *Sphaera mundi* was republished in 1630, 1635 and 1653; the last two editions have appended a posthumous work of Biancani's, *Novum instrumentum ad horologia describenda*, which describes his method for constructing a sundial.

Riccardi I, 127; Carli-Favaro 83; Cinti 95 (third ed.); *Jesuit Science in the Age of Galileo* 5. Barbieri, 'The Jesuit acousticians and the problem of wind instruments (c. 1580-1680),' *Analecta Musicologica* 38 (2007), pp. 155-204. Blackwell, *Galileo, Bellarmine, and the Bible*, 1991. Heilbron, *Galileo*. McColley, 'Josephus Blancanus and the Adoption of Our Word 'Telescope',' *Isis*, Vol. 28 (1938), pp. 364-365. Wallace, *Galileo's Logic of Discovery and Proof*, 1992. Wallace, 'Galileo's Jesuit



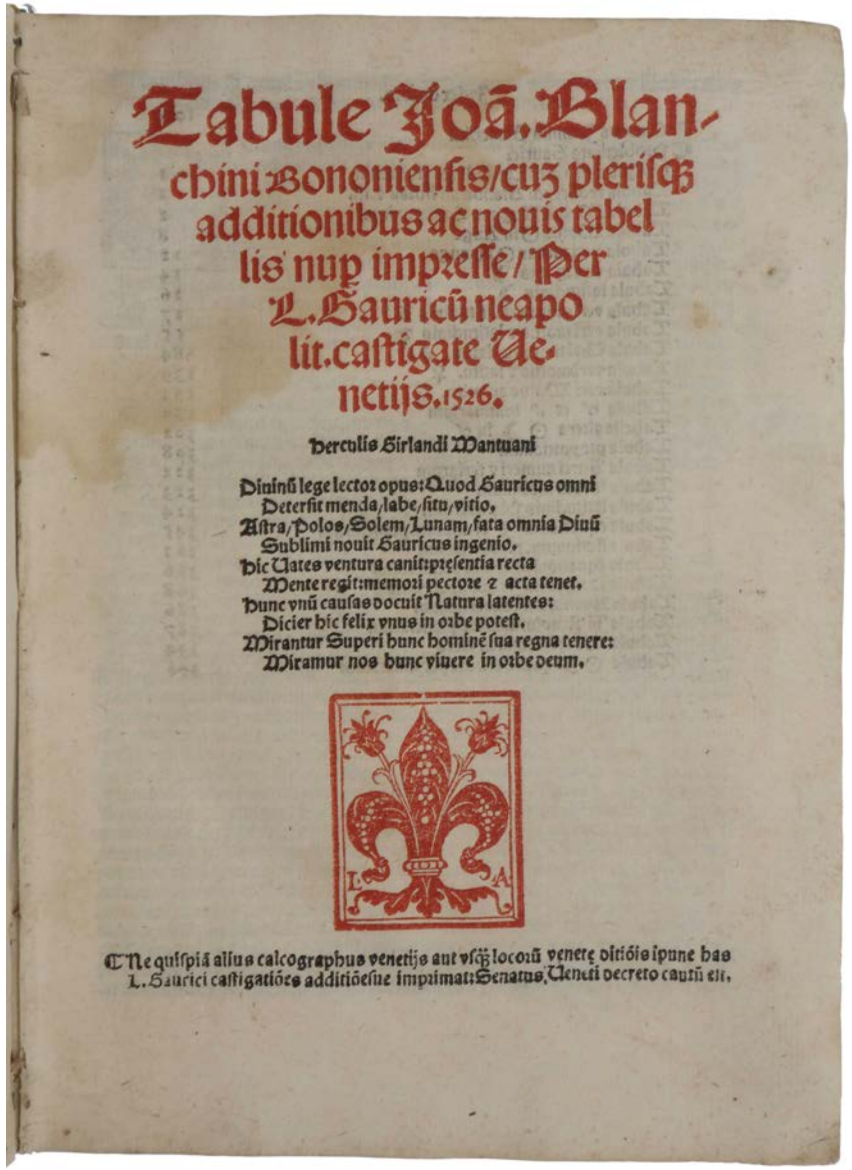
THE LARGEST SET OF ASTRONOMICAL TABLES PRODUCED IN THE WEST

BIANCHINI, Giovanni. *Tabule Ioan. Blanchini Bononiensis, cum plerisque additionibus ac novis tabellis nuper impresse, per L. Gauricum neapolit. castigate.* Venice: Giunta Lucantonio, 1526.

$9,500

4to (215 x 151 mm), ff. [xxviii], 398, title and some of the tables printed in red and black, lily device printed in red on title and in black on final leaf, woodcut initials (numerous errors in pagination). Contemporary vellum, remains of ties, a fine and attractive copy.

First edition edited by Luca Gaurico, second edition overall (first, 1495), of "the largest set of astronomical tables produced in the West before modern times" (Chabas & Goldstein, p. viii). "Bianchini set out to achieve a correction of the Alfonsine Tables – the standard in Europe for a couple of centuries by the time he wrote – with those of Ptolemy. He was a great admirer of Ptolemy and critical of the corrupted Ptolemaic and Alfonsine texts then in current use" (Tomash, p. 141). This second edition contains almost twice as much astronomical data as the first. "Bianchini's set of auxiliary tables for computing planetary latitudes in the edition of 1526 was not included in the *editio princeps* of 1495, despite the fact that these tables appear in manuscript copies … they appear in a manuscript copied by Copernicus" (Goldstein & Chabas, p. 458). Bianchini was "the first mathematician in the West to use purely decimal tables" (Feingold, p. 20), at the same time as Al-Kashi in Samarkand, and he also used negative numbers and the rule of signs.



Bianchini (d. 1469), an astronomer attached to the Ferrara court of the Este, was considered by his disciple Regiomontanus to be the greatest astronomer of his time, and his *Tabulae* was one of the most sophisticated and widely-disseminated fifteenth-century attempts to correct the Alfonsine Tables, the thirteenth-century planetary tables that were relied upon by all astronomers and navigators well into the sixteenth century. His rigorous mathematical approach made the Alfonsine Tables available in a form that could be used by Renaissance astronomy. Among the known manuscripts of Bianchini's *Tabulae* in European public collections is one copied by Regiomontanus at Vienna in 1460 (Nuremberg Stadtbibliothek MS Cent V 57), and another copied later in the century by Copernicus himself at Padua (Uppsala MS Copernicana 4, ff. 276-81), underlining the influence of the *Tabulae* on the two greatest astronomers of the early modern period. "There can be little doubt that early in his career Copernicus depended on Bianchini's tables for planetary latitude which, in turn, are based on Ptolemy's models for the *Almagest*. Hence, Bianchini's tables can be considered as a source for Copernicus's knowledge of astronomy" (Goldstein & Chabas, p. 470). Georg Peurbach and his student Regiomontanus visited Bianchini in Ferrara and corresponded with him, and they "were both calculating ephemerides from Bianchini's tables around 1456. Of their contemporaries (Regiomontanus' and Peurbach's), only Bianchini … possessed a comparable proficiency and originality" (*DSB* XV, pp. 474-5). ABPC/RBH list only one copy of this edition, and that defective, and none of the first edition. OCLC lists five copies in US (Brown, Burndy, Columbia, Huntington, Michigan).

"As an exact science astronomy makes extensive use of numerical computations. In early astronomy, this is best exemplified by astronomical tables in the tradition of Ptolemy's *Almagest* that dates to the 2nd century AD. Throughout the Middle Ages, astronomers compiled a great variety of astronomical tables to help computers determine the positions and other circumstances of the heavenly bodies and to help them solve astronomical problems related to the daily rotation, the determination of the times of eclipses, etc. … Astronomers addressing a variety of problems put together different tables and compiled 'sets of tables,' that is, consistent collections of astronomical tables embracing all or some aspect of mathematical astronomy and usually accompanied by a text, called 'canons', explaining their use. Most sets of tables compiled in Europe in the Middle Ages followed the structure of those composed in Arabic, that is, handbooks called *zijes*.

"In the Renaissance the mathematical sciences played an important role in humanistic culture, and they were highly appreciated at various social levels. Mathematical astronomy was regarded as especially valuable, for it was associated with cosmology and philosophy, as well as with astrology and astrological medicine. In other words, there was a considerable market for publications that included almanacs, ephemerides, and lunaria, several of them ranking among the best sellers in scientific publications, as well as sets of astronomical tables. The investment of time and money by the printer in producing these sets of tables was significant, and the fact that more than one edition of the same set appeared is an indication of the popularity of this genre. In particular, Bianchini's tables were printed three times between 1495 and 1553.

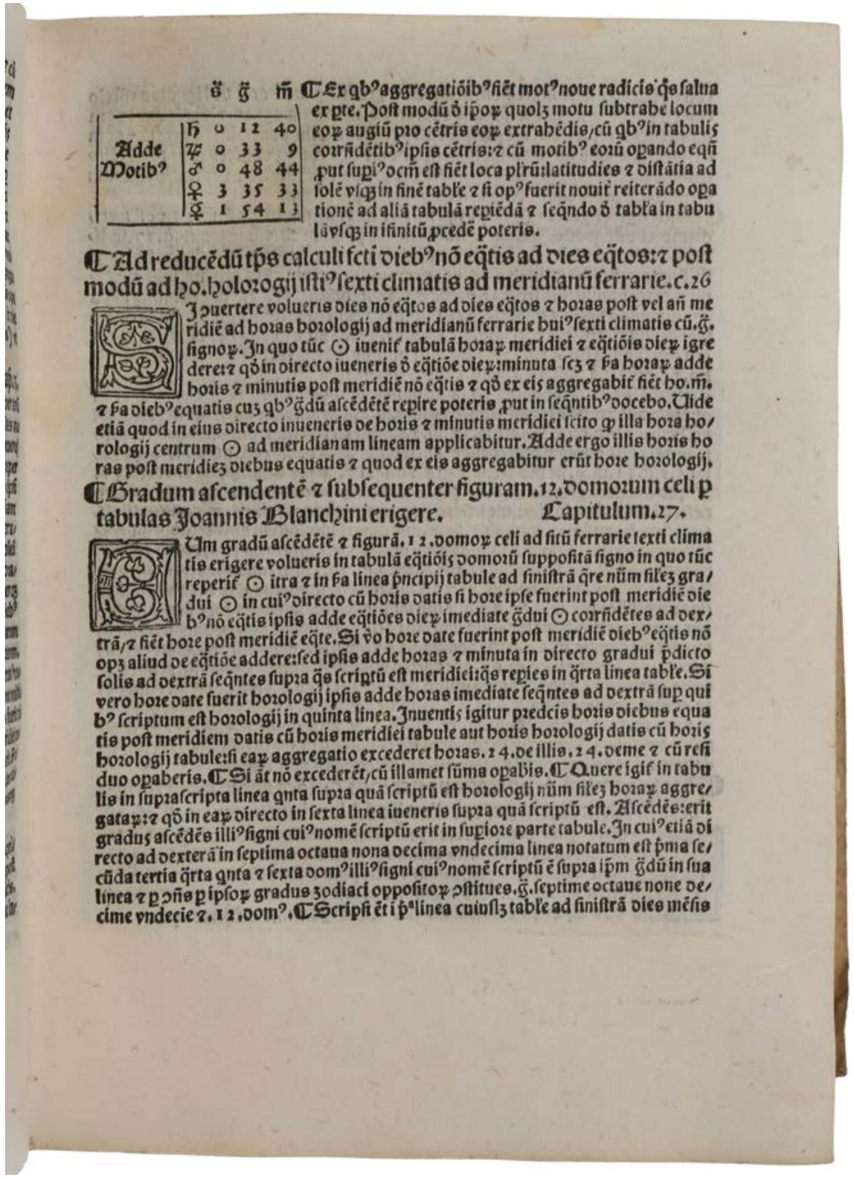
"By the time Bianchini compiled his tables (c. 1442), European astronomers has access to several variants of the Parisian Alfonsine Tables, that is, a set of tables which was recast beginning in the 1320s by a group of notable scholars working in Paris, and based on the work done by the astronomers in the service of King Alfonso X of Castile in the second half of the 13th century. Unfortunately, only the canons of the original Castilian Alfonsine Tables are extant, not the tables themselves.

"All these sets of astronomical tables are in the tradition of Arabic zijes: they contain a great many tables and, at their core, are those for the determination of the positions and motions of the five planets and the luminaries. The position of a planet in longitude (along the ecliptic), as well as the Sun and the Moon, is computed from tabulated values for mean motions and equations … in addition to tables for planetary longitude, there are tables for eclipses, planetary latitudes (the distance of a planet north or south of the ecliptic at any given time), etc. …

"The Alfonsine tradition lies within the Ptolemaic tradition, having a set of parameters in common as well as the same underlying model. Nevertheless, we find a great variety of tables in this tradition, and among them are those of Bianchini … his set depends directly on the Alfonsine tradition, but differs from all previous sets in various critical ways: the tables for the planets and the luminaries have a consistent format based on an internal organizing principle different from other sets of tables, and his tables contain the largest number of entries ever computed in the Alfonsine tradition …

"Probably due to their substantial size and complexity, the tables of Bianchini were not copied very often in manuscript, but frequently enough to suggest to the printer that there was a market for them. And so they were published in 1495 in Venice for the first time …

"The *editio princeps* (1483) of the Parisian Alfonsine Tables devoted 120 pages to numerical tables, excluding the star catalogue. In these pages we have counted more than 51,000 numbers of one or two digits, of which 41,000 have been computed, and about 10,000 are for the arguments in the tables (i.e., belonging to sets of consecutive numbers). The tables authored by Bianchini fill 633 pages in the edition of 1495 and contain about 315,000 numbers of one or two digits, that is, more than 6 times the amount in the Parisian Alfonsine Tables. Of these,



300,000 have been computed (more than 7 times the amount in the Parisian Alfonsine Tables), and about 15,000 are for the arguments. It should be noted that the second edition of Bianchini's tables (1526) enlarged the number of tables from 68 to 111, thus considerably increasing the undertaking of printing numbers" (Chabas & Goldstein, pp. 1-11).

Many of Bianchini's tables are 'double argument tables'. "The simplest astronomical table consists of two columns of numbers, such that for each value in the first column there corresponds one and only one entry, representing what nowadays is called a function. The first column gives the successive values of the argument, currently called the independent variable. The information contained in such a table can be represented as a two-dimensional graph, although it was not done so at the time. Astronomical tables in the *Almagest* were not all of the simplest kind, for many of them had more than two columns, such that the entries in each column depended on a single argument. In the Latin West a special form of astronomical tables, introduced in the 14th century, is called a 'double argument table', that is, a table with two arguments, one set at the head of each column and another set at the head of each row, corresponding (in modern terms) to a function of two variables. This ingenious type of table can be represented as a three-dimensional graph. The advantage of double argument tables is that they reduce the number of steps in the computation of a planetary position, etc. But this meant that the table maker had to produce many more entries in the tables, which required him to perform a larger number of computations" (Chabas & Goldstein, p. 1).

"The book has two dedications, one to Leonello d'Este (d. 1450), … and a later one addressed to Frederick III, Holy Roman Emperor … the dedication to Emperor Frederick was suggested by Bianchini's patron at the time, Borso, and was presented to the Emperor on the occasion of his visit to Ferrara in January 1452 …Prior to the dedications in the first two printed editions, we find an encomium in praise of Bianchini's book that was written by Augustinus Moravus in January 1495 at Padua. In these editions the tables are preceded by canons consisting of an Introduction and 51 chapters …

"The Introduction begins with references to Ptolemy and the *Almagest*: 'Ptholomeus qui merito illuminator divine astrologie vocari potest, in suo libri Almagesti.' Several scholars other than Ptolemy are mentioned (Hipparchus, Thabit ibn Qurra, al-Battani, the compilers of the Toledan Tables, and Alfonso X, among others), but we note that none of them are later than Alfonso (d. 1284). The Introduction focuses on two astronomical matters, precession/trepidation and the latitude of the planets. Bianchini praises the work of Alfonso and in the first table of the treatise he addresses the problem of precession/trepidation strictly in accordance with the Alfonsine corpus. As for the planetary latitudes, Bianchini indicates that he compiled tables following the instructions given by Ptolemy in Book XIII of the *Almagest*, which is indeed the case, to overcome 'significant discrepancy from the truth, especially for Venus and Mercury', found in other sets of tables. The Introduction closes with some basic information helpful to the reader when using his tables …

"In the edition of 1526 the editor, Luca Gaurico, added 8 short paragraphs after Chapter 51. The title of the first is 'Verum ascendentis gradum per earum seminis rectificare secundum Jacobum Dundum patavinum', apparently based on a previous work by the astronomer Jacopo de Dondi of Padua (1298-1359), and that of the eighth, 'Latitudinem 5 errantum supputare,' On the other hand, the edition of 1553 has only the first 18 chapters" (Chabas & Goldstein, pp. 15-19).

"Giovanni Bianchini was appointed by Nicolo d'Este to a position in the Ferrara accounting office in 1427, and was made director in 1430. He became Fattor generale in 1433, ambassador to Milan in 1446, was sent to Rome in 1450 because of some business involving coinage, and spent three months in Venice in 1454. He had achieved this high standing despite his lacking a formal education and his never having been to the university. Nothing is known about his birth and death dates; he probably died in 1466 or shortly thereafter, at an advanced age.

"Bianchini had published several large tables. One of these, on the motions of the planets, he dedicated to Leonello de Ferrara in 1442. The sixty-fold division of the signs (after the Alfonsine Tables) was continued in these tables; an innovation that he introduced was a set of tables from which the synodic revolution could be deduced from the true position of the planets for each day. Regiomontanus had made himself a copy in Vienna of these tables and an abbreviated commentary, albeit first in 1460 …

"When Frederick III was in Italy in 1452, he took Bianchini into his service as an advisor and elevated him to the nobility. According to the heraldic letter of May 18, 1452, his coat-of-arms showed the Imperial Eagle and an armillary sphere. In gratitude Bianchini dedicated an annotated table to him … This work is supposed to give the foundations of astrology, but instead is a miscellaneous collection of unrelated tables without any of Bianchini's own input …

"Later, Bianchini published another collection of tables, *Tabulae primi mobilis*, to which he repeatedly referred in his letters. These tables made it possible to correct celestial events to the Ferrara horizon … Part of this table and those of the first work were printed in Venice in 1495, and were edited by Gauricus later (1526 and 1553)" (Zinner, pp. 37-8).

Bianchini wrote five other treatises, which survive only in manuscript: *Compositio instrumenti*, on the construction and use of an instrument to determine the altitude of the stars; *Canones tabularum super primo mobile*, on spherical trigonometry; *Flores Almagesti*, his largest work, dealing with arithmetic, algebra, proportion, and various astronomical matters; *Canones tabularum de eclipsibus luminarium*, which reports observations he had made on several lunar and solar eclipses; and *Tabulas magistrales*, a set of decimal tables including tangents and cosecants.

Houzeau & Lancaster 12595. Tomash B150 (manuscript). Chabas & Goldstein (eds.), *The Astronomical Tables of Giovanni Bianchini*, 2009. Goldstein & Chabas, 'Ptolemy, Bianchini, and Copernicus: Tables for Planetary Latitudes,' *Archive for History of Exact Science* 58 (2004), pp. 453-73. Zinner, *Regiomontanus*, 1990.

DISCOVERY OF SURGICAL ANESTHESIA

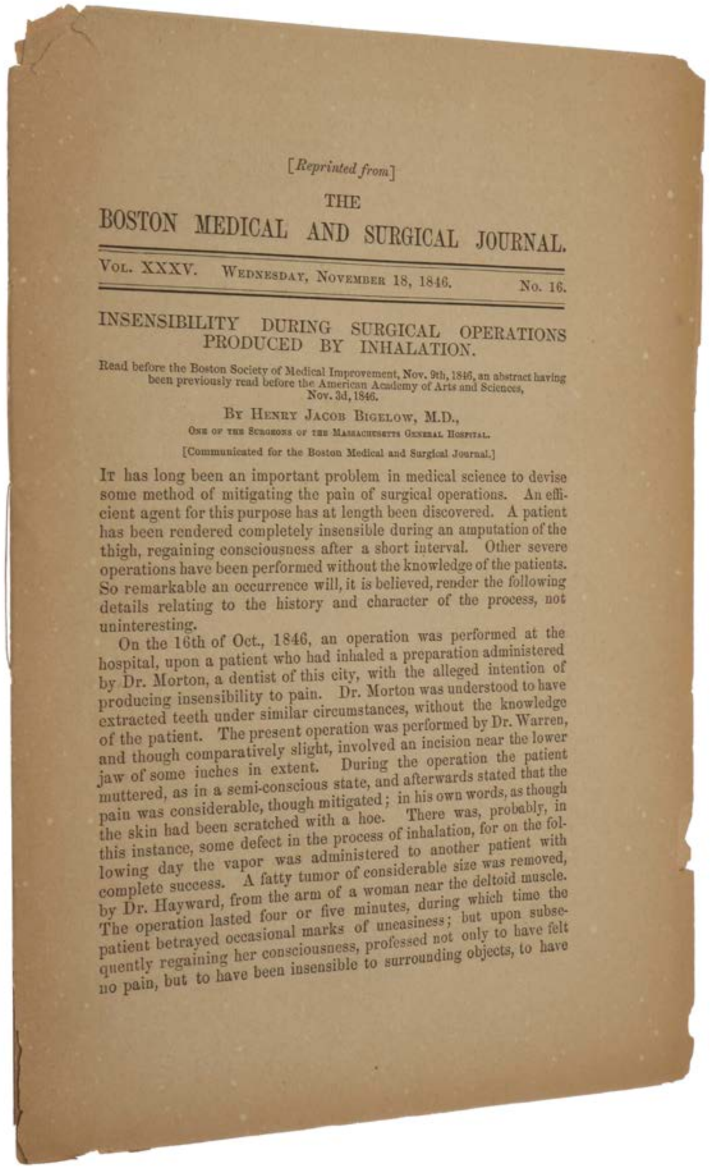
Grolier/Norman, *One Hundred Books Famous in Medicine* 64a

BIGELOW, Henry Jacob. *Insensibility During Surgical Operations Produced by Inhalation.* [Boston: David Clapp, December 1846].

$4,500

Reprinted from: The Boston Medical and Surgical Journal, vol. XXXV, no. 16. 8vo (230 x 154 mm), pp. [309]. 310-316. Stitched in self-wrappers as issued, extremeties slightly frayed, corners ands pine with wear. Custom slip case.

First separate edition, very rare, of "the first published announcement of the discovery of surgical anesthesia, the most significant contribution to medicine made in the United Sates during the nineteenth century. In the summer of 1846, W. T. G. Morton, a Boston dentist, began investigating the anesthetic properties of sulphuric ether, and by September was using it successfully in his practice. Bigelow at this time was a rising young surgeon with connections to the Massachusetts General Hospital, and it was probably through his influence that Morton was allowed to give there, on 16 October, the first public demonstration of the efficacy of ether as a surgical anesthetic in an operation performed by John Collins Warren. The demonstration was highly successful, as was a repeat performance made the next day, but Morton, who wished to patent the process, refused to disclose the nature of his preparation or to allow any further trials. Bigelow, however, forced the issue by communicating Morton's results in a brief announcement made on 3 November to the American Academy of Arts and Sciences. On 7 November an amputation was performed with ether, and Morton authorized Bigelow's publication of the present detailed account of its use, read



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THE

BOSTON MEDICAL AND SURGICAL JOURNAL.

Vol. XXXV. Wednesday, November 18, 1846. No. 16.

INSENSIBILITY DURING SURGICAL OPERATIONS PRODUCED BY INHALATION.

Read before the Boston Society of Medical Improvement, Nov. 9th, 1846, an abstract having been previously read before the American Academy of Arts and Sciences, Nov. 3d, 1846.

By Henry Jacob Bigelow, M.D.,

One of the Surgeons of the Massachusetts General Hospital.

[Communicated for the Boston Medical and Surgical Journal.]

It has long been an important problem in medical science to devise some method of mitigating the pain of surgical operations. An efficient agent for this purpose has at length been discovered. A patient has been rendered completely insensible during an amputation of the thigh, regaining consciousness after a short interval. Other severe operations have been performed without the knowledge of the patients. So remarkable an occurrence will, it is believed, render the following details relating to the history and character of the process, not uninteresting.

On the 16th of Oct., 1846, an operation was performed at the hospital, upon a patient who had inhaled a preparation administered by Dr. Morton, a dentist of this city, with the alleged intention of producing insensibility to pain. Dr. Morton was understood to have extracted teeth under similar circumstances, without the knowledge of the patient. The present operation was performed by Dr. Warren, and though comparatively slight, involved an incision near the lower jaw of some inches in extent. During the operation the patient muttered, as in a semi-conscious state, and afterwards stated that the pain was considerable, though mitigated; in his own words, as though the skin had been scratched with a hoe. There was, probably, in this instance, some defect in the process of inhalation, for on the following day the vapor was administered to another patient with complete success. A fatty tumor of considerable size was removed, by Dr. Hayward, from the arm of a woman near the deltoid muscle. The operation lasted four or five minutes, during which time the patient betrayed occasional marks of uneasiness; but upon subsequently regaining her consciousness, professed not only to have felt no pain, but to have been insensible to surrounding objects, to have before the Boston Society of Medical Improvement on 9 November and printed in the 18 November issue of the *Boston Medical and Surgical Journal*" (Norman). "There have been many advances in the medical world over time that have greatly contributed to ameliorating and prolonging human life. The employment of surgical anesthesia is arguably one of the greatest medical discoveries of all time, and has immensely broadened our ability to treat the ill. While Dr. Henry Jacob Bigelow (1818-1890) was not the inventor of anesthesia, he was the first to publish and advocate its use in the 19th century … His contributions to the medical field have set him apart as one of the most influential and famous surgeons of America in the 19th century" (Malenfant *et al*). ABPC/RBH list four copies in the last 40 years. OCLC lists only two copies in US (Brown & Stanford).

"Theoretically, when administered, the perfect anesthetic agent should have analgesic properties, induce unconsciousness, prevent memory formation, relax the patient to prevent unwanted movement and be reasonably safe to use. The first agent that was demonstrated to have all these qualities was sulphuric ether [diethyl ether]. Ether was considered ideal due to the fact that low concentrations are required to anesthetize patients, ether does not cause hypoxia when administered, does not cause respiratory depression while acting as an anesthetic and it has a slow induction in the patient. Moreover, ether was easily transported, was much more versatile than nitrous oxide and was easily inhaled because it is so volatile. Ether was therefore a very safe and useful anesthetic, even when used by untrained and uneducated administrators. However, its discovery and widespread use as a general anesthetic took centuries to develop and was fraught with controversy …

"William E. Clarke, a medical student from Rochester, first administered ether as a general anesthetic in January 1842 to young woman named Hobbie who had a tooth removed by Elijah Pope, a dentist. Despite the fact that the procedure was successfully completed without pain, neither Clarke nor Pope published this discovery or made any claim to it until 40 years later. Similarly, on March 30, 1842, Dr. Crawford W. Long from Jefferson, Georgia, administered ether via inhalation from an ether soaked towel to James M. Venable before removing two small tumors from his neck. Long also proceeded to conduct a comparative trial to prove that, "insensibility to pain was caused by ether and was not simply a reflection of the individual's pain threshold or as a result of self hypnosis." Despite his ground-breaking methodology and research, Dr. Long did not publish his findings until 1849. By this time, the use of ether as an anesthetic had been widespread for three years and thus Dr. Long was also not credited with the discovery of the first inhalation anesthetic.

"On October 16, 1846, William Thomas Green Morton publicly demonstrated that diethyl ether was that perfect agent that possessed all the theoretical qualities previously mentioned. Dr. John Collins Warren invited W.T.G. Morton to demonstrate his claims of anesthesia, with permission, on Edward Gilbert Abbot as a vascular lesion was excised from the left side of his neck. Morton arrived late to the Bullfinch amphitheatre at the Massachusetts General Hospital in Boston after assembling an apparatus whereby to deliver the ether to the patient. He brought with him his anesthetic apparatus which he called the 'Letheon,' so named after the river Lethe in classical Greek mythology which seemingly obliterated painful memories. The apparatus consisted of a tube, placed in the patient's mouth, connected to a glass globe with a hole on the opposite side of the tube designed to drag air over a rag soaked in sulphuric ether. The patient then inhaled ether gas through the apparatus for four minutes until he fell asleep. At this point, Warren was able to perform surgery while the patient was both unaware of his surroundings and experienced no pain. When the procedure was over, it is claimed that Warren turned to his audience and exclaimed, 'Gentlemen, this is no humbug.'

“Dr. Charles T. Jackson, a teacher of Morton’s at Harvard Medical School, claims to have been aware of the analgesic properties of ether by February 1842, because he himself had used it to alleviate his own pain. Jackson then claimed that he had taught Morton about the possible anesthetic use of ether and encouraged him to use ether in his dental practice. Morton had also previously learned from both Horace Wells and Charles Jackson through a shared a dental practice with Wells and had studied with him at Hartford between 1841-1843. The partnership broke up when Wells left after financial losses and Morton went on to attend Harvard Medical School in Boston in March of 1844. While attending medical school Morton lived with and was taught by Charles Jackson. Morton saw the analgesic properties that ether possessed when applied directly to the skin and started experimenting on dogs, and later used ether in his dental practice when extracting rotten teeth. It was these experimentations and through this reputation that Morton was invited to publicly demonstrate his claim to having discovered a safe anesthetic agent.

“After the first trial at Massachusetts General Hospital, Morton went on to demonstrate the anaesthetic property of ether on October 17, 1846, when surgeon George Hayward successfully removed a tumour from a woman’s arm without pain. Following this second demonstration, Morton wanted to profit from his discovery and thus refused to tell anyone what his letheon mixture consisted of. It was only under threat of not being allowed to administer any further anaesthesia that Morton disclosed that the compound was, in fact, sulphuric ether. On November 7, 1846, George Hayward performed a leg amputation and a lower jaw removal under ether anaesthesia at the Massachusetts General Hospital with the third and fourth documented administration of ether as a general anaesthetic. Henry Bigelow officially announced the discovery of ether as an anaesthetic in the *Boston Medical and Surgical Journal* in the November 18, 1846 issue. Bigelow also sent a letter to Robert Liston, professor of clinical surgery at the University of London, and to Francis Boott in Great Britain, announcing the discovery. Boott subsequently gave his niece, Miss Lonsdale, anaesthesia on December 19, 1846, when she had a tooth extracted by British dentist, James Robinson. Boott wrote to the *Lancet* explaining, ‘the whole process of inhalation, extracting and waking was over in three minutes.’ Following this publication, ether as a general anaesthetic was documented in Dumfries, England [*sic*] on December 19, 1846, by James Frazer as William Scott operated on a patient, and subsequently on December 21, 1846, by Robert Liston at the University College Hospital for the amputation of a thigh and avulsion of a toenail. Following the operation Liston is quoted as stating, ‘This Yankee dodge beats mesmerism hollow.’ The use of ether as an anaesthetic quickly spread throughout Europe and had continued use throughout Russia, South Africa and Australia by the summer of 1847.

“Following Morton’s public demonstration of ether on October 16, 1846, it did not take long for the ‘ether controversy’ to ensue. Morton, Wells, and Jackson all sought to claim the discovery as their own. Morton applied for a patent for the Letheon, which he was granted on November 12, 1846. Jackson had previously contacted Morton demanding that he was entitled to ten per cent of Morton’s profit, which Morton reluctantly later agreed to. In 1847, the French Academy of Medicine awarded the Monthyon prize of 5,000 Francs jointly to Morton and Jackson. However, Morton refused to accept his half of the reward maintaining that the discovery of ether as an anaesthetic was his and his alone. Morton spent most of the remainder of his life fighting for the claim to his discovery and for financial compensation. The matter ultimately came before the US Congress where the House of Representatives agreed to compensate Morton an undetermined amount. However, this compensation was ultimately dismissed by the Senate and thus Morton was never given any official financial reward in his lifetime. Ultimately, Morton’s refusal to accept anything but full claim to the discovery of ether anaesthesia impeded his recognition and acceptance in the medical community. Many of his peers did not like him and judged him more on his character than his discovery.

"In his book, *Tarnished Idol* (2001), Richard J. Wolffe says of Morton:

'Although Morton was responsible for bringing ether anaesthesia into everyday surgical use, he was motivated to do so not by scientific or humanitarian reasons but out of a desire to find a way to perform painless tooth extraction in order to fit more patients … and thereby increase his income considerably, and afterward to patent the process and profit even more from it by leasing its use to other dentists and medical professionals.

'[Morton was] unpolished, a poorly educated man, with little scientific knowledge and possessed of an unscrupulous character … perhaps even a criminal mind that led him to lie, steal, and commit gross misdeeds in order to achieve his goals … the pursuit of money, no matter how gained. He forged ahead ruthlessly, appropriating the ideas of others, in order to prove the pain alleviating properties of ether, not in the service of humanity or science, but because in his view, the patenting of such a discovery would bring him a fortune … clearly it is another of the bitter ironies of history that fate chose such an unworthy and ill prepared agent to preside as midwife at the birth of the death of pain'" (Van Heerden, pp. 386-9).

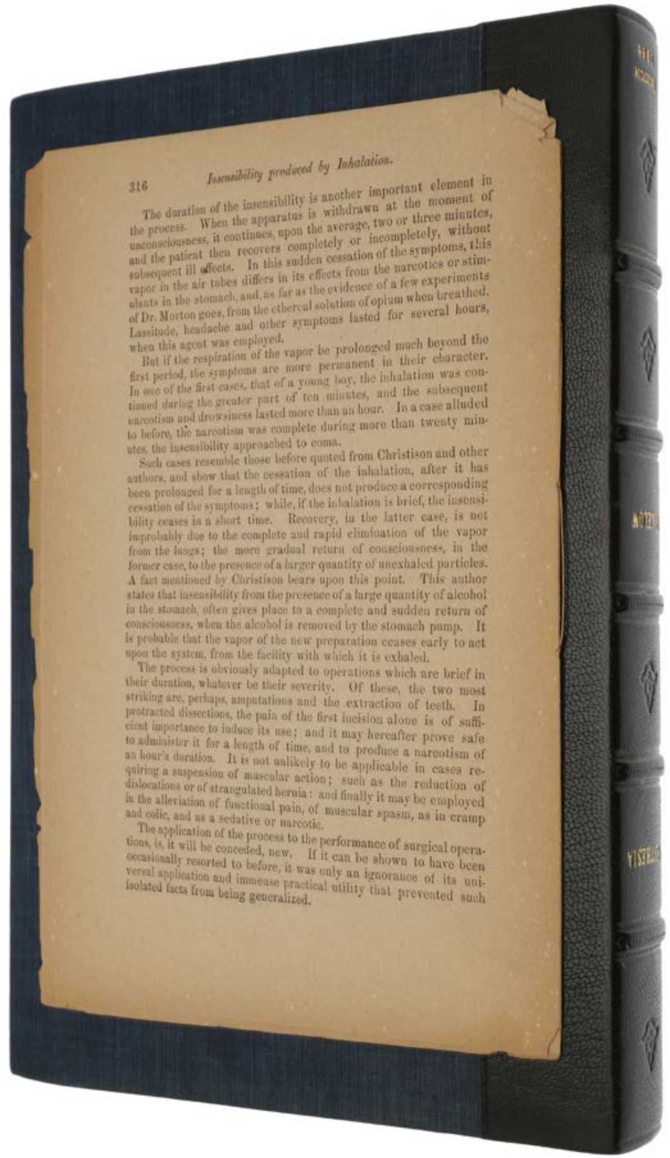
"Bigelow was born March 11, 1818 in Boston. His father, Jacob Bigelow, taught medicine at Harvard. Bigelow entered Harvard College at fifteen years old and, after a not entirely smooth undergraduate career (including an incident in which he discharged a musket in his Hollis Hall room) graduated in 1837. He studied medicine both at Harvard and at Dartmouth College (at the latter, under Oliver Wendell Holmes, Sr.), receiving his M.D. at Harvard in 1841. He was elected a Fellow of the American Academy of Arts and Sciences in 1846.

"His 'Insensibility during Surgical Operations Produced by Inhalation' (1846), detailing the discovery of ether anesthesia, was selected by readers of the *New England Journal of Medicine* as the 'most important article in *NEJM* history' in commemoration of the journal's 200th anniversary. 'Dr. Harlow's case of Recovery from the passage of an Iron Bar through the Head' (1850) brought the case of Phineas Gage out of complete obscurity into merely relative obscurity, and largely neutralized remaining scepticism about the case. Bigelow described the structure and function of the Y-ligament of the hip joint in great detail, and it still carries his name. In 1878 he published 'Lithotrity by a Single Operation', in which he described his technique for 'the crushing and removal of a stone from the bladder at one sitting.' Prior to this, surgeons would crush a bladder stone and then spend only a few minutes removing the pieces. The remaining fragments would remain for a later session for removal. This resulted in much discomfort and complications as the remaining fragments found an exit on their own. Removing the entire bladder stone in one procedure was a great advancement.

"Bigelow died October 30, 1890 after an accident, at his country home in Newton, Massachusetts" (Wikipedia, accessed 21 March 2018).

This separate printing of Bigelow's article is something of a bibliographical puzzle. It has the appearance of an offprint, with 'Reprinted from' at the head of the first page, followed by the title and date of the journal issue exactly as it appears in the journal publication. However, the main text has been reset, and the final seven controversial paragraphs referring to Jackson and Morton's proposed patent have been omitted – hence the separate issue is paginated [309]-316, while the journal issue is [309]-317. The separate issue was therefore presumably issued later than the journal issue (as is usually, although not always, the case with offprints). Fulton & Stanton suggest a publication date in December 1846, based on the reprinting of the article in the *Hartford Courant*, dated 26 December, which has the same text as the separate issue. Fulton & Stanton (IV. 1) also state of the journal issue that "no exact offprint appears to have been made", so the offered work is without doubt the earliest separate printing.

Cushing B380; Dibner 128, note; Fulton & Stanton, *The centennial of surgical anesthesia, an annotated catalogue* (1946), IV.1; Garrison-Morton 5651; Grolier/ Medicine 64A; *Heirs of Hippocrates* 1859; Norman 232; Osler 1355; Wellcome II, p. 166. Duncum, *The Development of Inhalation Anaesthesia* (1947), pp. 99-120. Keys, *The History of Surgical Anesthesia* (1963), p. 29. Malenfant *et al*, 'Henry Jacob Bigelow (1818-1890): his contributions to anatomy and surgery,' *Clinical Anatomy* 24 (2011), 539-43. Van Heerden, 'The controversial conquering of pain,' *The Proceedings of the 16th Annual History of Medicine Days*, March 30th and 31st, 2007 Health Sciences Centre, Calgary, AB, pp. 383-390.



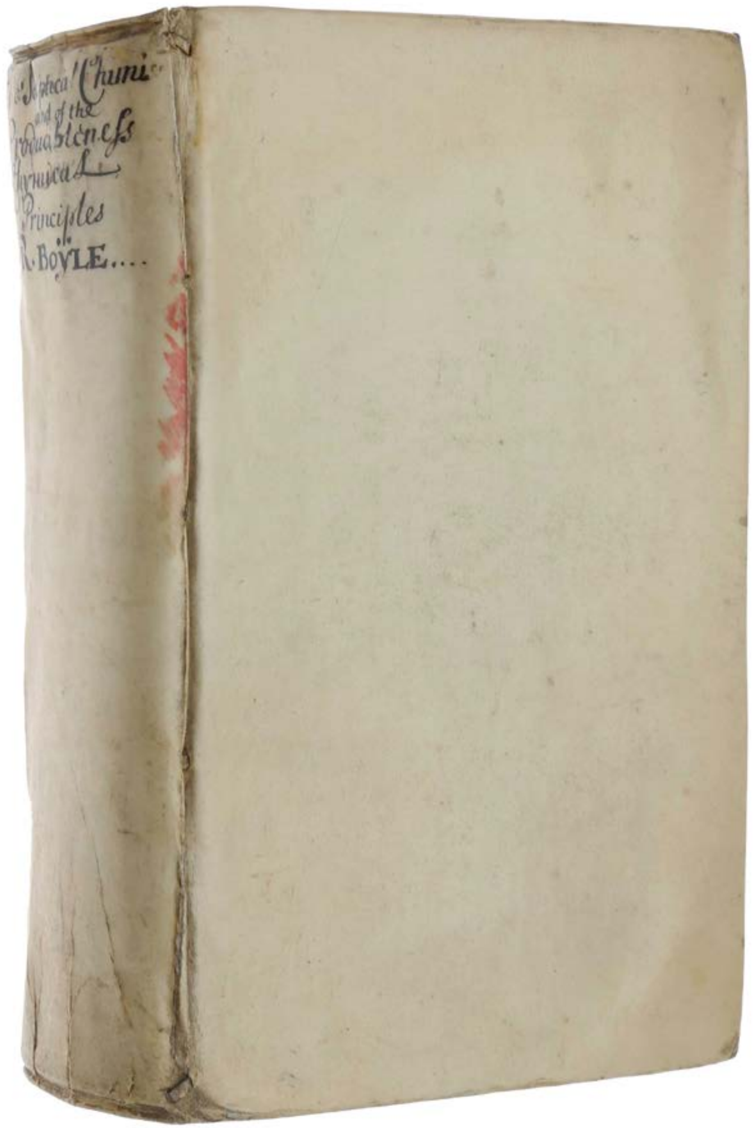
WITH THE VERY RARE ADVERTISEMENT LEAF

BOYLE, Robert. *The Sceptical Chymist: or Chymo-Physical Doubts and Paradoxes, touching the experiments whereby vulgar spagirists are wont to endeavour to evince their salt, sulphur and mercury, to be the true principles of things. To which in this edition are subjoyn'd divers Experiments and Notes about the Producibleness of Chymical Principles.* Oxford: Henry Hall for R. Davis and B. Took, 1680.

$40,000

Two parts in one vol., 8vo (167 x 105 mm), pp. [22], 440; [28], 268. Contemporary vellum, spine lettered in manuscript (pale red marking to spine and rear board), a very fine copy. Custom blue cloth slipcase and chemise, blue morocco spine label.

Second edition in English (first, 1661), complete with the very rare advertisement leaf which is lacking from most copies, of this landmark in the history of science, "his most important work [where he] set down his corpuscular theory of the constitution of matter, which finally freed chemistry from the restrictions of the Greek concept of the four elements, and was the forerunner of Dalton's atomic theory" (Sparrow). "Boyle's most celebrated book is his *Sceptical Chymist* … It contains the germs of many ideas elaborated by Boyle in his later publications" (Partington II, p. 496). The physicists, Boyle called them 'hermetick philosophers', upheld the Peripatetical or Aristotelian doctrine of the four elements – fire, air, earth, and water. The chemists, 'vulgar spagyrists', were disciples of Paracelsus who believed in the *tria prima* – salt, sulphur, and mercury. Boyle showed that both of these theories were totally inadequate to explain chemistry and was the



first to give a satisfactory definition of an element. This second edition of the *Sceptical Chymist* contains the first printing of the second part, *Experiments and Notes about the Producibleness of Chymical Principles*. The first edition of the *Sceptical Chymist* hardly ever appears on the market and now commands a very high price – the last complete copy sold at auction realized £362,500 in 2015. Fulton located five copies of this second edition complete with the advertisement leaf; four are recorded on ABPC/RBH in the last 40 years (only one since the Norman sale, and that in a modern binding).

Provenance: Gift inscription to the chemist A. W. Tangye, manager and director of Brunner Mond, from [?] Hutchins, dated 12 December 1922, on the front free endpaper.

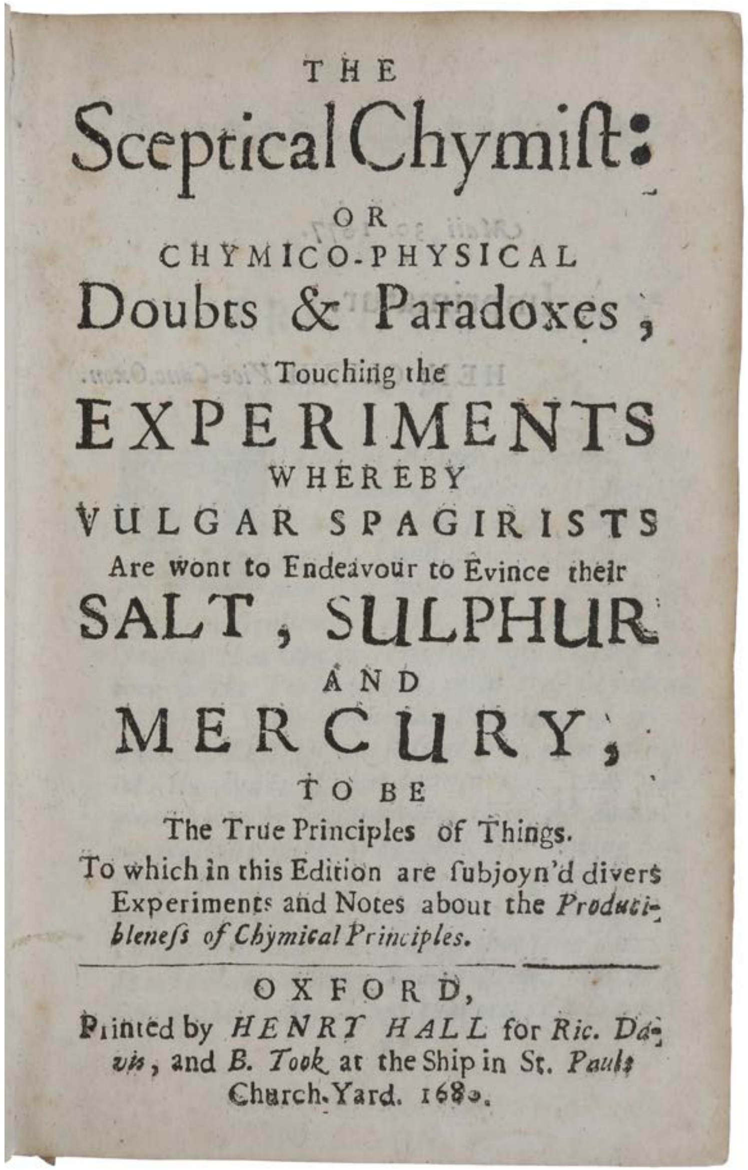
"The 'Sceptical Chymist' is one of the great books in the history of scientific thought, for it not only marks the transition from alchemy to modern chemistry but is a plea, couched in most modern terms, for the adoption of the experimental method. Boyle inveighed against the inaccurate terminology of the 'vulgar spagyrists' and the 'hermetick philosophers,' as he termed the alchemists who refused to define their terms … He predicted that many more [elements] existed than had been described, but insisted that many substances, then thought to be elemental, were, in fact, chemical compounds. He set forth the modern distinction between a compound and a mixture, pointing out that a true chemical compound possessed properties entirely different from either of its constituents" (Fulton).

"The importance of Boyle's book must be sought in his combination of chemistry with physics. His corpuscular theory, and Newton's modification of it, gradually led chemists towards an atomic view of matter ... Boyle distinguished between mixtures and compounds and tried to understand the latter in terms of the simpler chemical entities from which they could be constructed. His argument was designed to lead chemists away from the pure empiricism of his predecessors and to stress the theoretical, experimental and mechanistic elements of chemical science. The *Sceptical Chymist* is concerned with the relations between chemical substances rather than with transmuting one metal into another or the manufacture of drugs. In this sense the book must be considered as one of the most significant milestones on the way to the chemical revolution of Lavoisier in the late eighteenth century" (PMM).

"Boyle (1627-91) has ben called the founder of modern chemistry, for three reasons: (1) he realized that chemistry is worthy of study for its own sake and not merely as an aid to medicine or alchemy – although he believed in the possibility of the latter; (2) he introduced a rigorous experimental method into chemistry; (3) he gave a clear definition of an element and showed by experiment that the four elements of Aristotle and the three principles of the alchemists (mercury, sulphur and salt) did not deserve to be called elements or principles at all, since none of them could be extracted from bodies" (Partington II, p. 495).

The *Sceptical Chymist* takes the form of a dialogue, clearly modeled on Galileo's *Dialogo*, involving four participants. The Aristotelian Themistius and the Paracelsian Philoponus state their positions briefly, but soon fall silent. A wide-ranging discussion ensues between the sceptical Carneades (Boyle himself) and Eleutherius, the open-minded enquirer. Carneades argues – citing many experimental examples – that the Aristotelian four-element system and the Paracelsian three-principle model give equally inadequate explanations of what happens when complex substances are attacked by fire, or by powerful solvents. He shows that these processes often generate new compounds, rather than the promised 'primitive and simple, or perfectly unmingled bodies', which remain stubbornly elusive. His second proposal is more speculative – and theologically more dangerous. Boyle believed, and hoped to prove in time, that the ultimate constituents of bodies were minute atoms, differing only in 'bulk, figure, texture and motion'. This idea was first suggested by the ancient Greek natural philosophers Leucippus and Democritus. Their successor, Epicurus, incorporated it into a godless materialistic world-view that was universally condemned by Christian theologians. Consequently, atomistic theories were suppressed for centuries. By the mid-17th century the works of the classical Greek atomists had been printed, translated and commented upon by scholars such as Pierre Gassendi, though there was still considerable hostility to them from clergy of all persuasions. But Boyle – a devout (though somewhat unorthodox) Christian who funded translations of the Gospels into many languages, including Gaelic and Turkish – saw no reason why a benign deity could not have chosen to create an atomic universe.

"This work has often been acclaimed as a turning point in the evolution of modern chemistry, a crushing blow to traditional alchemy, but in fact Boyle's message is a more complex one. In his text he made a clear distinction between 'the true *Adepti*' and 'those Chymists that are either Cheats, or but Laborants.' While dismissive of the latter, his view of the former was that, 'could I enjoy their Conversation, I would both willingly and thankfully be instructed' by them. In other words, Boyle had no quarrel with those who aspired to the higher mysteries of alchemy. Rather, his book was targeted at distillers, refiners and others, who were so preoccupied with hands-on processes that they lacked an interest in theory, and also at the authors of chemical textbooks who combined a similar preoccupation with practical preparations with a reliance on Paracelsian principles. Hence *The Sceptical Chymist* is primarily an attack on the Paracelsian tradition, and particularly on its theory that the world was made up of the three principles of salt, sulphur and mercury … But he also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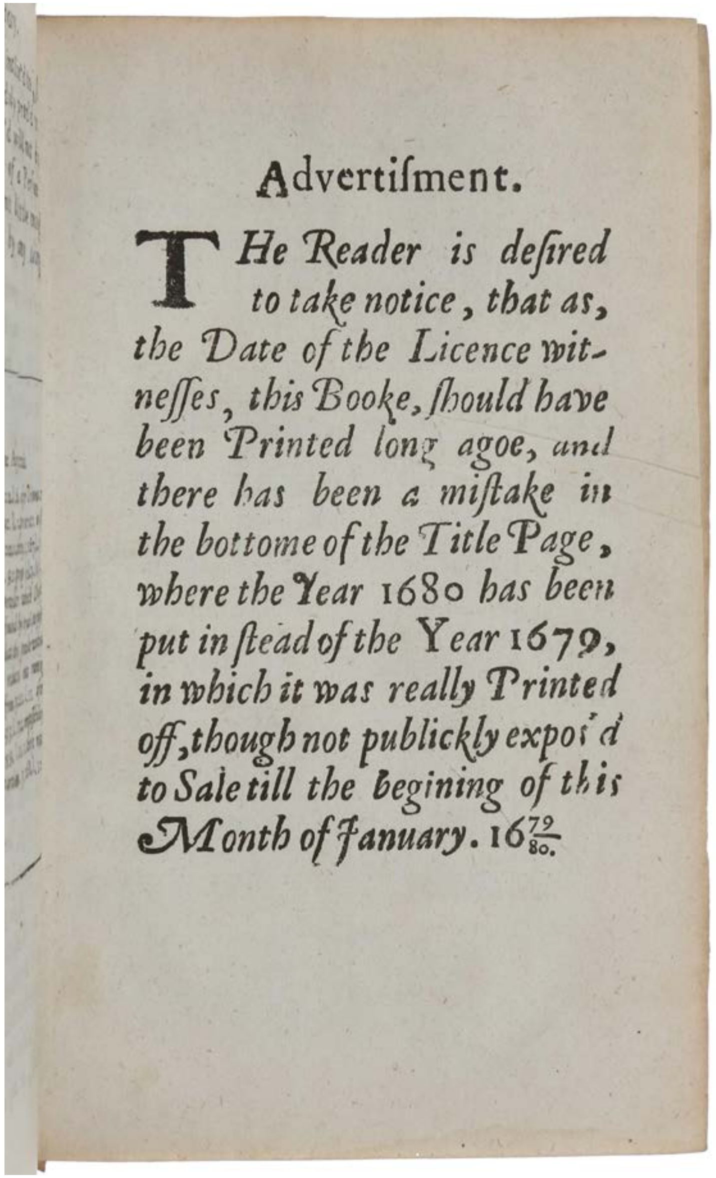
The True Principles of Things.
To which in this Edition are subjoyn'd divers
Experiments and Notes about the *Produci-bleness of Chymical Principles.*

OXFORD,
Printed by *HENRY HALL* for *Ric. Davis*, and *B. Took* at the Ship in St. *Pauls* Church-Yard. 1680.

made a broader appeal for chemical investigation to be informed by a clear explanatory structure, criticising the practical chemists whom he attached in the book on the grounds that 'there is a great Difference between being able to make Experiments, and being able to give a Philosophical Account of them'" (Hunter, pp. 119-120).

Experiments and Notes about the Producibleness of Chymical Principles, here in its first edition, has separate title and pagination (and was issued separately – Wing B3972). It "echoes the earlier work in containing a vindication of alchemical adepts able to carry out transmutation, in contrast to those who wrote 'courses of Chymistry' and the like. Boyle also reiterated his criticism of the Paracelsian concept of the three principles of salt, sulphur and mercury, supplementing *The Sceptical Chymist* by illustrating the extent to which these and the 'spirits' which chemists also commonly – and rather vaguely – invoked could be more precisely defined. In the case of salts, he argued that there were three distinct families: acid salts, volatile salts, and alkalies or lixiviate salts – all of which could be produced or destroyed by chemical processes (in this connection he also criticized the acid/alkali theory). He also dealt with sulphur, but it was his treatment of mercury which was most complicated, reflecting the interest in this substance that underlay his alchemical concerns, and particularly the conviction that common mercury could be converted into a more potent 'philosophical mercury' … This part of *Producibleness* echoes earlier alchemical writers both in its language and in its conceptual apparatus, the work as a whole being potentially 'useful to fellow aspiring adepts.' Boyle's commitment to alchemy is not to be underestimated" (*ibid*., p. 186).

Fulton initially believed that the advertisement leaf, which states that the book was actually printed in 1679 rather than 1680, existed in only one copy, but he later



Advertiſment.

THe Reader is deſired to take notice, that as, the Date of the Licence witneſſes, this Booke, ſhould have been Printed long agoe, and there has been a miſtake in the bottome of the Title Page, where the Year 1680 has been put in ſtead of the Year 1679, in which it was really Printed off, though not publickly expos'd to Sale till the begining of this Month of January. 16 79/80.

found a few other examples. The leaf exists in two states, one in which the date of publication is given as January 1679/80 (as here), and another, with a different setting of type, giving 1679/78. Fulton suggests that Boyle insisted on having the date corrected "lest continental readers might suspect him of plagiarizing writers who had been guilty of plagiarizing him." The imprimatur is dated 30 May 1677. Boyle's name does not appear on the title.

Dibner, *Heralds* 39; Grolier/Horblit 14; Norman 299; PMM 141; Sparrow, *Milestones* 27 (all for the first edition). ESTC R16310; Fulton 34; Madan 3261, 3260. Partington II, pp. 495 *et seq*. Hunter, *Boyle. Between God and Science*, 2009.

MORE THAN 150 PLATES OF MACHINES

BÖCKLER, Georg Andreas. *Theatrum Machinarum Novum...* Nuremberg: Christoff Gerhard for Paul Fürst, 1661.

$18,500

Folio (312 x 223 mm), pp. [xii], 68, including engraved title, and letterpress title printed in red and black, ornamental initials and head and tailpieces, with 154 engraved plates. Contemporary vellum with yapped edges.

First edition, an exceptionally fine copy in an untouched contemporary binding, of this superbly illustrated work with 154 plates of various types of powered mills and hydraulic machinery. "Here is another of the great 'machine' books with many beautiful engravings of gunpowder mills, saw mills, water raising devices, fire engines, roasting spits and so on. Böckler was a German architect and engineer interested in masses of gearing, complex workings, and devices that even by modern standards invite awe and admiration" (Hoover). The magnificent plates are of various types of motion drives powered by intricate systems of wheels employing water, wind, weights, horse power, human muscle, or some striking combinations of these. Plates 73 and 74 depict paper-making equipment and processes, which are "the clearest delineation of the art to this date" (Hunter, *The Literature of Papermaking*, page 18): they show the linen rags being pulped with water-powered hammers, while the vatman stands ready with a mould, the coucher presses the post, and the drying sheets hang on ropes above, ready to be sized, calendared, gathered into reams, and packaged. Plate 5 pictures a hand mill for making ink for copperplate printing. The last plate (no. 154) is extraordinary for its depiction of a fire engine water pump made by the Nuremberg inventor

Hans Hautsch in 1658. The suction-and-force mechanism of Hautsch's clever device (described on pp. 60-1 of Böckler's text) enabled twenty-four men to raise water to a height of eighty to one hundred feet in a continuous stream. Current historians of engineering view it as the basis of the modern fire engine. Among the other ingenious machines is a famous attempt at designing a perpetual motion machine (p. 59). However, Jakob (pp. 124-5) emphasizes that Böckler's work is at a higher technical level, and has far fewer 'miraculous machines' than other Baroque machine books, such as those of Agostino Ramelli and Salomon de Caus. Many of the engravings are familiar because they were plagiarized in technology publications for the next hundred years. Although the book appears with some regularity on the market, copies in such fine condition as ours are notably rare.

"It was in Germany that two of the most eminent engineering visionaries lived. The first of these was Georg Andreas Böckler who published a truly remarkable book … called *Theatrum Machinarum Novum*, written and illustrated as a record of the progress of the art of engineering.

"As one might gather, not just from the title page but from a knowledge of the general conditions pertaining in Germany after the Thirty Years' War, Böckler's acquaintance with machinery was restricted almost entirely to mills of one sort or another. In most of these, regardless of the motive power, he depicts the precursor of the geared transmission familiar to this day.

"The seventeenth-century engineers had neither the theoretical knowledge nor the technical equipment to design and shape gear-wheels which would mesh with minimum friction. In fact, friction as such, although made use of in such applications as the sack-lift in a mill, was little understood. The construction of pinions to mesh with larger gear-wheels had yet to assume the form common today. However, the problem of shifting the direction of rotation of a drive through 90° was solved by the invention of the *wallower* driven either by a contrite wheel (a wooden wheel with tooth pegs protruding around the circumference parallel to the axis) or by a cogwheel having teeth projecting radially around the circumference at right-angles to the axis … The wallower comprised two discs of wood, each drilled with a matching set of concentric holes near the perimeter. The discs, usually with square centre bores to aid fixing and to transmit rotary motion, were mounted on a shaft separate by a gap of as much as the mechanism dictated, and threaded through the holes, from one disc to the next, were wooden rods. The result looked not unlike a birdcage or lantern, hence its more common name. When it was meshed with a large wheel having suitably spaced wooden pegs around either its diameter (the contrite) or its periphery (the cog), depending on whether parallel or perpendicular motion was desired, a serviceable gear train was the result. Friction, though cut efficiency drastically. All this is depicted in Böckler's *Theatre of New Machines*" (Ord-Hume, *Perpetual Motion* (2015), pp. 47-8).

Among the many other remarkable mills illustrated in Böckler's Theatre, we mention Plate 72, which shows a 'fulling mill'. Fulling is a step in fabric production that involves pounding cloths to clean them. In the illustration, tappets, C, on the shaft, B, raise and lower mallets, D, which pound the woollen cloth. Other mills are used for grinding flour (Plates 37, 41, 46, 47, 59), for sharpening stones (Plate 34), and for sharpening tools and knives (Plate 36).

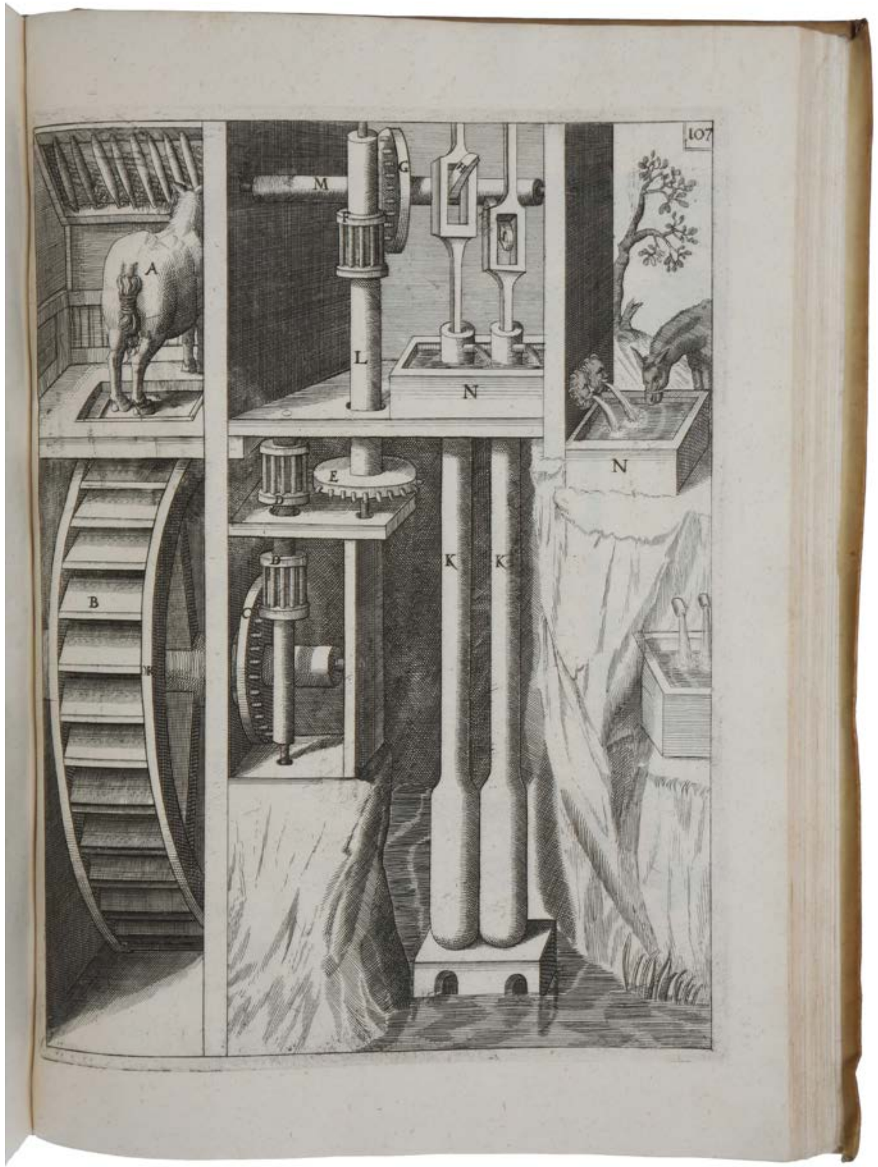
"The continuous rotary motion produced by the vertical water wheel was applied to both working wood and rolling and cutting metals during the medieval period, as well as to milling and grinding … The rotary motion of the water wheel may also have been used in the medieval period for other tasks. There is evidence … of water-powered chain-of-bucket or rag-and-chain pumps for draining mines" (Reynolds, *Stronger Than a Hundred Men*: *A History of the Vertical Water Wheel*

(2002), pp. 76-8). This last application is illustrated on Plate 116.

"Probably the most widely applied water-powered innovation in the food processing industry in this period was the mechanical bolter, used in flour mills to automatically sift flour. The bolter was basically a sheet or roll of wire mesh or cloth (most often canvas or linen, but sometimes silk or another fabric). The flour produced by the mill was fed through or over the device, which was shaken by a mechanism (several were possible) taking power from the drive train leading from the water to the millstones … The bolter depicted by Böckler [on Plate 45] indicates just how simple the device could sometimes be" (*ibid*, p. 138). Other devices powered by water wheels are an irrigation pump (Plates 35, 95, 98, 109, 110), a forge (Plate 79) with bellows and hammer powered by an undershot water wheel, and a corn mill (Plates 45, 46, 47).

The key breakthrough in fire-fighting arrived in the seventeenth century with the first fire engines. Manual pumps, rediscovered in Europe after 1500, were only force pumps and had a very short range due to the lack of hoses. Hans Hautsch (1595-1670) improved the manual pump by creating the first suction and force pump and adding some flexible hoses to the pump. His fire-engine consisted of a water cistern about 8 feet long, 4 feet high, and 2 feet in width, and was drawn on a kind of sledge somewhat larger than the cistern. It was worked by 28 men, and a stream of water an inch in diameter was forced, by means of this engine, to an elevation of nearly 80 feet. This remarkable machine is illustrated on Plate 154.

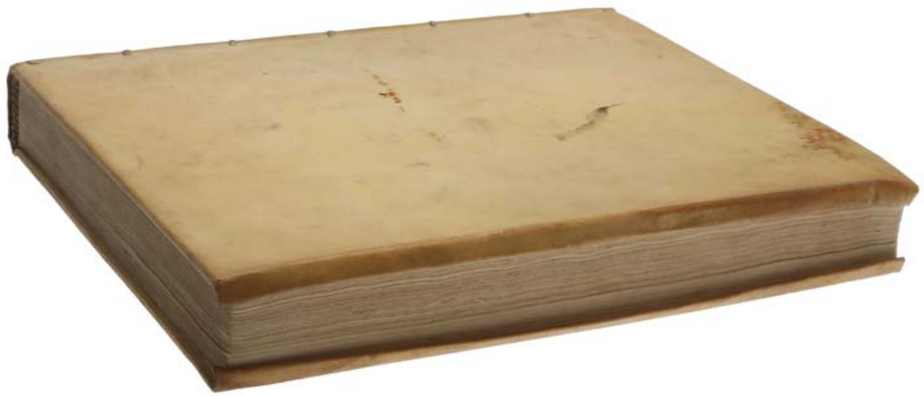
A recurring theme in the book is the perpetual motion machine. "The use of water-power seems particularly prone to implant the idea in the human mind. This is probably attributable to the assumption that water comes from nowhere in particular and costs Man nothing. This deludes the miller into assuming that his power costs him nothing by concealing the fact that his power is bought and



paid for in terms of units of energy and that it can be delivered to him but once. In any event, it would seem that the proprietor of a water-mill – especially of one whose driving stream was subject to seasonal diminutions of flow – was forever trying to make his water run back uphill and work for him again. Later and wiser mill engineers accumulated their energy when it was plentiful by constructing mill-ponds with sluice gates so that when the natural water flow was diminished, reserves could be drawn upon which did not defy the laws of Nature.

"Unfortunately for the peace of the medieval mind, it knew of at least one highly plausible scheme for making water run uphill. If the end of a pipe, coiled like the thread of a screw, is immersed in water, and the whole pipe rotated like a screw, the water will climb up the pipe and keep on climbing so long as the pipe is kept turning. This strange but perfectly workable invention is called an Archimedean screw … What we know and understand about the Archimedean screw is that the pipe must be turned by some outside agency. This illuminating piece of information was not understood by our ancestors who, with glinting eyes, asked 'What could be more simple than to connect such an Archimedean screw with the water-wheel of a mill, and make the mill run the screw, and the screw run the mill?' To Böckler, as to so many others both before and after his time, the answer was that nothing indeed was more simple. Böckler's mills, which he illustrated in plenitude, all worked on this principle … One notable feature of the Archimedean perpetual motion machine depicted here is the shape of the motive blades which bear a strong resemblance to the modern turbine" (Ord-Hume, pp. 48-50). This Archimedean screw arrangement is beautifully illustrated on Plate 54, which shows an overshot water wheel that powers a grindstone and an Archimedes screw that returns the water to the reservoir driving the wheel.

"Another means for making a mill raise the water for its own power which Böckler used in several instances consisted of a series of cups attached to an endless rope. The cups were expected to re-deliver the water direct to the wheel. But it was the self-moving wheel that appeared the most plausible. Here, with an apparent permanent preponderance of weights on one side of the wheel, once motion was started it seemed obvious that the wheel would not only rotate continuously but would generate enough power to pump water" (*ibid*., p. 50). This perpetual motion machine is illustrated on Plate 130: the water wheel, C, through the gearing network D, E, F G, H, I, drove a chain-of-buckets pump K which lifted water to reservoir A, from which the water wheel derived its power.



As Knoespel points out (p. 110), a comparison of Böckler' work with earlier machine books indicates the transformation then underway in the status of human beings relative to that of machines, "for the focal point within the illustrations has shifted from the human to the mechanical … Böckler shows a more developed awareness of how machines alter the status of workers was well as owners in his seventeenth-century illustrations. In one, a curtain has been drawn aside to reveal a couple at leisure eating dinner while the mill, tended by workers, operates on the floor beneath them (plate 53). Here the machine begins to determine the roles played by humans. The various illustrations portraying humans attentively watching a machine's operation indicate even further the centrality of the apparatus in the drama being portrayed."

Born in Cronheim ca. 1617, Böckler was an architect in Nuremberg. In addition to the present work he is the author of *Architectura Curiosa Nova* (Nuremberg, 1664), which dealt with the theory and application of hydrodynamics for water-jets, fountains and well heads with many designs for free-standing fountains. Böckler died in Ansbach in 1667.

Böckler's *Theatre* proved extremely popular, with later German editions appearing in 1673, 1703 and 1705, and Latin translations in 1662 and 1686.

Graesse I, 459; Stanitz 46; Zachert/Zeidler I, 220; [for the 1662 Latin edition see:] Macclesfield 2195; Horblit 132; Honeyman 359. Singer, *History of Technology* III.16-17. Hoover, *Bibliotheca De re Metallica*, 142 (for the 1686 Latin edition). Jakob, *Maschine. Mentales Modell und Metapher*. *Studien zur Semantik und Geschichte der Techniksprache*, 1991; Knoespel, 'Gazing on Technology: Theatrum Mechanorum and the Assimilation of Renaissance Machinery,' *Literature and Technology* (Greenberg & Schachterle, eds.), 1992, pp. 99-124.

BRAGG'S LAW OF CRYSTALLOGRAPHY

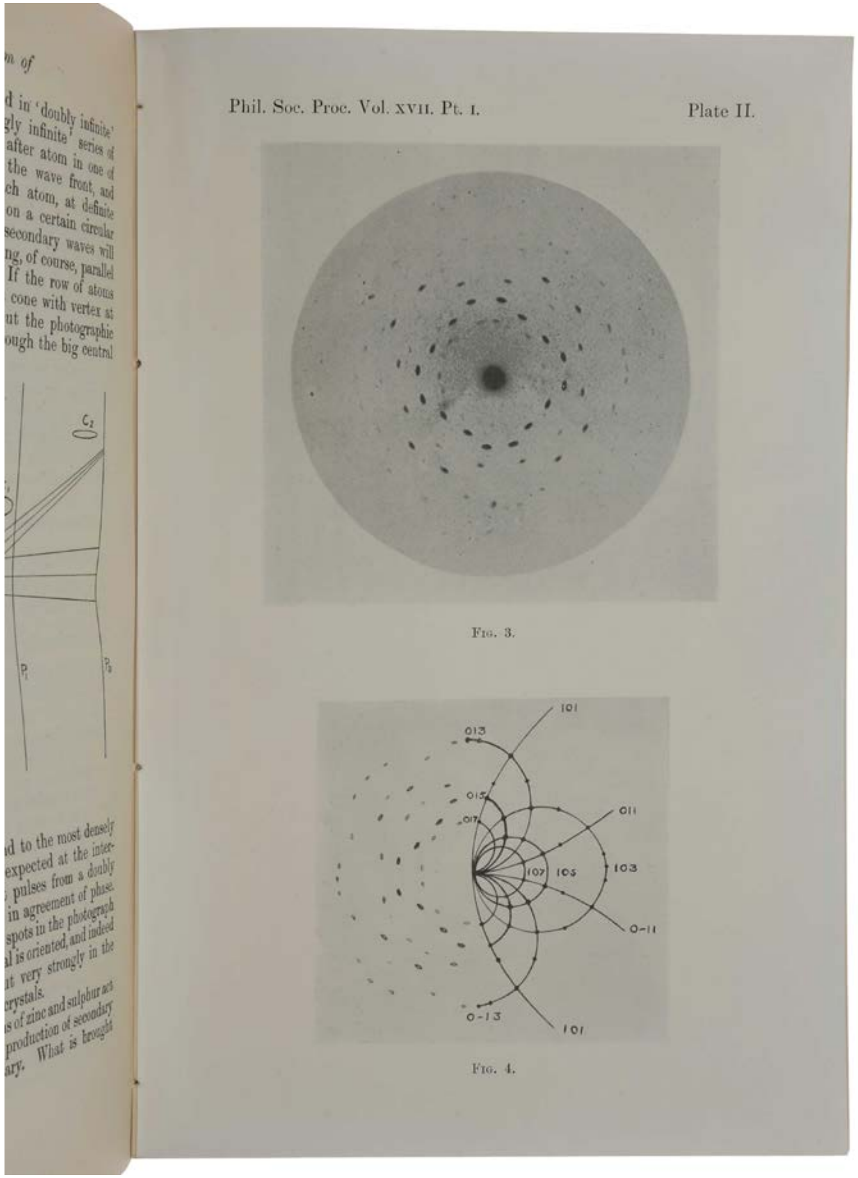
BRAGG, William Lawrence. *The diffraction of short electromagnetic waves by a crystal.* Cambridge: University Press, 1913.

$2,800

Pp. 43-57 in Proceedings of the Cambridge Philosophical Society, Vol. XVII, Part 1. 8vo, pp. 159. Original printed wrappers (front wrapper with library ink stamp and a few tiny chips to edges).

First edition, journal issue, of this epoch-making paper, which introduced "Bragg's law" of X-ray crystallography. "The importance of this work cannot be overstated, for it heralded a revolution in the scientific understanding of crystals and their atomic arrangements. This discovery led to many of the most important scientific achievements of the last century, and these continue to the present day. This paper was the beginning of the field of X-ray crystallography, a subject that has enabled us to establish the complete structures of crystals, starting from the very simple to the most complex materials, such as proteins, viruses and the molecule that forms the very essence of life, namely DNA. Around 20 or so Nobel Prizes have been awarded for research that has used the ideas described in this paper. Modern genetics, medicine and the study of materials owe an incalculable debt to William Lawrence, who at the astonishingly young age of 22, made a discovery that has changed our understanding of the world around us. Both father and son shared the 1915 Nobel Prize for their work, with William Lawrence remaining to the present day the youngest Nobel Prize winner ever" (*Bragg Centenary 1913-2013*).

"Bragg started his first important work as a result of the claim–made in 1912 by Friedrich, Knipping, and Laue–that they had observed the diffraction of



X-rays by a crystal. William Henry Bragg [Lawrence's father], who advocated a corpuscular theory of X-rays, was greatly interested in Laue's work, despite the fact that the observed effect was explained in terms of, and strongly supported Barkla's alternative wave theory of X-radiation. Lawrence and his father discussed Laue's findings in 1912, and William Henry developed the theory that the diffraction effect might be explicable as the shooting of corpuscles down avenues between lines of atoms in crystals. Bragg seems to have found this suggestion unconvincing, although he was careful not to contradict his father in public, and after further study of Laue's paper, came to the conclusion that this was indeed a diffraction effect … In his paper Laue had calculated the conditions for diffracted intensity maxima for the simple cubic system where the incident beam was parallel to one side of the cell … While Bragg concurred with Laue's identification and treatment of the problem, he nonetheless, in an impressive display of physical insight, reconceptualized the effect as that of the reflection of X rays off crystal planes, and formulated this in the expression $L = 2d \cos i$, which showed the relationship between angle of incidence i, wavelength L, and distance between parallel atomic planes d. (This expression … became universally known in the community of crystallographers as "Bragg's law.") This reworking was of far-reaching significance, for when compared with Laue's expression, Bragg's law (and the notion of reflection) rendered the process of diffraction easier to visualize and simplified calculation–advantages that were particularly important in the early development of X-ray crystallography" (DSB).

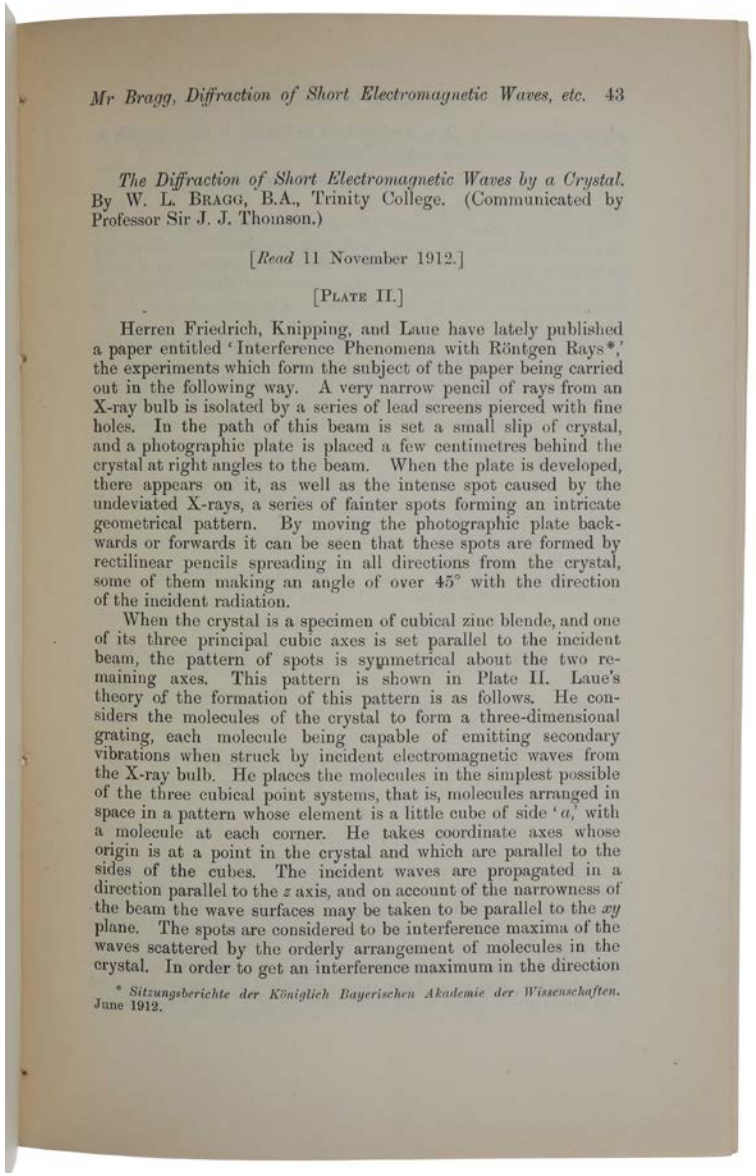
"The history of modern Crystallography is intertwined with the great discoveries' of William Lawrence Bragg (WLB), still renowned to be the youngest Nobel Prize in Physics. Bragg received news of his Nobel Prize on the 14th November 1915 in the midst of the carnage of the Great War. This was to be shared with his father William Henry Bragg (WHB), and WHB and WLB are to date the only father and son team to be jointly awarded the Nobel Prize. Experiments made in early 1912 by a German team working under the physicist Max Laue, had shown that X-rays could be scattered by a crystal, but they could not quite explain their results in full. It was WLB, at the age of 22 years, who worked out how to interpret their results and how to determine the atomic structures of crystalline solids for the first time. Father and son subsequently continued to work together, solving many crystal structures, including that of common salt and diamond, until the outbreak of the Great War in 1914. Following the war, both WLB and WHB set up renowned research groups devoted to Crystallography, producing ever more important discoveries that have led to over 26 Nobel Prizes.

"WLB came from a middle-class family originating in Cumbria. He was brought up initially in Adelaide, Australia but then moved to England with his parents in 1906, where he was further educated in Cambridge. It was there that he met his wife-to-be, Alice Grace Jenny Hopkinson. She came from a totally different background, one related to the aristocracy and even to royalty. Unlike WLB, Alice had no understanding of science and was of a very different personality. He was shy, private, given to periods of depression, and intensely focussed on his research. Nonetheless he had many outside interests too; bird-watching, gardening, travelling, and especially sketching and painting, and was devoted to his family. It may be that it was this artistic bent, with his keen visual acuity, that enabled WLB at such a young age to succeed where the German scientists had failed, for Crystallography is both a mathematical and visual science. He was certainly not a member of the establishment. Alice, on the other hand, was lively, outgoing and forthright in expressing her opinions. And yet, despite these huge differences, they formed a love-match that persisted throughout all their lives together.

"The story about WLB and his discoveries, his scientific achievements, especially those leading to many Nobel Prizes, have been well documented. However little has been made known about Alice. Fortunately, both left behind hitherto unpublished autobiographies, which reveal much about their personalities and the events that shaped their lives.

“WLB’s account begins with his early years in Australia, his move to England and his famous discovery, followed by his close involvement in his work during Wold War I, where his experiments on sound-ranging enabled the enemy guns to be located with some precision. This is described in much detail. His autobiography is accompanied by many of his sketches made during his extensive travels, and he describes the many famous people whom he met and with whom he worked. Alice’s autobiography gives much detail about her early family members, some of whom were part of the German upper classes. She describes their personalities as well as their idiosyncrasies. After her marriage to WLB, she immersed herself in public duties, becoming Mayor of Cambridge, and Chair of the Marriage Guidance Council, among many other activities. She is particularly revealing about her attitudes to certain individuals within the Royal Society, who shunned her husband after he took over the Directorship of the Royal Institution following a rancorous affair that ended with the ousting of the previous Director. She has interesting comments to make too over WLB’s controversial willingness to write a Foreword to James Watson’s famous book, *The Double Helix*, in which WLB was compared unflatteringly to Colonel Blimp. Watson has since claimed that it was Lady Bragg who persuaded her husband to write this, but in her autobiography she makes it clear that it was WLB’s decision alone.

“WLB will be remembered, not only for his scientific research, but also for his impact on the many schoolchildren who attended his Schools’ Lectures at the Royal Institution. Approximately 20,000 children attended each year over a ten-year period. These lectures were filled with amazing practical demonstrations covering all areas of science. WLB used to say that he wanted to *show* science to children.



Mr Bragg, Diffraction of Short Electromagnetic Waves, etc. 43

The Diffraction of Short Electromagnetic Waves by a Crystal. By W. L. Bragg, B.A., Trinity College. (Communicated by Professor Sir J. J. Thomson.)

[*Read* 11 November 1912.]

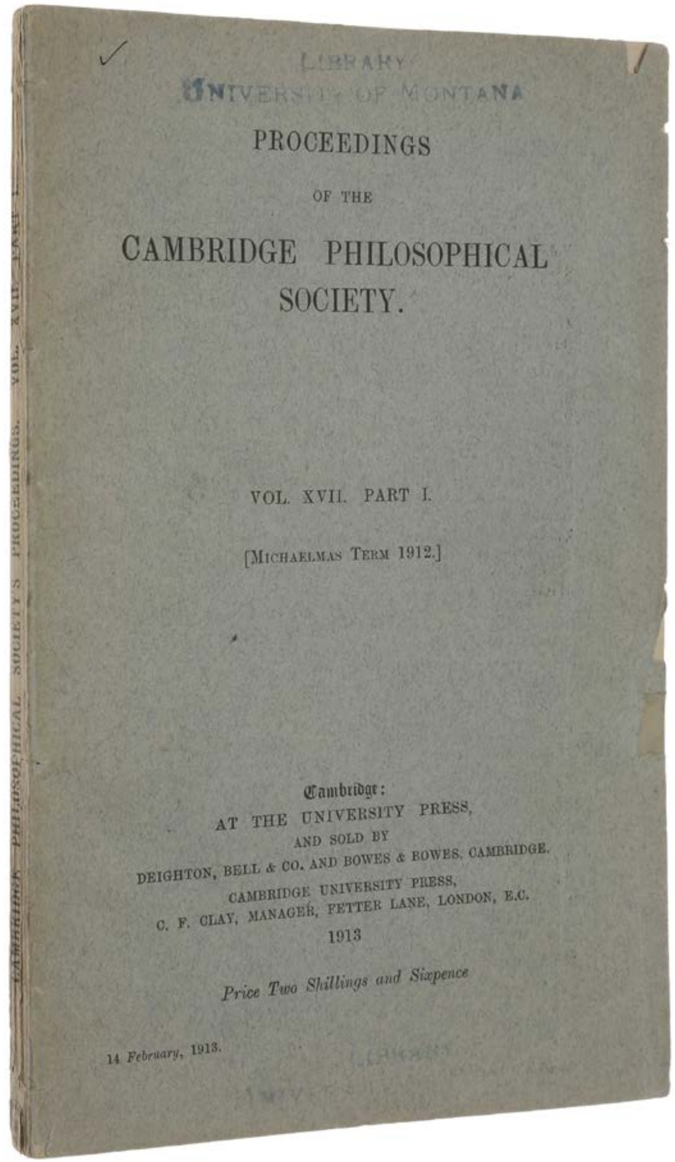
[Plate II.]

Herren Friedrich, Knipping, and Laue have lately published a paper entitled ‘Interference Phenomena with Röntgen Rays*,’ the experiments which form the subject of the paper being carried out in the following way. A very narrow pencil of rays from an X-ray bulb is isolated by a series of lead screens pierced with fine holes. In the path of this beam is set a small slip of crystal, and a photographic plate is placed a few centimetres behind the crystal at right angles to the beam. When the plate is developed, there appears on it, as well as the intense spot caused by the undeviated X-rays, a series of fainter spots forming an intricate geometrical pattern. By moving the photographic plate backwards or forwards it can be seen that these spots are formed by rectilinear pencils spreading in all directions from the crystal, some of them making an angle of over 45° with the direction of the incident radiation.

When the crystal is a specimen of cubical zinc blende, and one of its three principal cubic axes is set parallel to the incident beam, the pattern of spots is symmetrical about the two remaining axes. This pattern is shown in Plate II. Laue’s theory of the formation of this pattern is as follows. He considers the molecules of the crystal to form a three-dimensional grating, each molecule being capable of emitting secondary vibrations when struck by incident electromagnetic waves from the X-ray bulb. He places the molecules in the simplest possible of the three cubical point systems, that is, molecules arranged in space in a pattern whose element is a little cube of side ‘a,’ with a molecule at each corner. He takes coordinate axes whose origin is at a point in the crystal and which are parallel to the sides of the cubes. The incident waves are propagated in a direction parallel to the z axis, and on account of the narrowness of the beam the wave surfaces may be taken to be parallel to the xy plane. The spots are considered to be interference maxima of the waves scattered by the orderly arrangement of molecules in the crystal. In order to get an interference maximum in the direction

* *Sitzungsberichte der Königlich Bayerischen Akademie der Wissenschaften.* June 1912.

"WLB and his father can truly be said to have transformed all our lives, for their work has enabled us to understand the structures of metals, organic and inorganic compounds, pharmaceuticals, proteins, viruses, and just about everything that exists in solid form. It is interesting to speculate what the world would look like had WLB not made his discovery so long ago" Glazer, 'William Lawrtence Bragg and Crystallography,' blog.oup.com/2015/08/lawrence-bragg-crystallography/).



PMM 417 - MATTER A FORM OF ENERGY

BROGLIE, Louis Victor Pierre Raymond de. *Ondes et Mouvements. Collection de Physique Mathématique. Fascicule I.* Paris: Gauthier-Villars, 1926. [Offered with:] *La Mecanique Ondulatoire. Premier Fascicule du Mémorial des Sciences Physiques.* [*Ibid.*], 1928.

$2,800

8vo (251 x 167 mm), pp. vi, 133 [1], [6]; [6] 57, original printed wrappers, light sunning and very light wear to extremeties, some contemporary annotations in the text.

First edition of these expanded presentations of the ideas in de Broglie's epoch-making doctoral thesis on the quantum theory, which, Einstein said, "lifted a corner of the great veil" (Isaacson, *Einstein: His Life and Universe*, p. 327). In that work he developed the startling and revolutionary idea that material particles such as electrons have a wave as well as a corpuscular nature, analogous to the dual behavior of light demonstrated by Einstein and others in the first two decades of the twentieth century. "He made the leap in his September 10, 1923, paper ['Ondes et quanta,' *Comptes Rendus*, t. 177]: $E = h\nu$ should hold not only for photons but also for electrons, to which he assigns a 'fictitious associated wave'" (Pais, *Subtle is the Lord*, p. 436). "Louis de Broglie achieved a worldwide reputation for his discovery of the wave theory of matter, for which he received the Nobel Prize for physics in 1929. His work was extended into a full-fledged wave mechanics by Erwin Schrödinger and thus contributed to the creation of quantum mechanics" (DSB). De Broglie was awarded the 1929 Nobel Prize in physics "for his discovery of the wave nature of electrons." De Broglie's book *Ondes et mouvements* (1926) was selected by Carter and Muir for the *Printing and the Mind of Man* exhibition and catalogue (1967).

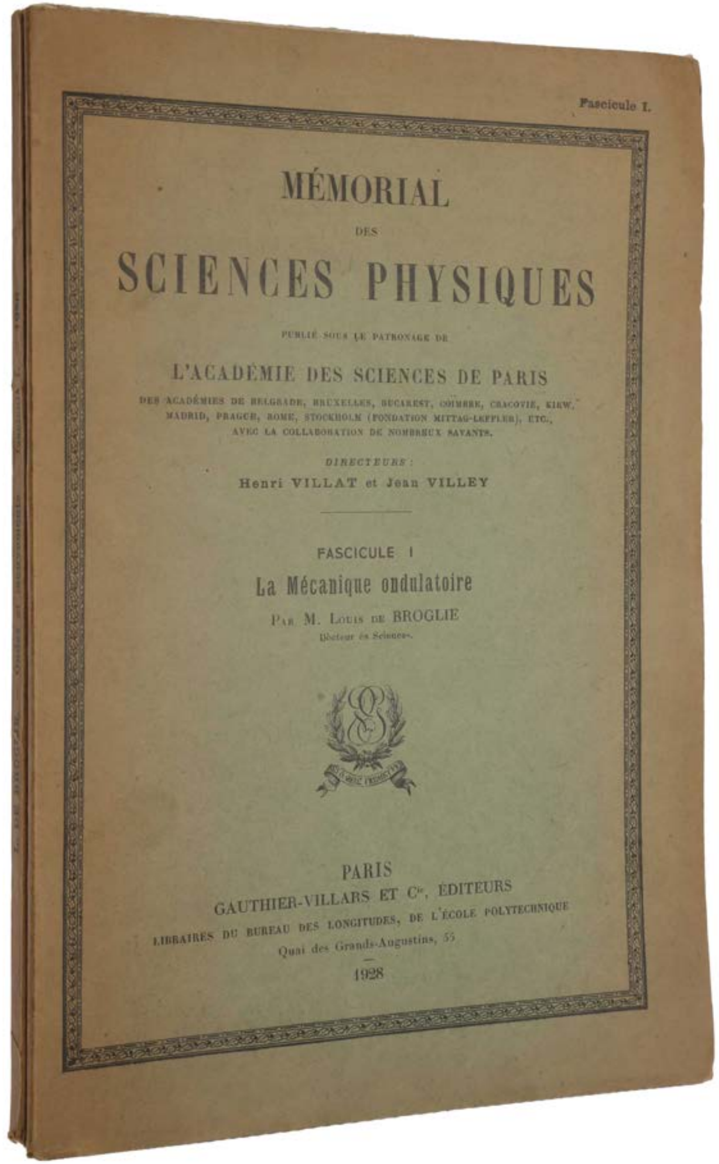
In his 1905 paper 'Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt' ('On a Heuristic Viewpoint Concerning the Production and Transformation of Light'), "Einstein postulated that light is composed of individual quanta (later called photons) that, in addition to wavelike behavior, demonstrate certain properties unique to particles. In a single stroke he thus revolutionized the theory of light and provided an explanation for, among other phenomena, the emission of electrons from some solids when struck by light, called the photoelectric effect" (*Britannica*). "The central idea of de Broglie's work … was that the formula $E = hv$ by which Einstein had related the frequency v of light to the energy E of light quanta should not only apply to light but also to material particles. For a particle at rest with mass m he concluded, since its energy is $E = mc^2$, that it performs an internal oscillation with frequency $v = mc^2/h$. He considered the motion of a particle, carefully taking into account the effects of the special theory of relativity, and was able to construct a wave which was always *in phase* with the internal oscillation of the particle … he gave an application of his theory by showing that he could naturally explain the discrete electron orbits in Bohr's model of the hydrogen atom. Each stable orbit should be closed in the sense that the same phase should be assumed by the matter wave after completion of an orbit" (Brandt, *The Harvest of a Century*, Chapter 32, p. 133).

In a second *Comptes Rendus* note, De Broglie also predicted on the basis of his theory that 'a stream of electrons traversing a very small aperture will show the phenomenon of diffraction.' This was experimentally observed by C. J. Davisson and L. H. Germer in 1927, work for which they received the Nobel Prize in Physics in 1937. "Thus the duality of both light and matter had been established, and physicists had to come to terms with fundamental particles which defied simple theories and demanded two sets of 'complementary' descriptions, each applicable under certain circumstances, but incompatible with one another" (PMM 417). Finally, in a third note, De Broglie derived from his theory "a result of Planck on the kinetic theory of gases, by making the assumption that 'the state of a gas will be stable only if the waves corresponding to all the atoms form a system of stationary waves.' He also showed that "the interplay between the propagation of a particle and of its associated matter wave could be expressed in more formal terms as an identity between the fundamental variational principles of Pierre de Fermat (rays), and Pierre Louis Maupertuis (particles)" (DSB).

When de Broglie first published his theory of matter waves he was practically unknown in scientific circles, although his elder brother Maurice had already done important experimental work on X-rays and his illustrious family was famous in France. His ideas became widely known only with the publication of his doctoral thesis *Recherches sur la théorie des quanta* in the summer of 1924, which is an elaboration of the content of the three *Comptes Rendus* notes. Einstein's support for de Broglie's ideas brought them to the attention of the principal actors in the development of quantum theory, notably Schrödinger, whose wave mechanics was an extension and completion of de Broglie's work. An account of Schrödinger's development of de Broglie's ideas into what became wave mechanics is given in the 1928 work offered here.

"In his communications of 1923, and later in his 1924 PhD thesis, de Broglie did not want to commit himself to any physical interpretation of the waves. He granted physical relevance only to these wave features which could be directly related to the particle motion, namely their phase, while eluding any questions pertaining to their amplitude and proper dynamics. They were, as he dubbed them, "fictitious." However, in the months following his PhD, de Broglie started to explore the consequences of his wave-particle model for the problem of the interaction of light with matter. He also considered the possibilities of more physically interpreting his particle-associated waves. Willing to acknowledge the reality of the particles, he tried to conceive them as embodied by the singularities of the waves. However, he had then to cope with the Schrödinger view, where only continuous matter waves were considered. He first attempted to save his dualism by conceiving Schrödinger's equation as actually admitting pairs of solutions characterized by a common phase. He thought of each pair as consisting of a singular solution, with the singularity identified with the particle, while the corresponding continuous regular solution (the only one considered by Schrödinger) was interpreted as conveying solely statistical information. In this approach, the probabilistic (Max Born's) interpretation of the continuous wave reflected the inherent neglect of the singularity (the particle). This so-called double-solution interpretation was hence a causal one, conceiving Schrödinger waves as conveying all the potential outcomes, while concealing the realities of the underlying particle dynamics. These dynamics were non-classical, owing to the fundamental fact that the particle was coupled to the wave via the guiding mechanism which related the particle's velocity to the gradient of the wave phase" (DSB). "In early 1926, Louis de Broglie published a book, *Ondes et Mouvements*, in which he outlined the main results of his 'phase wave' approach to atomic theory" (Mehra & Rechenberg, *Historical Development of Quantum Theory*, Vol. 5, p. 686, n. 105).

Norman 348; *PMM* 417 (both for *Ondes et Mouvements*).



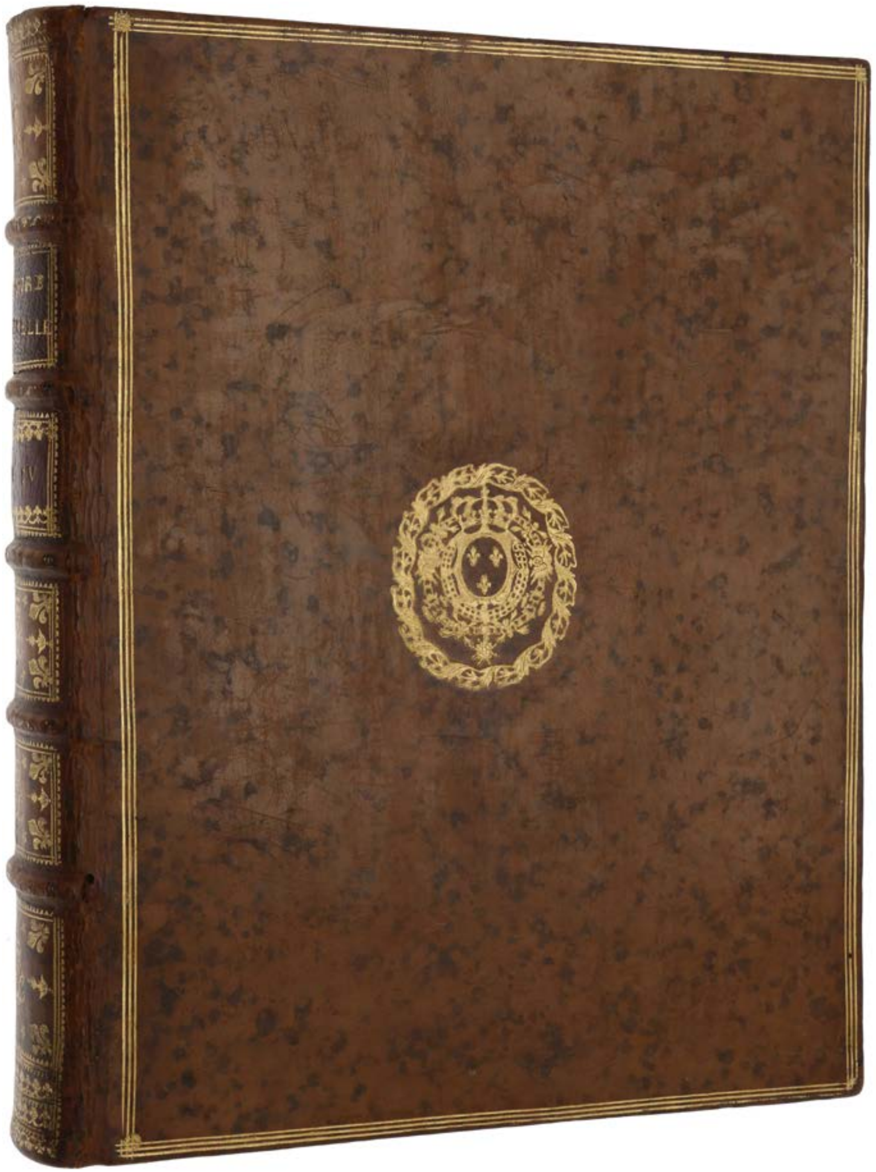
PMM 198 - AN EXCEPTIONALLY FINE SET BOUND WITH THE ARMS OF LOUIS XVI

BUFFON, Georges-Louis Leclerc, Comte de. *Histoire Naturelle, Générale et Particulière, avec la Description du Cabinet du Roi*. Paris: Imprimerie Royale, 1749–1804. Comprising: *Histoire naturelle, générale et particulière, avec la description du Cabinet du Roi*, 15 vols, 1749–67; *Histoire naturelle des oiseaux*, 9 vols, 1770–83; *Histoire naturelle des minéraux*, 5 vols, 1783–88; *Supplément à l'histoire naturelle*, 7 vols, 1774–89; *Histoire naturelle des quadrupèdes ovipares et des serpens*, 2 vols, De Thou, 1788–89; *Histoire naturelle des poissons*, 5 vols, Plassan, An VI–XI (1798–1803); *Histoire naturelle des cétacés*, 1 vol, Plassan, 1804.

$95,000

44 vols., 4to (252 x 193 mm), with engraved vignettes on the titles of the first 15 vols., numerous engraved headpieces, and 1262 engraved plates (including two allegorical plates in vol. I and engraved portrait frontispiece in first vol. of Supplément), 12 maps, and 4 folding tables, complete with the polar bear plate which is often missing (half-title of Vol. V misbound at beginning of vol. IV). Contemporary, and uniform, marbled calf, covers with gilt fillet and gilt arms of Louis XVI in the centre, his monogram in each spine panel, spines richly gilt with two red-morocco lettering-pieces.

First edition, a fine and absolutely complete copy in unrestored contemporary French calf of this monumental work, "the most celebrated treatise on animals ever produced" (Dibner), but also including treatises on cosmology, geology and palaeontology. This copy was almost certainly bound for a member of the Royal family. All volumes have the arms of Louis XVI on the covers and in the



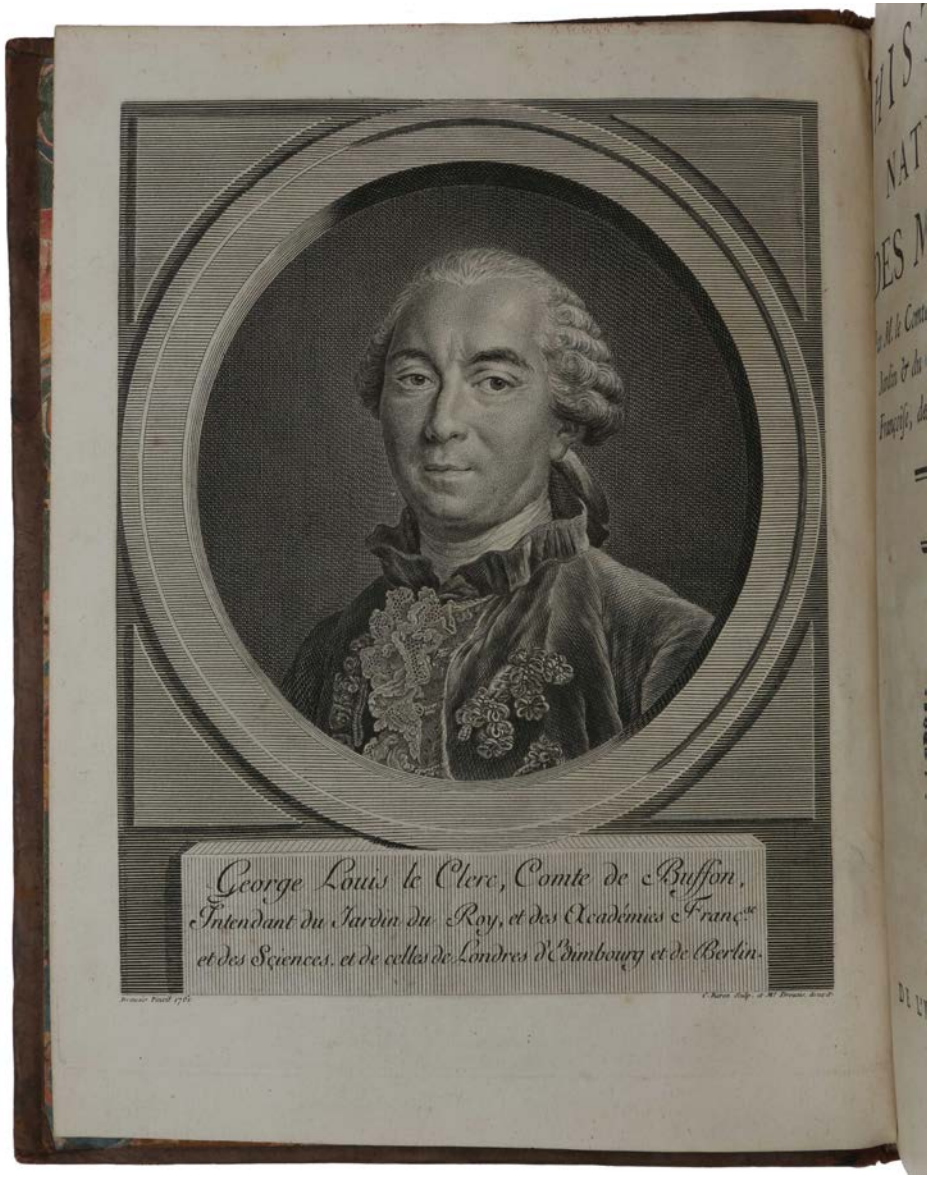
spine panels – we have found only one other copy with these arms on the covers and spines, namely that in the Bibliothèque nationale, which was bound in red morocco, presumably for the King himself. Buffon "was the first to present the universe as one complete whole and to find no phenomenon calling for any but a purely scientific explanation" (PMM). "Buffon's work is of exceptional importance because of its diversity, richness, originality, and influence. Buffon was among the first to create an autonomous science, free of any theological influence. He emphasized the importance of natural history and the great length of geological time. He envisioned the nature of science and understood the roles of paleontology, zoological geography, and animal psychology. He realised both the necessity of transformism and its difficulties" (DSB). This work also represents the birth of evolutionary theory. "Georges Buffon set forth his general views on species classification in the first volume of his *Histoire Naturelle*. Buffon objected to the so-called 'artificial' classifications of Andrea Cesalpino and Carolus Linnaeus, stating that in nature the chain of life has small gradations from one type to another and that the discontinuous categories are all artificially constructed by mankind. Buffon suggested that all organic species may have descended from a small number of primordial types; this is an evolution predominantly from more perfect to less perfect forms" (Parkinson). "It is a great pity that his [Buffon's] ideas were scattered and diffused throughout the vast body of his Natural History with its accounts of individual animals. Not only did this concealment make his interpretation difficult, but it lessened the impact of his evolutionary ideas … However, almost everything necessary to originate a theory of natural selection existed in Buffon. It needed only to be brought together and removed from the protective ecclesiastical coloration which the exigencies of his time demanded" (Eiseley, p. 45). In addition to its comprehensive coverage of natural history (including mankind) and minerals, the work incorporates in the first volume Buffon's highly important *Théorie de la terre*, elaborated in the fifth volume of the *Supplément* as *Des Époques de la nature* – these treatises contain Buffon's theory that the earth was created by a collision between the sun and a comet, the first attempt to reconstruct geological history in a series of stages, and his notion of 'lost species', which opened the way to the development of palaeontology. Like that other great product of the enlightenment, the *Encyclopédie*, the *Histoire Naturelle* was a collaborative enterprise, outliving its instigator and chief author. The two scientists who were foremost among the several contributors were Daubenton and Lacépède (first as Comte de, then as Citoyen): they completed the work after Buffon's death in 1788. We purchased the present copy from a collector who had acquired it at auction in 1973 (Priollaud & Lavoissière, La Rochelle, 18/19 October); the auction catalogue (included here) singles out the Buffon for mention on its front cover.

"Buffon's monumental *Histoire Naturelle, Générale et Particulière*, his one great work, was the principal commercial rival to Diderot's thirty-five volume *Encyclopédie*, the most impressive publishing venture of the age, and the two have often been compared. Like the *Encyclopédie*, the *Histoire Naturelle* was a vast repository of authenticated fact that remained in use as a general reference work long after the death of its compiler. It differed from the *Encyclopédie*, however, in that the presentation of factual data was everywhere subordinated to the steady unfolding of a singularly unified world view. Buffon, like Diderot, employed collaborators, but only a few and never on the basis of equality; their contributions, by their own efforts and his editing, were transformed into pastiches of his style; the guiding ideas were always his. The *Encyclopédie* was a team effort, given a measure of unity by the organising genius of Diderot; the *Histoire Naturelle*, despite assistance received, was entirely Buffon's.

"In the early 1740s, following his appointment as superintendent of the Jardin du Roi in Paris, Buffon undertook the preparation of an analytical and descriptive catalogue of the Jardin's already extensive collection of botanical and zoological specimens, and the *catalogue raisonné* shortly developed into the *Histoire Naturelle* … The thirty-five volumes he himself saw through the press included three general introductory volumes, twelve volumes on mammals, nine volumes on birds, five volumes on minerals, and six volumes entitles *Suppléments*.

"In the more general essays, Buffon digressed freely, touching upon (or discussing at considerable length) a variety of moral, social, theological, and philosophical questions that have little obvious connection to natural history … On the whole, however, the *Histoire Naturelle* was devoted to matters more suitable for presentation to the Académie Royale des Sciences, of which Buffon was perpetual treasurer, such as accounts of experiments he himself had performed, extended descriptions of specimens gathered from the four corners of the earth, general, definitive descriptive accounts of mammals, birds, and minerals, and the exposition of theories concerning the probably interrelationships of the phenomena described" (Fellows & Milliken, pp. 21-2).

"Buffon's longest and most ambitious project within his central work, the *Histoire Naturelle*, was his attempt to extract a simple and straightforward account of the origin and development of the 'terraqueous globe' from data drawn from the almost brand-new earth sciences of his time. The first essay to be completed, *La Théorie de la Terre* (Vol. I), was dated 1744, and the definitive essay, the most famous of all his essays, the *Époques de la Nature* (Supp. Vol. V), was published in 1773, a third of a century later … the field of cosmogony, the elaboration of a general theory explaining both the origin and 'mechanism' of the solar system and the earth itself, seemed to offer an opportunity to 'complete' the work of Sir Isaac Newton, to add something new, something definitely Buffonian, to the fundamental principles of the 'New Physics' created by Newton, and thus to assume, in the eyes of future generations, a stature equal to that of Newton himself" (*ibid*., p. 66).



"In the *Théorie de la terre*, Buffon, like most of his contemporaries, states neptunian views. He has no hesitations about animal or plant fossils or the stratigraphic principles set forth by Steno. The presence of sea fossils and sedimentation of rock beds indicate former submersion of present continents, of which the topography, shaped under the water by ocean currents, is diminished by erosion and the action of the waters that carry earth to the sea. No explanation of the re-emergence of formerly submerged continents is offered. Buffon resolutely refused to accept the notion of catastrophes, including the biblical flood, which many of his contemporaries upheld. He offered several hypotheses (such as subsidence of the ground or earthquakes) to account for the displacement of the sea, but he insisted that such changes 'came about naturally'. Buffon was an advocate of 'real causes': 'In order to judge what has happened, or even what will happen, one need only examine what is happening… Events which occur every day, movements which succeed each other and repeat themselves without interruption, constant and constantly reiterated operations, those are our causes and our reasons'.

"On the other hand, in his cosmogony Buffon also rejected slow causes. According to Newton, planets and their movement had been created directly by God: this was the only possible explanation of the circumstance that the six planets then known revolved in the same direction, in concentric orbits, and almost on the same plane. Buffon's cosmogony was designed to replace the intervention of God by means of a natural phenomenon, a 'cause whose effect is in accord with the laws of mechanics'. He then hypothesized that a comet, hitting the sun tangentially, had projected into a space a mass of liquids and gases equal to 1/650 of the sun's mass. These materials were then diffused according to their densities and reassembled as spheres which necessarily revolved in the same direction and on almost the same plane. These spheres turn on their own axis by virtue of the obliquity of the impact of the comet on the sun; as they coalesced, they assumed the form of spheroids flattened on both poles. Centrifugal force, due to their rapid rotation, tore from these spheres the material that then became the satellites of the new planets.

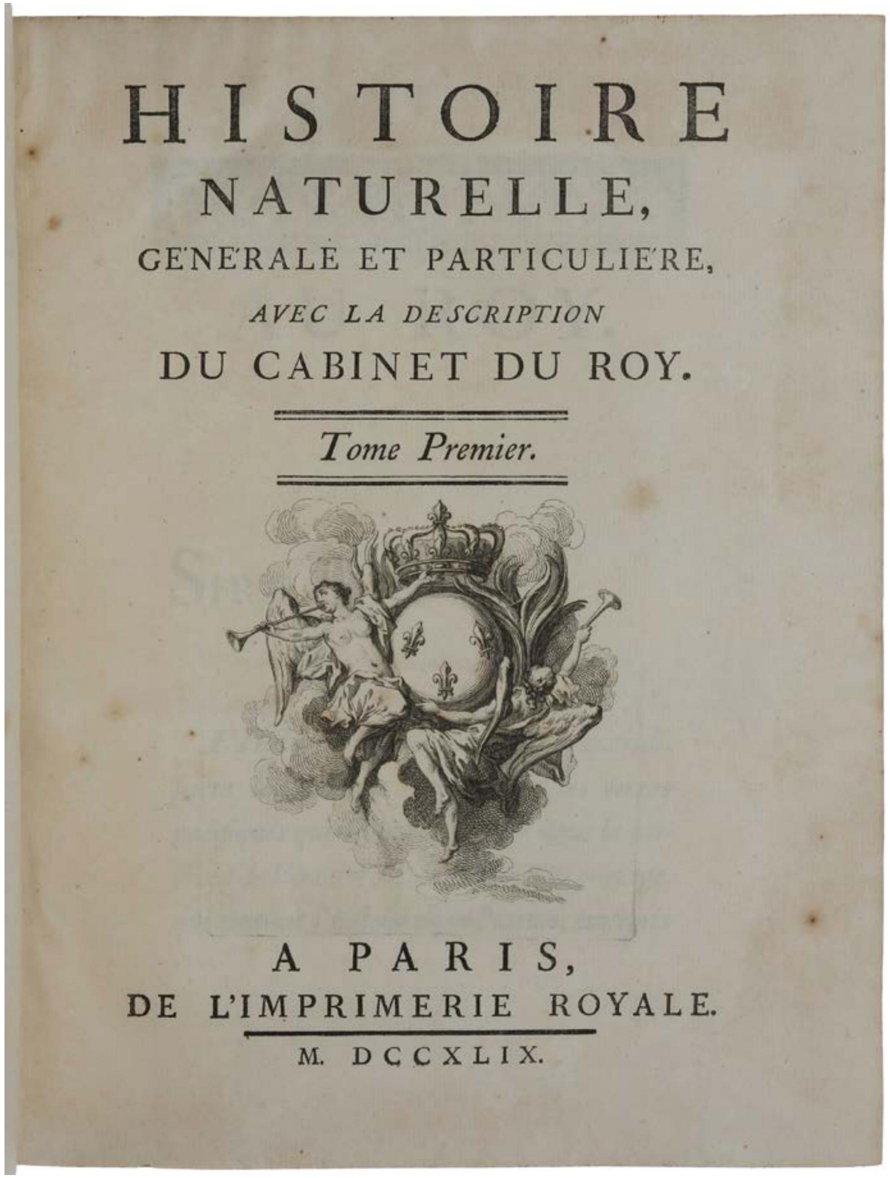
"This cosmogony, one of the first based on Newtonian celestial mechanics, is remarkable for its coherence. It is founded on the then generally accepted idea that comets are very dense stars, at least at their nucleus. But it also raises some serious difficulties, which were brought to light by Euler: according to the laws of mechanics, the material torn from the sun should have fallen back into it after the first revolution; the densest planets should be farthest away from the sun; and the planetary orbits should always coincide at the point of initial impact. Finally, as early as 1770, it became apparent that comets had a very low density, which destroyed the impact hypothesis.

"The *Époques de la nature* presents a plutonian history of the earth—a piece was torn from the sun, the mass took form, the moon was torn from it by centrifugal force, and then the globe solidified during the first epoch. In the course of this solidification, primitive mountains, composed of 'vitreous' matter, and mineral deposits were formed (marking the second epoch). The earth cooled, and water vapors and volatile materials condensed and covered the surface of the globe to a great depth. The waters were soon populated with marine life and displaced the 'primitive vitreous material', which was pulverized and subjected to intense chemical activity. Sedimentary soil was thus formed, derived from rocks composed of primitive vitreous matter, from calcareous shells, or from organic debris, especially vegetable debris such as coal. In the meantime, the water burst through the vaults of vast subterranean caverns formed during the cooling period; as it rushed in, its level gradually dropped (third epoch). The burning of the accumulated combustible materials then produced volcanoes and earthquakes, the land that emerged was shaped in relief by the eroding force of the waters (fourth epoch). The appearance of animal life (fifth epoch) preceded the final separation of the continents from one another and gave its present configuration to the surface of the earth (sixth epoch) over which man now rules (seventh epoch).

"This work is of considerable interest because it offers a history of nature, combining geology with biology, and particularly because of Buffon's attempt to establish a universal chronology. From his experiments on cooling, he estimated the age of the earth to be 75,000 years. This figure is considerable in comparison to contemporary views which set the creation of the world at 4000–6000 BC. In studying sedimentation phenomena, however, Buffon discovered the need for much more time and estimated a period of as long as 3,000,000 years. That he abandoned that figure (which appears only in the manuscript) to return to the originally published figure of 75,000 years, was due to his fear of being misunderstood by his readers. He himself thought that 'the more we extend time, the closer we shall be to the truth' (*Époques de la nature*, p. 40).

"The *Époques de la nature* contains a great deal of mineralogical material that was restated and elaborated in the *Histoire naturelle des minéraux*. Buffon's work on mineralogy was handicapped by its date of appearance, immediately before the work of Lavoisier, Haüy, and Romé de I'Isle. Although it was soon out of date, Buffon's book does contain some interesting notions, particularly that of the 'genesis of minerals', that is, the concept that present rocks are the result of profound transformations brought about by physical and chemical agents. Buffon did not have a clear concept of metamorphic rocks, however. It is also noteworthy that Buffon was one of the first to consider coal, 'the pyritous and bituminous matter', and all of the mineral oils as products of the decomposition of organic matter.

"In the second volume of the *Histoire naturelle* (1749), Buffon offers a short treatise on general biology entitled *Histoire des animaux*. He takes up this subject again in the *Discours sur la nature des animaux* (Vol. IV) and in a great many later texts.



Although he deals with nutrition and development in these, he is most interested in reproduction. This, of course, was a question much discussed at that time, but for Buffon reproduction represented the essential property of living matter.

"Buffon rejected the then widely accepted theory of the pre-existence and preformation of embryos. He spurned its dependence on the direct intervention of God and held it to be incapable of explaining heredity. He further refuted the connected theories of ovism and animalculism because no one had actually seen the egg of a viviparous animal and because spermatozoa were not 'animalcules', but rather aggregates of living matter that were also to be found in female sexual organs …

"He set forth the principle of epigenesis because it exists in nature and allows heredity to be understood. Buffon revived the ideas of certain physicians of the late seventeenth century who were faithful to an old tradition, and assumed that nutritive matter was first used to nourish the living being and then was utilized in the reproduction process when growth was completed. After being ingested, the nutritive matter received a particular imprint from each organ, which acted as a matrix in the reconstitution of that organ in the embryo. But Buffon departs from his predecessors on two points: (1) he sees the action of these molds as capable of modifying the nutritive substance internally, due to 'penetrating forces' (conceived of on the basis of Newtonian attraction), and (2) he considers nutritive material to be already living. Buffon also conceived of living universal matter composed of "organic molecules", which are a sort of living atom. His thinking was therefore formed by a mechanistic tradition, complicated by Newton's influence, and balanced by a tendency toward vitalist concepts.

"This tendency diminished as time passed. In 1779, in the *Époques de la nature*, Buffon dealt with the appearance of life on the earth—that is, the appearance of living matter, or organic molecules. He explained that organic molecules were born through the action of heat on "aqueous, oily, and ductile" substances suitable to the formation of living matter. The physicochemical conditions that made such formation possible were peculiar to that period of the earth's history; consequently spontaneous generation of living matter and organized living creatures can no longer occur. Buffon thus resolved the contradiction in his text of 1749, in which he maintained that while living matter was totally different from the original matter, nevertheless 'life and animation, instead of being a metaphysical point in being, is a physical property of matter' …

"Because he rejected the concept of family and denied the value of making classifications, Buffon also rejected, at the beginning of his work, the hypothesis of generalized transformism offered by Maupertuis in 1751 in the *Système de la nature*. Buffon's theory of reproduction and the role he attributes to the 'internal mold', as the guardian of the form of the species, prevented him from being a transformist. This same theory of reproduction did not prevent Buffon from believing in the appearance of varieties within a species, however. Buffon believed in the heredity of acquired characteristics; climate, food, and domestication modify the animal type. From his exhaustive research for the *Histoire naturelle des quadrupèdes*, Buffon came to the conclusion that it was necessary to reintroduce the notion of family. But he attributes to this word—or to the word *genus*, which he also uses—a special meaning: a family consists of animals which although separated by 'nature', instinct, life style, or geographical habitat are nevertheless able to produce viable young (that is, animals which belong biologically to the same species, e.g., the wolf and the dog). What the naturalist terms species and family, then, will thus become, for the biologist, variety and species. Buffon was thus able to write, in 1766, the essay *De la dégénération des animaux*—in which he showed himself to be a forerunner of Lamarck—while he continued to affirm the permanence of species in the two *Vues de la nature* (1764–1765) and *Époques de la nature* (1779).

"Buffon's final point of view concerning the history of living beings can be summarized as follows: No sooner were organic molecules formed than they spontaneously grouped themselves to form living organisms. Many of these organisms have since disappeared, either because they were unable to subsist or because they were unable to reproduce. The others, which responded successfully to the essential demands of life, retained a basically similar constitution— Buffon affirms unity in the plan of animals' composition and, in variations on that plan, the principle of the subordination of organs. Since the earth was very hot and 'nature was in its first stage of activity', the first creatures able to survive were extremely large. The earth's cooling drove them from the North Pole toward the equator and then finally caused their extinction. Buffon offered this in explanation of the giant fossils discovered in Europe and North America, which he studied at length (to the point of becoming one of the founders of paleontology). The organic molecules which were left free in the northern regions formed smaller creatures which in turn moved toward the equator, and then a third and fourth generation, which also moved south. Originating in Siberia, these animal species spread out to southern Europe and Africa, and toward southern Asia and North America. Only South America had an original fauna, different from that of other continents.

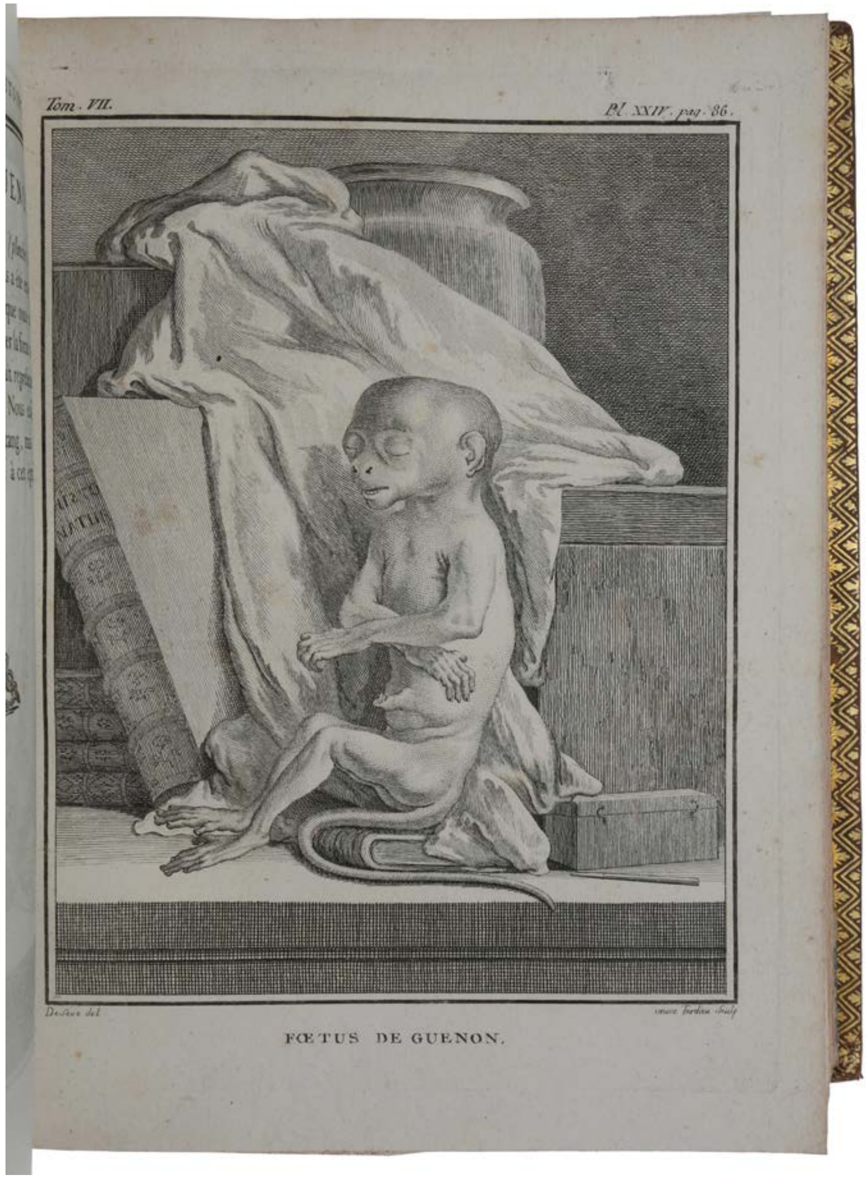
"In the process of migration, the species varied in response to environment. There are few varieties of the large mammals because they reproduce slowly. The smaller mammals because they reproduce slowly. The smaller mammals (rodents, for example) offer a large number of varieties because they are very prolific. The same is true of birds. Going back to the basic types, quadrupeds may be divided into thirteen separate species and twenty-five genera. But Buffon was not a transformist, because he believed that these thirty-eight primitive types arose spontaneously and simultaneously from an assembly of organic molecules …

"In the *Histoire naturelle de I'homme*, published in 1749 (Vols. II, III), and in many of his other works as well, Buffon studied the human species by the same methods that he applied to animal species, including the psychological, moral, and intellectual life of man. At the same time that he proclaimed the absolute superiority that the ability to reason gives man over animals, he demonstrated how the physiological organization and development of the sensory organs make reasoning possible. Throughout his work Buffon specifies that reason developed only through language, that language grew out of life in society, and that social life was necessitated by man's slow physiological growth (since man is dependent on his mother long after birth). For the same reason, the elephant is the most intelligent of animals, while social life makes beavers capable of astonishing work.

"It was, therefore, as a physiologist and as a naturalist that Buffon studied man and his reason; and it was as a biologist that he affirmed the unity of the human species. Aside from a few safe formulas, theology never comes into the picture. According to the *Époques de la nature*—and, in particular according to its manuscript—it is clear that the human species has had the same history as the animals. Buffon even explains that the first men, born on an earth that was still hot, were black, capable of withstanding tropical temperatures. Through the use of the resources of his intelligence and because of the invention of fire, clothes, and tools, man was able to adapt himself to all climates, as animals could not. Man is therefore the master of nature; and he can become so to an even greater degree if he begins to understand 'that science is his true glory, and peace his true happiness' (*Époques de la nature*, p. 220)" (DSB).

'[Buffon] brought forward an impressive array of facts suggesting evolutionary changes … It fascinated him as, a century later, it was to fascinate Darwin. He had devised a theory of 'degeneration'. The word sounds odd and a trifle morbid today, because we are in the habit of thinking of life as 'evolving', 'progressing' from one thing to another. Nevertheless, Buffon's 'degeneration' is nothing more than a rough sketch of evolution. He implied by this term simply change, a falling away from some earlier type of animal into a new mold. Curiously enough, as his work proceeded, Buffon managed, albeit in a somewhat scattered fashion, at least to mention *every significant ingredient which was to be incorporated into Darwin's great synthesis of 1859* [i.e., *Origin of Species*]" (Eiseley, p. 39).

Over 1,000 of the plates are the work of Jacques de Sève, père et fils: a full list of the artists is provided by Nissen. Most sets lack some or all of the *Supplément* volumes, and/or various plates. Vol. III of the Oiseaux sometimes contains a duplicate plate; one being a cancel as it has the wrong plate number engraved on



it, otherwise both versions are identical. Plate counts differ sometimes because the first volume contains two maps which are often included in the plate count, whereas the other 10 maps are very large folding maps. These and the tables are sometimes bound in a separate volume, or, as here, in with the main work.

Dibner 193 (33 vols. only); *En Français dans le texte* 152; Nissen ZBI 672; Norman 369; PMM 198; Sparrow 23; Ward and Carozzi 383 (36 vols. only). Eiseley, *Darwin's Century*, 1958. Fellows & Milliken, *Buffon*, 1972.

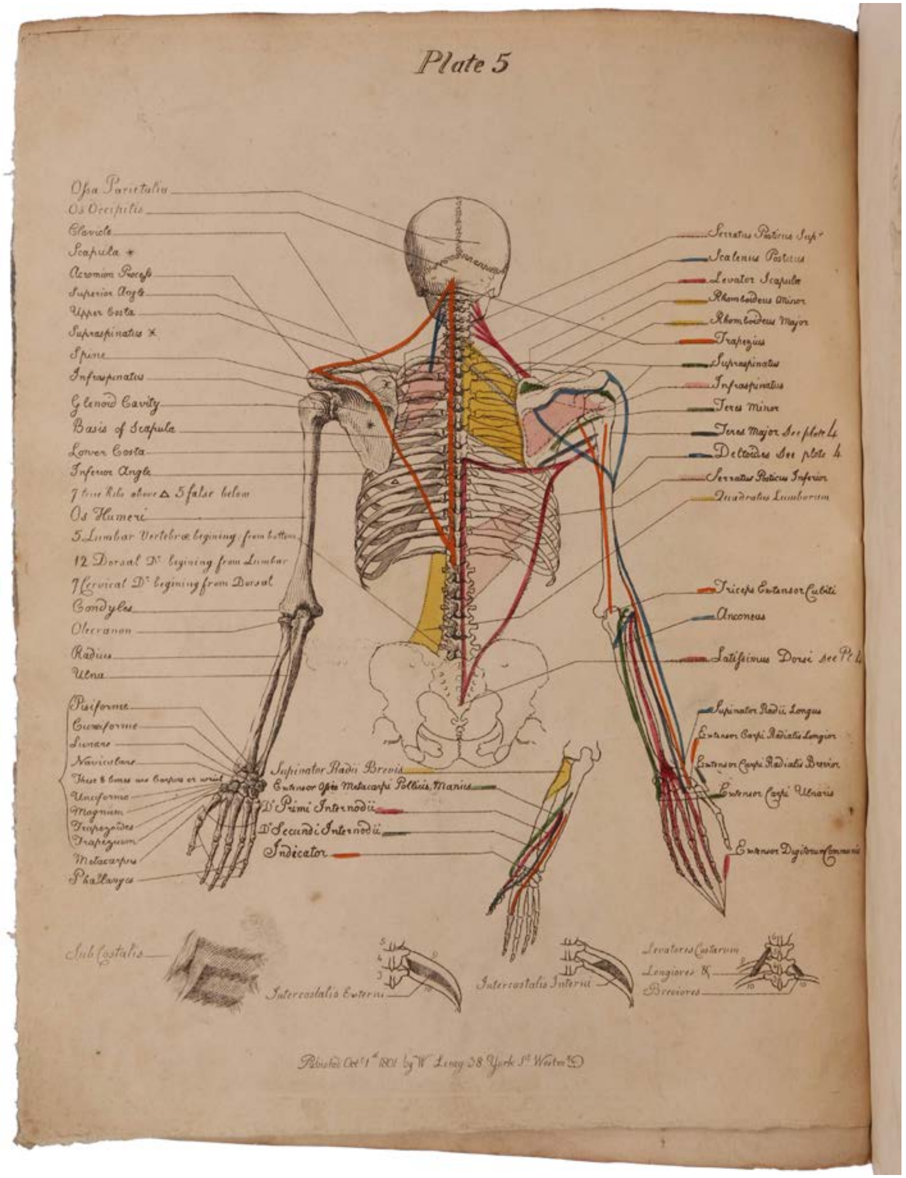
THE FATHER OF MODERN PLASTIC SURGERY

CARPUE, Joseph Constantine. *A Description of the Muscles of the Human Body, as they appear on Dissection; with the Synonyma of Cowper, Winslow, Douglas, Albinus, and Innes, and the Nomenclature of Dumas…* London: T. Lewis, 1801.

$9,500

4to (280 x 215 mm), pp. xii, 55, [1, blank], [8], with seven engraved plates, four with hand-colouring. Original boards (rebacked), untrimmed. Light toning througout. Boards with some wear.

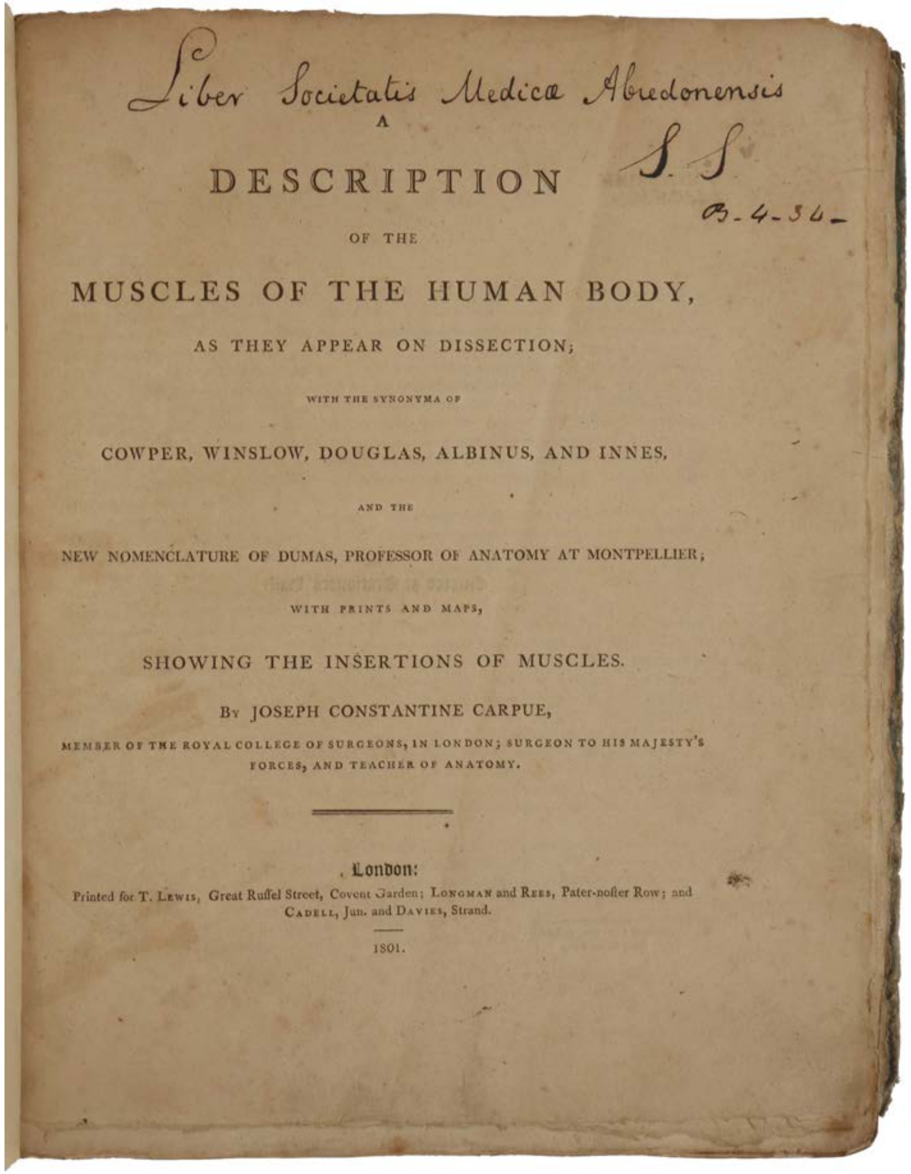
First edition, very rare, of the first work by the great English surgeon and father of modern plastic surgery. Its remarkable coloured anatomical illustrations are much reproduced even today. Carpue began his surgical studies at St. George's Hospital in London in 1796 after being educated in France and traveling widely in Europe, Scotland, and Wales. He was appointed to the surgical staff of the Duke of York's Hospital in Chelsea in 1799 and a year later began teaching anatomy. "He succeeded in a number of unrecognized tasks that are themselves landmarks not only in plastic surgical history, but surgical history: devising the first prospective observational study, using exclusion criteria, maintaining appropriate patient confidentiality, setting a standard for preoperative disclosure and ethical approval over a century before these measures were codified, having independent documentation of his preoperative and postoperative findings" (Freshwater). This work is not described in the standard medical bibliographies, and no copies appear in auction records since this copy last appeared at Sotheby's in 1967 in the sale of the property of The Medico-Chirurgical Society of Aberdeen.



Provenance: The Medico-Chirurgical Society of Aberdeen (its ownership markings appear in holograph on the title page and by ink stamp on the first and final text leaves).

"Joseph Constantine Carpue was born in May 1764 in Brook Green, which still is an affluent neighborhood in London, England. His grandfather, Charles, had made the family fortune as a shoe manufacturer and his uncle, William Lewis, was a leading publisher in London. Carpue was "a late bloomer"; for more than a decade after leaving the Jesuit college of Douai he vacillated about his future. Perhaps this was a manifestation of his innate curiosity, for he explored a host of careers. As a Catholic, Carpue first thought of becoming a priest; next he toyed with the idea of joining his uncle's publishing business. The law appealed to him briefly, as the 1791 Roman Catholic Relief Act allowed Catholics to join the legal profession. He was next "smitten with admiration for Shakespeare" and considered a career on the stage. Finally, on August 5, 1796, Carpue registered at St. George's Hospital Medical School for a one-year term. Carpue was an unusual student for two reasons, first, he enrolled when he was 32 years old, and second, he was a college graduate, which was the exception to the rule for proto-surgeons of the 18th century. He studied under surgeon Everard Home, John Hunter's brother-in-law and successor at St. George's.

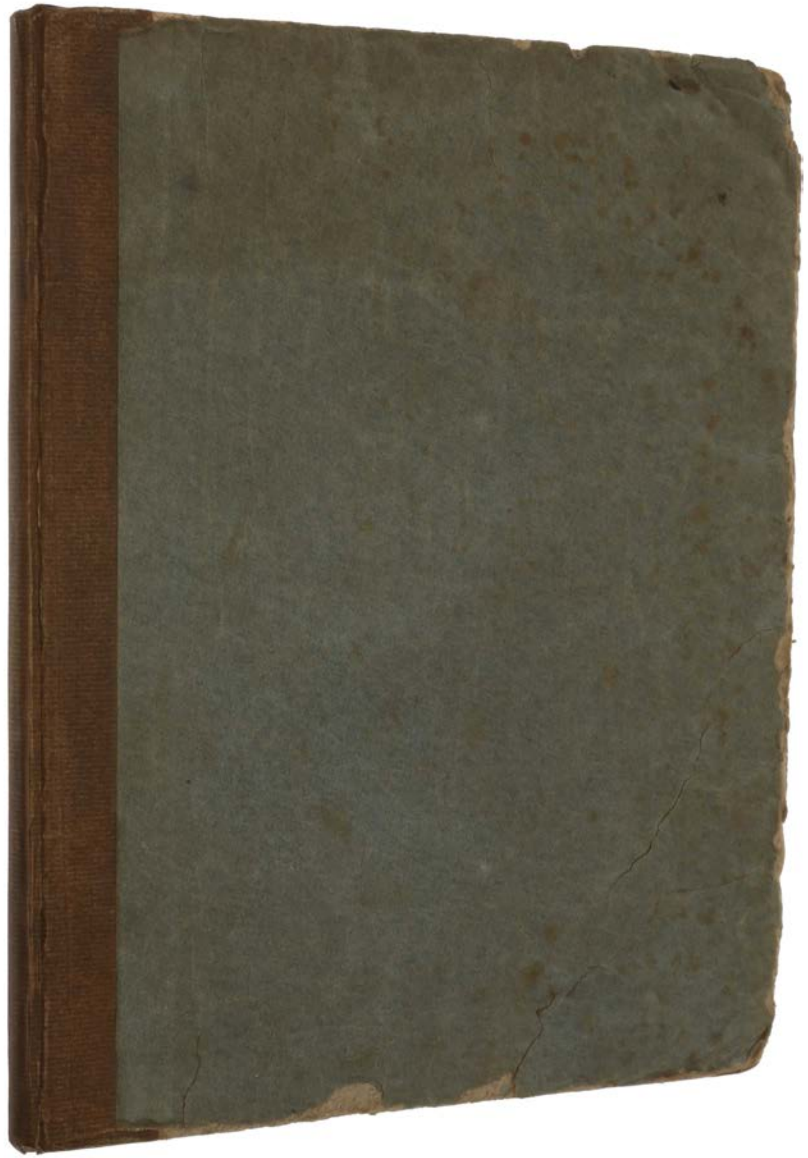
"In the late 18th century, surgery was still rife with nepotism and, as such, Carpue's professional prospects were limited. His abilities were known to Home, who offered him £500 a year to serve as his assistant. It is unknown if Carpue accepted Everard Home's offer, but in 1799, Carpue become a staff-surgeon at the Duke of York's Hospital, a military hospital in Chelsea. He accomplished this through the influence of Thomas Keate, whom he had known as a surgeon at St. George's, and who was surgeon general of the Army. No records remain describing the patients Carpue treated while at Chelsea before he resigned in 1807.



“In 1800, Carpue tutored George Norman to prepare for the Royal College of Surgeons’ examination. Norman had only his prior medical education of an apprenticeship with his father, a surgeon in Bath. Norman had approached Carpue and said, ‘I wish I knew anatomy as well as you, Carpue.’ After Norman passed his M.R.C.S. examination on June 4, 1801, he insisted that Carpue accept 20 guineas as payment. This spurred Carpue to present formal classes in anatomy and surgery. Later that year, Carpue confirmed his reputation as an anatomist and teacher by publishing “A Description of the Muscles of the Human Body as They Appear on Dissection” that was self-illustrated. Drawing was part of his unique teaching style; he was thought to have been the first anatomy instructor to draw diagrams while demonstrating anatomy, which resulted in his nickname ‘The chalk professor.’ Carpue’s classes proved to be popular not only with students preparing for their fellowship examination, but also with aristocrats, members of parliament, barristers, and law students” (Freshwater).

“Carpue was introduced to and much appreciated by George IV, both before and after his accession to the throne. He was consulting surgeon to the St. Pancras Infirmary, but never received any recognition from the College of Surgeons, either by election to the council or to an examinership. He was a fellow of the Royal Society. He died on 30 Jan 1846, in his eighty-second year, having been much shaken in an accident on the South-Western Railway soon after its opening” (DNB).

Freshwater, ‘Joseph Constantine Carpue and the Bicentennial of the Birth of Modern Plastic Surgery,’ *Aesthetic Surgery Journal* 35 (2015), pp. 748-58. Not in Norman.



DECIPHERING HIEROGLYPHICS - HIS FIRST DETAILED ACCOUNT

CHAMPOLLION, Jean-François. *Précis du Système Hiéroglyphique des Anciens Égyptiens, ou recherches sur les éléments premiers de cette écriture sacrée sur leurs diverses combinaisons et sur les rapports de ce système avec les autres méthodes graphiques Égyptiennes. Avec un volume de planches.* Paris: Treuttel & Würtz, 1824.

$9,500

Two vols., 8vo (220 x 143 mm). [Text:] pp. [iv], xvi, 410, with 16 lithographed plates; [Atlas:] [ii], 45, with 32 folding lithographed plates (numbered and lettered 1-21 and A-K). Contemporary half calf and marbled boards. A very fine copy.

First edition of Champollion's first detailed account of his decipherment of Egyptian hieroglyphics, following his brief but revolutionary *Lettre à M. Dacier relative à l'alphabet des hiéroglyphes phonétiques*, published two years previously. "In this first announcement of his discovery [i.e., the *Lettre*], Champollion contented himself with stating his conviction that hieroglyphics had been a phonetical script from the earliest ages. In was only later, in his *Précis du systeme hieroglyphique*, published in 1824, that he presented his decipherment of the names of pharaohs and gods, like Ramses and Thutmos, belonging to the ancient era. In his *Précis*, Champollion developed his full elaboration of the 'general theory of the hieroglyphic system' … Champollion's *Précis* is a masterpiece" (Weissbach, pp. 36-7). "The complete elaboration of Champollion's discovery came in his 1824 masterpiece, the *Précis du Système Hieroglyphiques des Anciens Egyptiens.* As he stated at the outset, he would show that the alphabet he had established applied to 'all epochs,' and that his discovery of the phonetical values unlocked the entire

system. He would work out 'the general theory of the hieroglyphic system ... [which] will give us the full and entire understanding of all hieroglyphic texts'" (Schiller Institute). ABPC/RBH list four complete copies in the past 20 years.

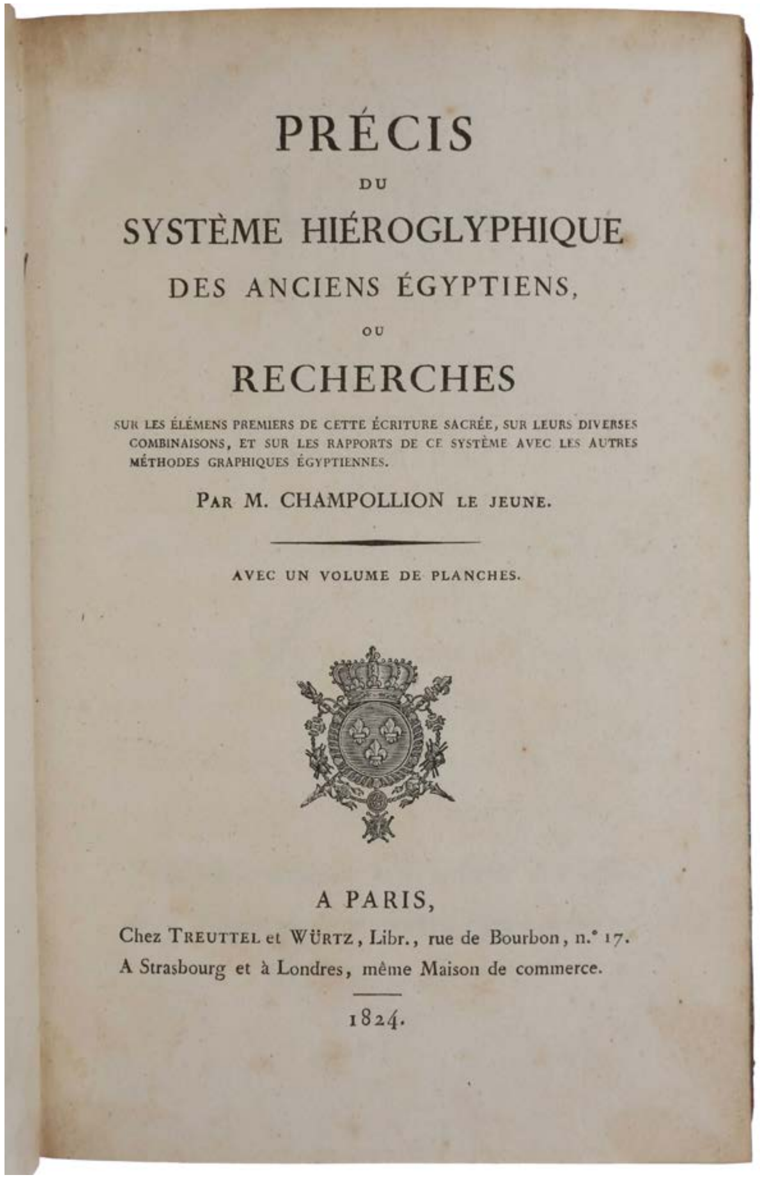
Provenance: Jacob-Élisée Cellérier (signature in each volume). Cellérier (1785-1862), French theologian, was born at Satigny. He studied at Geneva, was ordained to the ministry in 1808, and for some time assisted, and finally succeeded, his father Jean in the ministry. In 1816 he was appointed professor of Hebrew and Biblical literature at Geneva, and occupied that chair till 1854. He was the author of *Grammaire Hébraïque* (1820), the first Hebrew grammar in French, and numerous books and periodical articles dealing with religious topics.

Hieroglyphic writing had long fascinated scholars such as Athanasius Kircher in the seventeenth century and Georg Zoega in the eighteenth, but the real breakthrough in its decipherment came with the discovery of the Rosetta Stone, an ancient stele found in the Nile delta by Napoleon's army in 1799. Its inscription, recorded in three distinct scripts – ancient Greek, Coptic, and hieroglyphic – would provide scholars with the first clues to unlocking the secrets of Egyptian hieroglyphs, a language lost for nearly two millennia. As early as 1802, the Frenchman Silvestre de Sacy (1758-1838) and the Swede Johan David Akerblad (1763-1813) tried to penetrate the secrets of the Rosetta stone. Between 1814 and 1818, the artifact was studied by the celebrated English scientist Thomas Young (1773-1829), who had many of the same language skills as Champollion, but it would be Champollion who would eventually break the code.

Born in Figeac, France, Champollion (1790-1832) had as a boy learnt many languages, including Hebrew, Arabic, Syriac, Chaldean and Chinese (and later added Coptic, Ethiopic, Sanskrit, Persian and others). He became interested in hieroglyphs, and first learned about the Rosetta stone, on a childhood visit to the great mathematical physicist Joseph Fourier, who was Napoleon's scientific advisor on his 1798 Egyptian expedition. But his quest really began in 1808, when he determined that fifteen signs of the demotic script corresponded with alphabetic letters in the Coptic language. He therefore concluded that this modern language held at least the last vestiges of that spoken by the ancient Egyptians. By 1818, after having examined an obelisk from Philae, he came to understand that some of the glyphs had a phonetic value and were thus part of an alphabet, even though other symbols were strictly symbolic ideograms. But his real breakthrough came with the Rosetta Stone. Others had examined this stele before him, but it was Champollion who recognized Ptolemy's name in Greek and demotic, and was thereby able to identify the hieroglyphic rendering. Champollion did not publish any of his decipherment work, concealing it from his competitors, until in 1822 he gave a lecture, published as *Lettre à M. Dacier relative à l'alphabet des hiéroglyphes phonétiques,* to the Académie des Inscriptions et des Belles Lettres – Bon-Joseph Dacier had been president and permanent secretary of the Académie since 1782. In this document he wrote: "I am convinced that the same hieroglyphic-phonetic signs used to represent the sound of Greek and Roman proper names were used in hieroglyphic texts carved long before the Greeks came to Egypt, and that these already reproduced sounds or articulation in the same way as the cartouches carved under the Greeks and Romans. The discovery of this precious and decisive fact is due to my work on pure hieroglyphic script. It would be impossible to prove it in the present letter without going into lengthy detail."

The publication of the *Lettre à M. Dacier* resulted in a priority dispute with British philologists, especially Young, who felt that Champollion had failed to acknowledge his work as having provided the platform from which decipherment had finally been reached. The dispute was exacerbated by the tense political climate between Britain and France in the aftermath of the Napoleonic wars. Young's claims that the new decipherments were merely a corroboration of his own method meant that Champollion would have to publish more of his data to make clear the degree to which his own progress built on a systematic approach that was not found in Young's work. He realized that he would have to make it apparent to all that his was a total system of decipherment, whereas Young had merely deciphered a few words. Over the next year he published a series of articles about the Egyptian gods, including some decipherments of their names. Building on his progress, Champollion now began to study other texts in addition to the Rosetta stone, studying a series of much older inscriptions from Abu Simbel. During 1823, he succeeded in identifying the names of pharaohs Ramesses and Thutmose written in cartouches in these ancient texts. With the help of a new acquaintance, the Duke de Blacas, in 1824 Champollion finally published the *Précis du système hiéroglyphique des anciens Égyptiens*, dedicated to and funded by King Louis XVIII. Here he presented the first correct translation of the hieroglyphs and the key to the Egyptian grammatical system.

"Champollion announced in his introduction to the *Précis*, that he would set out to demonstrate, explicitly in opposition to the opinion of Young, the following: '1. That my hieroglyphic alphabet applies to the hieroglyphic royal inscriptions of all epochs; 2. That the discovery of the phonetic alphabet of hieroglyphics is the true key to the entire hieroglyphic system; 3. That the ancient Egyptians used it in all epochs, to represent alphabetically the sounds of the words of their spoken language; 4. That all the hieroglyphic inscriptions are in large part composed of purely alphabetical signs, and such as I have determined them. 5. I shall attempt to know the nature of the different sorts of characters used simultaneously in the hieroglyphic texts. 6. Finally, I shall try to deduce from all these propositions, once proven, the general theory of the hieroglyphic system . . . [which] will give us the full and entire understanding of all
hieroglyphic texts.'



"After demonstrating the phonetic use of hieroglyphics to write foreign names, under the Greeks and Romans, Champollion hypothesized that the same signs carry phonetic values in other words. He applies them first to grammatical forms, then to the names of Egyptian kings, of all epochs, and then to the names of pharaohs.

"He demonstrates how hieroglyphics can denote a name, either symbolically, or figuratively, or phonetically. For example, the god Amon (also Amen, Ammon), supreme god of Thebes, was depicted figuratively through an image of him, symbolically, as an obelisk, and phonetically. Or, take the name of the god Ra (also Re and Ri), king of Thebes, of whom Eratosthenes had written. This is presented as a red disc with a perpendicular line underneath it. The name is figurative, in that it depicts the Sun, whose name in Egyptian is Re; it is also phonetic, in that the Sun disc, Re, stands for R, and the line under it, stands for the vowel E. The same god's name can also be written phonetically, with a mouth (Ro) and an extended arm (the vowel E).

"By deciphering the names of the pharaohs of ancient Egypt, and the inscriptions which indicate their genealogy, Champollion succeeded in confirming the chronology of the dynasties, as presented by Manethon, Herodotus, and Diodorus of Sicily – a fact whose significance he did not underestimate. He wrote, 'I therefore had to conclude, and I have concluded from these facts so numerous and so evident, first, that the use of the Egyptian phonetic writing, of which I was the first to publish the alphabet in my *Lettre a M. Dacier*, dates back to the remotest antiquity; and, secondly, that the system of hieroglyphic writing, considered up to now as formed purely of signs that represent ideas and not sounds or pronunciations, was, on the contrary, formed of signs, a large part of which express the sounds of words of the spoken language of the Egyptians, that is to say, of phonetic characters' [*Précis*, p. 298].

"The phonetic hieroglyphic system, Champollion proved by his decipherments, was in use continually from the 19th century B.C., until the conversion of Egyptians to Christianity.

"The French researcher was also fully aware of the implications of his breakthrough for Egyptian studies. 'These facts destroy, it is true,' he wrote, 'all the systems advanced thus far on the nature of Egyptian hieroglyphic writing; they render void all the explications of texts or monuments hazarded for three centuries; but men of knowledge, for the sake of truth, will easily sacrifice all hypotheses enunciated thus far, and which are in contradiction with the fundamental principle that we have just recognized; all regrets, if there are any in this regard, should diminish and cease entirely, to the extent that one appreciates . . . the results of the works of the moderns, who have devoted themselves to the study of hieroglyphic inscriptions, starting from the absolute principle that the holy writing of the Egyptians was uniquely composed of signs of ideas, and that this people did not know alphabetical writing, or the signs of sounds, but for the Greeks alone' [*Précis,* p. 299].

"In his systematic presentation of hieroglyphic writing, Champollion catalogued 864 forms of signs, which include representations of physical objects (celestial bodies, animals, plants, and so on), geometrical forms, and fantastic creatures (human bodies with animal heads), and so on. The figures are presented in profile, he realized, in order to indicate the direction in which the line should be read; if they face left, it means one must read from left to right. They can also be presented vertically.

"Comparing the Egyptian language to the Chinese, Champollion points out that the monosyllabic words of the former, do not end in vowels, and therefore it would not be possible to invent an alphabet based on signs for syllables. Instead, he writes, the inventor of the hieroglyphic alphabet must have analysed the monosyllables, and separated the consonant from vowel sounds, to which he then assigned signs. These characters were not arbitrary, but, as he had anticipated in his *Lettre à M. Dacier*, were the initial sound of the word, whose image was used as a character. 'A voice or an articulation may have as a sign the image of a physical object, whose name, in the spoken language, begins with the voice or articulation [sound] which one wants to express' [*Précis*, p. 363].

"Champollion elaborated a complete table for this: Thus, an eagle, called *Akhom* or *Ahom* in Egyptian, stands for A; a perfume pan, called *Berbé*, stands for B; a knee, called *Ke'li*, stands for K; a lion, called *Laboi*, stands for L, and so forth (*Précis*, pp. 360-361). One sound can thus be represented by several different images.

"And, in each case, the characters may function phonetically, figuratively, and symbolically. Thus, indeed, 'the hieroglyphic writing is a complex system, a script at the same time figurative, symbolic, and phonetic, in the same text, in the same phrase, I would almost say, in the same word' [*Précis*, p. 375].

"Not only in the case of proper names, but also in the language as a whole, the figurative and symbolical functions are evident. For example, the word Het means "heart," and thus, by extension, spirit and intelligence. To express the idea "fearful," one would write "small heart"; "patient" is "heavy or slow heart"; "proud" is "high heart"; "timid" is "weak heart"; "indecisive" is "with two hearts"; "obstinate" is expressed through " hard heart"; "repentant" is "eating one's heart," and so forth (*Précis*, p. 336).

"Champollion's great work also developed the relationship among the three forms of Egyptian script, the hieroglyphic, the hieratic, and the demotic, which Clement of Alexandria had catalogued and explained. Champollion argued that the hieroglyphic script was the oldest of the three, and that it was used primarily for inscriptions of public monuments, meant to last. As there arose the need for a more expeditious form of writing, the hieratic was developed, as a kind of shorthand of the hieroglyphs. This script, used by priests on papyrus, embodies the figurative, symbolic, and phonetic functions.

"The last script to be developed, was the demotic, which is almost wholly phonetic, using symbolical characters only to portray gods and sacred things. Champollion declared, 'These three were used at the same time, throughout Egypt.' He added that 'all the classes of the nation used demotic script for their private correspondence and to record public and private acts that regulated family interests.'

"The conclusions reached at the end of the *Précis* dealt the death blow to the British lie, that the hieroglyphic system had been a cult object for a tiny elite. 'It is also certain,' Champollion wrote, 'as opposed to common opinion, that hieroglyphic writing, that is, the holy system, the most complicated of the three, was studied and understood by the most distinguished of all the classes of the nations – far from being, as had been said so often, a mysterious, secret script, whose knowledge was reserved to the priestly caste, to communicate only with a very small number of initiates. How could one persuade oneself, in effect, that all public buildings were covered inside and outside, by an innumerable quantity of inscriptions in sacred characters, if these characters were understood by only a few initiates?'

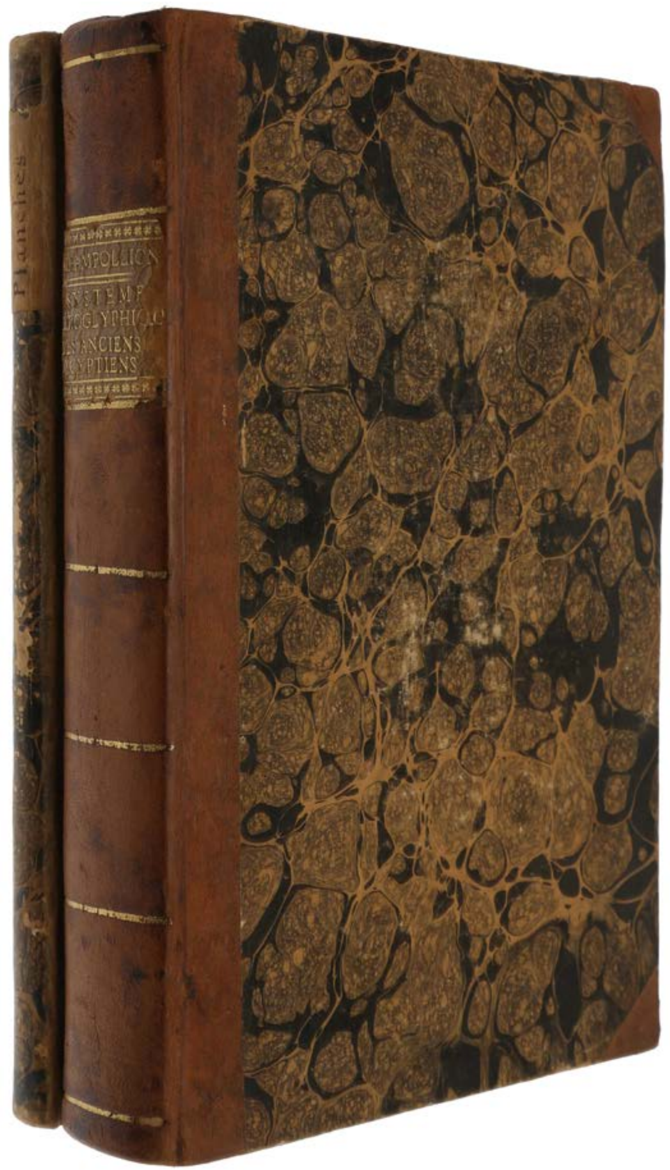
"Champollion added that the inscriptions were to be found on all sorts of materials, including humble wood, and that even amulets and other personal objects were decorated with them. Given the relatively simple, extremely systematic nature of the alphabet, there should have been little difficulty, he argued, for the general population to learn to read it.

"The results of Champollion's years of work, first presented in the *Lettre à M. Dacier*, caused an uproar throughout Europe. The 'British' school lined up against him, and resorted to slander, to reject the Frenchman's accomplishments. In Germany, the Humboldt brothers, Alexander and Wilhelm, joined with Jean Letronne and Silvestre de Sacy (who revised his earlier attitude), as well as with Dacier, Fourier, and many other important personalities, to rally to the defence of Champollion. However, the vilification campaign continued. It was in 1866 that further confirmation of Champollion's findings was made. Another hieroglyphic text was found, known as the Decree of Canopus. When it was successfully deciphered according to Champollion's system, there was no room left for doubt. Jean François Champollion was right" (Weissbach).

Champollion made his sole visit to Egypt in 1828-29, conducting the first systematic survey of the country's monuments, history and archaeology, and studying the tombs in the Valley of the Kings (a name he first coined). On his return, the first chair in Egyptian history and archaeology was created for him at the Collège de France. Champollion died on 4 March 1832 as a result of a stroke, while preparing the results of his expedition for publication.

A second edition was published in 1827-28.

Brunet I, 1780; Gay 1758; Graesse II, 116; Hage Chahine 881; Ibrahim-Hilmy I, p. 129; *En Français dans le texte* 234 (Remark). Weissbach, 'Jean François Champollion and the true story of Egypt,' *21st Century Science & Technology Magazine* 12 (2000), pp. 26-39 (http://21sci-tech.com/articles/Spring03/Champollion.pdf).



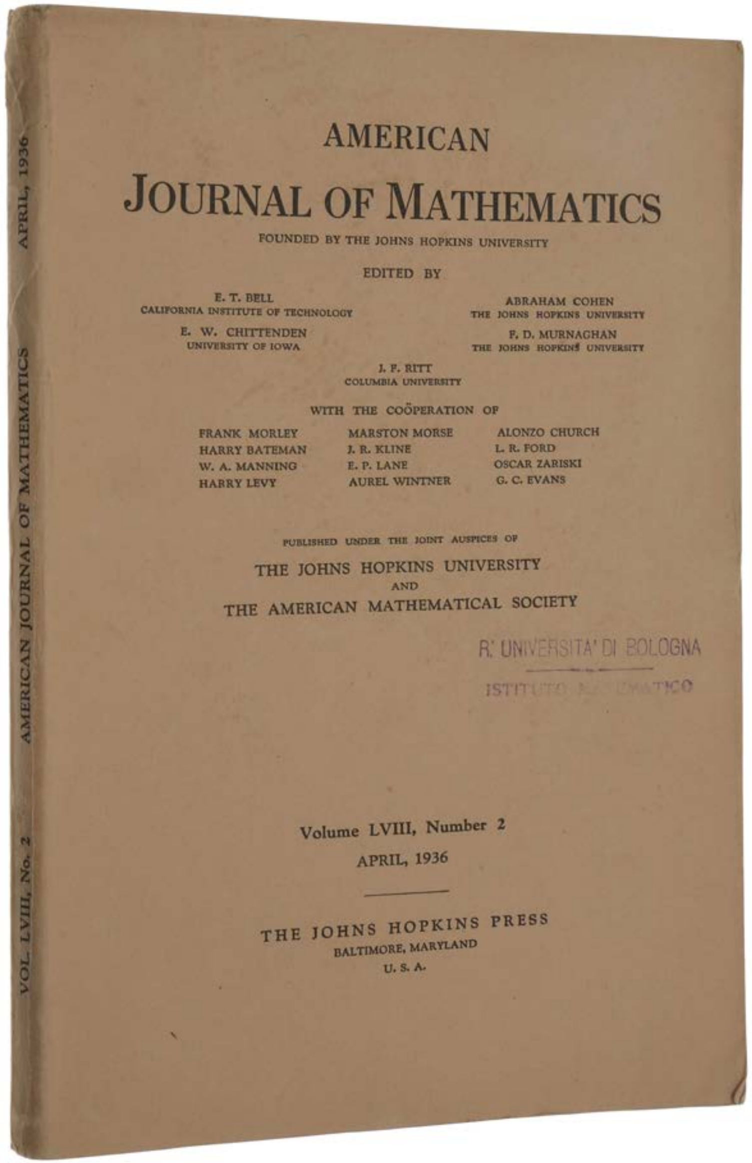
FIRST PROOF THAT THE ENTSCHEIDUNGSPROBLEM IS UNSOLVABLE

CHURCH, Alonzo. *An unsolvable problem in elementary number theory.* Baltimore, Maryland: John Hopkins, 1936.

$4.800

Pp. 345-363 in American Journal of Mathematics, Vol. 58, No. 2, April 1936. 8vo (243 x 163 mm), pp. 241-452. Complete journal issue in original printed wrappers. A relatively light damp stain to the upper margin of the text througout. Rubberstamp of the University of Bologna to front wrapper. Scarce.

First edition of the first proof that the *Entscheidungsproblem* ('decision problem') is unsolvable, published seven months before Alan Turing published his own independent proof in his paper 'On computable numbers, with an application to the Entscheidungsproblem.' Church's proof was via his 'lambda-calculus'; Turing's was via his 'Turing machines.' "Church got it right and he got it first … By any purely quantifiable evaluation Church's contribution was at least as important as Turing's" (Robert Irving Soare in *Alan Turing, his work and impact*, p. 67). The work of Church and Turing gave a negative answer to the problem posed by David Hilbert in 1928 of whether mathematics is 'decidable,' that is, whether there is an effective procedure to determine, for every mathematical statement, whether the statement is provable. Both the lambda-calculus and Turing machines have proved to be of seminal importance, not only for mathematical logic, but also for the development of computer science. Rare in the original printed wrappers.



"Alonzo Church, in his historic ['An unsolvable problem in elementary number theory,' 1936], provides a rigorous formal characterization of what it means to be solvable by means of an algorithm, what has come to be known as *Church's Thesis*. This made it possible for him to prove that one specific problem is algorithmically unsolvable. In [this] work, Church specified a finite set of premises that encapsulates this specific problem so faithfully that an algorithm for testing whether a given conclusion follows from those premises would also provide an algorithmic solution to that specific problem, although the problem is known to be unsolvable. From this conclusion Church could conclude that the Entscheidungsproblem itself is unsolvable" (Martin Davis, in *ibid*., p. 50).

"'The decision problem was brought to the fore of mathematics by the German mathematician David Hilbert (who in a lecture given in Paris in 1900 set the agenda for much of twentieth-century mathematics). In 1928 Hilbert described the decision problem as 'the main problem of mathematical logic', saying that 'the discovery of a general decision procedure is a very difficult problem which is as yet unsolved', and that the 'solution of the decision problem is of fundamental importance'… Hilbert's requirement that the system expressing the whole content of mathematics be *decidable* amounts to this: there must be a systematic method for telling, of each mathematical statement, whether or not the statement is provable in the system… The project of expressing mathematics in the form of a complete, consistent, decidable formal system became known as 'proof theory' and as the 'Hilbert programme'…

"Unfortunately for the Hilbert programme, however, it was soon to become clear that most interesting mathematical systems are, if consistent, *incomplete* and *undecidable* … In his incompleteness theorem, [Kurt] Gödel had shown that no matter how hard mathematicians might try to construct the all-encompassing formal system envisaged by Hilbert, the product of their labours would, if consistent, inevitably be incomplete … Gödel's theorem left the question of decidability open" (Copeland, *The Essential Turing*, pp. 46-8).

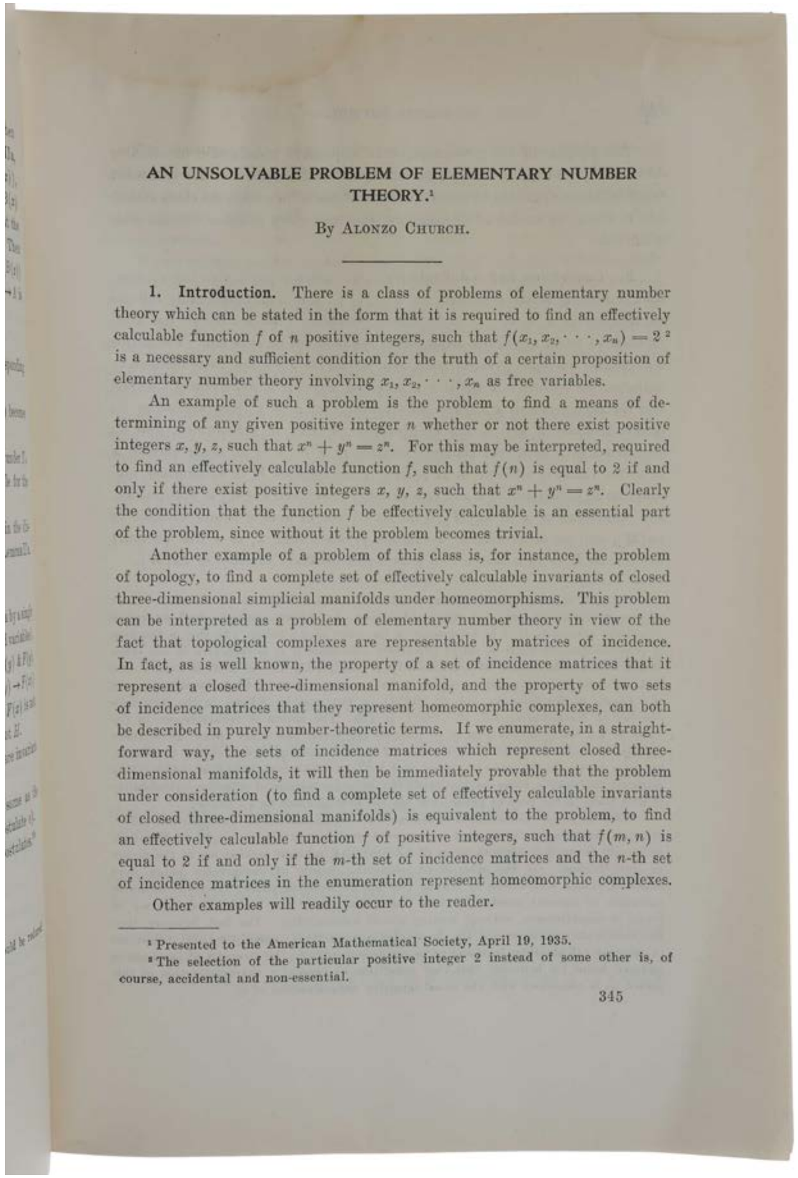
Any attempt to solve the *Entscheidungsproblem* hinges on exactly what is meant by saying that a function can be calculated by a finite algorithm, or that it is 'effectively calculable.' Turing later summarized the possibilities in his thesis ('Systems of logic based on ordinals,' 1939): "A function is said to be 'effectively calculable' if its values can be found by some purely mechanical process. Although it is fairly easy to get an intuitive grasp of this idea, it is nevertheless desirable to have some more definite, mathematically expressible definition. Such a definition was first given by Gödel at Princeton in 1934 ... These functions are described as 'general recursive' by Gödel ... Another definition of effective calculability has been given by Church [in the present paper] ... who identifies it with lambda-definability. The author has recently suggested [in 'On computable numbers'] a definition corresponding more closely to the intuitive idea. It was stated above that "a function is effectively calculable if its values can be found by some purely mechanical process". We may take this statement literally, understanding by a purely mechanical process one which could be carried out by a machine. It is possible to give a mathematical description, in a certain normal form, of the structures of these machines. The development of these ideas leads to the author's definition of a computable function, and to an identification of computability with effective calculability."

Church's student Stephen Kleene had proved in 1935 that the notions of 'general recursive' and 'lambda-definable' are equivalent, and Church proposed in the present paper that these should be taken as the definition of 'effective calculability.' Church "had developed a formalism called the 'lambda-calculus' and, with the logician Stephen Kleene, had discovered that this formalism could be used to translate all the formulae of arithmetic into a standard form. In this form, proving theorems was a matter of converting one string of symbols of the lambda-calculus into another string, according to certain rather simple rules. Church had then been able to show that the problem of deciding whether one string could be converted into another string was unsolvable, in the sense that there existed no formula of the lambda-calculus which could do it. Having found one such unsolvable problem, it had become possible to show that the exact question that Hilbert had posed must also be unsolvable. But it was not obvious that 'a formula of the lambda-calculus' corresponded to the notion of a 'definite method'. Church gave verbal arguments for the assertion that any 'effective' method of calculation could be represented by a formula of the lambda-calculus" (Hodges, *Alan Turing: The Enigma*, p. 112).

Knowing nothing about Church's work, Turing had been working on the decision problem, having been inspired by lectures of Max Newman. Just days after Turing completed his own solution, Newman received a copy of Church's paper. "It pre-empted the result, and threw into jeopardy the publication of Alan's work, scientific papers not being allowed to repeat or copy one another" (Hodges, p. 112). Turing's approach was very different from Church's, however, and Turing's paper was submitted on 28 May 1936 to the London Mathematical Society for publication in its *Proceedings*. The following day Turing wrote to his mother:

Meanwhile a paper has appeared in America, written by Alonzo Church, doing the same things in a different way. Mr Newman and I have decided however that the method is sufficiently different to warrant the publication of my paper too. Alonzo Church lives at Princeton so I have decided quite definitely about going there.

Newman wrote on 31 May to the Secretary of the London Mathematical Society, F.P. White, explaining the position:



AN UNSOLVABLE PROBLEM OF ELEMENTARY NUMBER THEORY.[1]

By Alonzo Church.

1. Introduction. There is a class of problems of elementary number theory which can be stated in the form that it is required to find an effectively calculable function f of n positive integers, such that $f(x_1, x_2, \cdots, x_n) = 2$[2] is a necessary and sufficient condition for the truth of a certain proposition of elementary number theory involving $x_1, x_2, \cdots, x_n$ as free variables.

An example of such a problem is the problem to find a means of determining of any given positive integer n whether or not there exist positive integers x, y, z, such that $x^n + y^n = z^n$. For this may be interpreted, required to find an effectively calculable function f, such that $f(n)$ is equal to 2 if and only if there exist positive integers x, y, z, such that $x^n + y^n = z^n$. Clearly the condition that the function f be effectively calculable is an essential part of the problem, since without it the problem becomes trivial.

Another example of a problem of this class is, for instance, the problem of topology, to find a complete set of effectively calculable invariants of closed three-dimensional simplicial manifolds under homeomorphisms. This problem can be interpreted as a problem of elementary number theory in view of the fact that topological complexes are representable by matrices of incidence. In fact, as is well known, the property of a set of incidence matrices that it represent a closed three-dimensional manifold, and the property of two sets of incidence matrices that they represent homeomorphic complexes, can both be described in purely number-theoretic terms. If we enumerate, in a straightforward way, the sets of incidence matrices which represent closed three-dimensional manifolds, it will then be immediately provable that the problem under consideration (to find a complete set of effectively calculable invariants of closed three-dimensional manifolds) is equivalent to the problem, to find an effectively calculable function f of positive integers, such that $f(m, n)$ is equal to 2 if and only if the m-th set of incidence matrices and the n-th set of incidence matrices in the enumeration represent homeomorphic complexes.

Other examples will readily occur to the reader.

[1] Presented to the American Mathematical Society, April 19, 1935.

[2] The selection of the particular positive integer 2 instead of some other is, of course, accidental and non-essential.

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I think you know the history of Turing's paper on Computable numbers. Just as it was reaching its final state an offprint arrived, from Alonzo Church of Princeton, of a paper anticipating Turing's results to a large extent.

I hope it will nevertheless be possible to publish the paper. The methods are to a large extent different, and the result is so important that different treatments of it should be of interest. The main result of both Turing and Church is that the Entscheidungsproblem on which Hilbert's disciples have been working for a good many years — i.e. the problem of finding a mechanical way of deciding whether a given row of symbols is the enunciation of a theorem provable from the Hilbert axioms — is insoluble in its general form.

Turing's paper was revised in August to include a note (p. 231) referring to Church's: "In a recent paper Alonzo Church has introduced an idea of 'effective calculability', which is equivalent to my 'computability', but is very differently defined. Church also reaches similar conclusions about the Entscheidungsproblem. The proof of equivalence between 'computability' and 'effective calculability' is outlined in an appendix to the present paper." Turing's paper appeared in two parts, in the issues dated 30 November and 23 December 1936.

"Alan Turing began working on the Entscheidungsproblem with no knowledge of what Church was doing. He began with his own explication of algorithmic solvability, or as he called it, computability, in terms of extremely simple abstract computing machines, what are now called 'Turing machines'. By analyzing what someone actually does when computing something, he provided a convincing argument for the adequacy of his formulation. (Later he proved that his concept was equivalent to Church's.) Like Church, he used what he had done to prove that a certain specific problem is unsolvable. In Turing's case the unsolvable problem was to determine algorithmically whether one of his given machines would ever produce a particular symbol, the so-called 'printing problem'" (Davis, p. 51). One formulation of the Entscheidungsproblem is: "Find an algorithm to determine whether a given sentence of first order logic is valid, that is, true regardless of what specific objects and relationships are being reasoned about … By using sentences of first order logic to mimic the step-by-step behaviour of his machines he was able to associate with any one of his machines a corresponding sentence of first order logic that is valid if and only if that machine eventually produces the symbol 0. Thus an algorithm for validity would automatically provide a solution to the printing problem, although it is, in fact, unsolvable. Thus Turing could conclude that the Entscheidungsproblem is algorithmically unsolvable" (*ibid*., pp. 49-51).

"Poor news though the unsolvability of the *Entscheidungsproblem* was for the Hilbert school, it was very welcome news in other quarters, for a reason that Hilbert's illustrious pupil von Neumann had given in 1927: 'If undecidability were to fail then mathematics, in today's sense, would cease to exist; its place would be taken by a completely mechanical rule, with the aid of which any man would be able to decide, of any given statement, whether the statement can be proven or not.' As the Cambridge mathematician G. H. Hardy said in a lecture in 1928: 'if there were ... a mechanical set of rules for the solution of all mathematical problems ... our activities as mathematicians would come to an end'" (Copeland, p. 53).

CHURCH, Alonzo. *A Note of the Entscheidungsproblem.* New York: The Association for Symbolic Logic, 1936.

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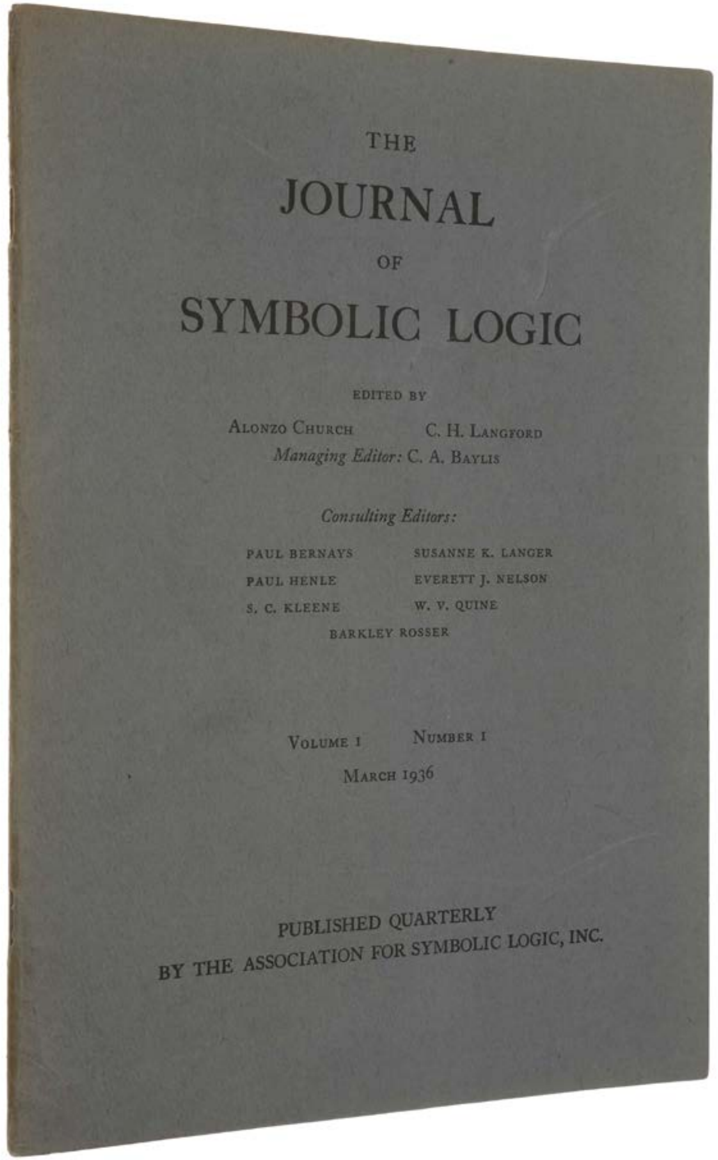

Pp. 40-41 in The Journal of Symbolic Logic, Vol. 1, No. 1, March 1936. 8vo (255 x 178 mm), pp. 44. Original printed wrappers, a very fine copy.

First edition, journal issue, of Church's solution to the 'Entschedungsproblem' ('decision problem'). "Church's paper, submitted on April 15, 1936, was the first to contain a demonstration that David Hilbert's 'Entscheidungsproblem' – i.e., the question as to whether there exists in mathematics a definite method of guaranteeing the truth or falsity of any mathematical statement - was unsolvable. Church did so by devising the 'lambda–calculus.' A few months earlier, Church had earlier shown the existence of an unsolvable problem of elementary number theory [although this was published later than the present paper], but [the offered] paper was the first to put his findings into the exact form of an answer to Hilbert's 'Entscheidungsproblem.' Church's paper bears on the question of what is computable, a problem addressed more directly by Alan Turing in his paper 'On computable numbers' published a few months later" (Hook & Norman: *Origins of Cyberspace*, 250). Turing's proof was via his 'Turing machines.' "Church got it right and he got it first … By any purely quantifiable evaluation Church's contribution was at least as important as Turing's" (Robert Irving Soare in *Alan Turing, his work and impact*, p. 67). Both the lambda-calculus and Turing machines have proved to be of seminal importance, not only for mathematical logic, but also for the development of computer science.

"The decision problem was brought to the fore of mathematics by the German mathematician David Hilbert (who in a lecture given in Paris in 1900 set the agenda for much of twentieth-century mathematics). In 1928 Hilbert described the decision problem as 'the main problem of mathematical logic', saying that 'the discovery of a general decision procedure is a very difficult problem which is as yet unsolved', and that the 'solution of the decision problem is of fundamental importance'… Hilbert's requirement that the system expressing the whole content of mathematics be *decidable* amounts to this: there must be a systematic method for telling, of each mathematical statement, whether or not the statement is provable in the system… The project of expressing mathematics in the form of a complete, consistent, decidable formal system became known as 'proof theory' and as the 'Hilbert programme'…

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Any attempt to solve the *Entscheidungsproblem* hinges on exactly what is meant by saying that a function can be calculated by a finite algorithm, or that it is 'effectively calculable.' Turing later summarized the possibilities in his thesis ('Systems of logic based on ordinals,' 1939): "A function is said to be 'effectively calculable' if its values can be found by some purely mechanical process. Although it is fairly easy to get an intuitive grasp of this idea, it is nevertheless desirable to have some more definite, mathematically expressible definition. Such a definition was first given by Gödel at Princeton in 1934 ... These functions are described as 'general recursive' by Gödel ... Another definition of effective calculability has been given by Church [in the present paper] ... who identifies it with lambda-definability. The author has recently suggested [in 'On computable numbers'] a definition corresponding more closely to the intuitive idea. It was stated above that "a function is effectively calculable if its values can be found by some purely mechanical process". We may take this statement literally, understanding by a purely mechanical process one which could be carried out by a machine. It is possible to give a mathematical description, in a certain normal form, of the structures of these machines. The development of these ideas leads to the author's definition of a computable function, and to an identification of computability with effective calculability."

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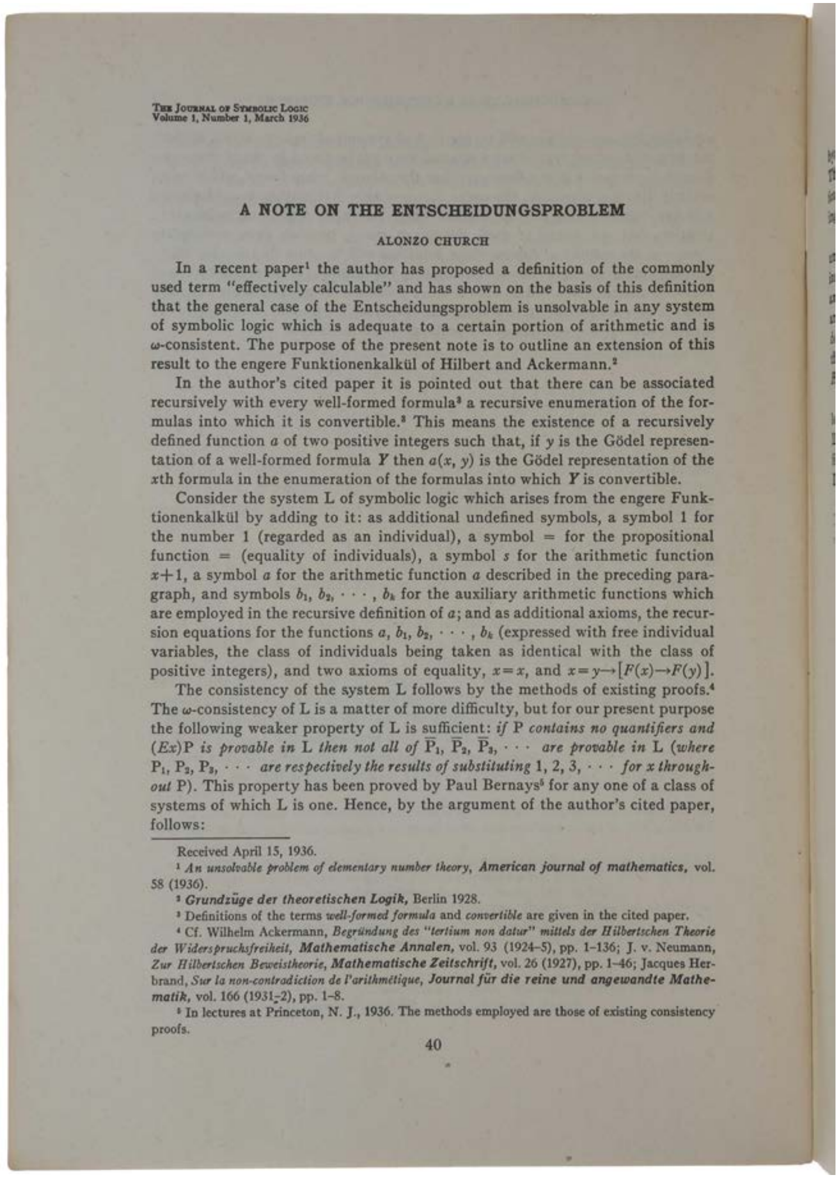
Church had given the first proof of the unsolvability of the Enscheidungsproblem by exhibiting a specific problem in number theory that was algorithmically unsolvable. "Alonzo Church, in his historic ['An unsolvable problem in elementary number theory'], provides a rigorous formal characterization of what it means to be solvable by means of an algorithm, what has come to be known as *Church's Thesis*. This made it possible for him to prove that one specific problem is algorithmically unsolvable. In [this] work, Church specified a finite set of premises that encapsulates this specific problem so faithfully that an algorithm for testing whether a given conclusion follows from those premises would also provide an algorithmic solution to that specific problem, although the problem is known to be unsolvable. From this conclusion Church could conclude that the Entscheidungsproblem itself is unsolvable" (Martin Davis, in *ibid*., p. 50). 'An unsolvable problem in elementary number theory' was published in the April 1936 issue of the *American Journal of Mathematics*. The present paper appeared in the March 1936 issue of *Journal of Symbolic Logic*, but the actual publication date must have been later as it is stated in a footnote on p. 40 that the paper was received on April 15, 1936.

Knowing nothing about Church's work, Turing had been working on the decision problem, having been inspired by lectures of Max Newman. Just days after Turing completed his own solution, Newman received a copy of Church's paper. "It pre-empted the result, and threw into jeopardy the publication of Alan's work, scientific papers not being allowed to repeat or copy one another" (Hodges, p. 112). Turing's approach was very different from Church's, however, and Turing's paper was



THE JOURNAL OF SYMBOLIC LOGIC
Volume 1, Number 1, March 1936

A NOTE ON THE ENTSCHEIDUNGSPROBLEM

ALONZO CHURCH

In a recent paper[1] the author has proposed a definition of the commonly used term "effectively calculable" and has shown on the basis of this definition that the general case of the Entscheidungsproblem is unsolvable in any system of symbolic logic which is adequate to a certain portion of arithmetic and is ω-consistent. The purpose of the present note is to outline an extension of this result to the engere Funktionenkalkül of Hilbert and Ackermann.[2]

In the author's cited paper it is pointed out that there can be associated recursively with every well-formed formula[3] a recursive enumeration of the formulas into which it is convertible.[3] This means the existence of a recursively defined function a of two positive integers such that, if y is the Gödel representation of a well-formed formula Y then $a(x, y)$ is the Gödel representation of the xth formula in the enumeration of the formulas into which Y is convertible.

Consider the system L of symbolic logic which arises from the engere Funktionenkalkül by adding to it: as additional undefined symbols, a symbol 1 for the number 1 (regarded as an individual), a symbol = for the propositional function = (equality of individuals), a symbol s for the arithmetic function $x+1$, a symbol a for the arithmetic function a described in the preceding paragraph, and symbols $b_1, b_2, \cdots, b_k$ for the auxiliary arithmetic functions which are employed in the recursive definition of a; and as additional axioms, the recursion equations for the functions $a, b_1, b_2, \cdots, b_k$ (expressed with free individual variables, the class of individuals being taken as identical with the class of positive integers), and two axioms of equality, $x=x$, and $x=y\rightarrow[F(x)\rightarrow F(y)]$.

The consistency of the system L follows by the methods of existing proofs.[4] The ω-consistency of L is a matter of more difficulty, but for our present purpose the following weaker property of L is sufficient: *if* P *contains no quantifiers and* (Ex)P *is provable in* L *then not all of* $\overline{P}_1, \overline{P}_2, \overline{P}_3, \cdots$ *are provable in* L (*where* $P_1, P_2, P_3, \cdots$ *are respectively the results of substituting* $1, 2, 3, \cdots$ *for* x *throughout* P). This property has been proved by Paul Bernays[5] for any one of a class of systems of which L is one. Hence, by the argument of the author's cited paper, follows:

Received April 15, 1936.

[1] *An unsolvable problem of elementary number theory*, **American journal of mathematics**, vol. 58 (1936).

[2] ***Grundzüge der theoretischen Logik***, Berlin 1928.

[3] Definitions of the terms *well-formed formula* and *convertible* are given in the cited paper.

[4] Cf. Wilhelm Ackermann, *Begründung des "tertium non datur" mittels der Hilbertschen Theorie der Widerspruchsfreiheit*, **Mathematische Annalen**, vol. 93 (1924–5), pp. 1–136; J. v. Neumann, *Zur Hilbertschen Beweistheorie*, **Mathematische Zeitschrift**, vol. 26 (1927), pp. 1–46; Jacques Herbrand, *Sur la non-contradiction de l'arithmétique*, **Journal für die reine und angewandte Mathematik**, vol. 166 (1931–2), pp. 1–8.

[5] In lectures at Princeton, N. J., 1936. The methods employed are those of existing consistency proofs.

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submitted on 28 May 1936 to the London Mathematical Society for publication in its *Proceedings*. Turing's paper was revised in August to include a note (p. 231) referring to Church's: "In a recent paper ['An unsolvable problem in elementary number theory'] Alonzo Church has introduced an idea of 'effective calculability', which is equivalent to my 'computability', but is very differently defined. Church also reaches similar conclusions about the Entscheidungsproblem [in 'A note on the Entscheidungsproblem']".

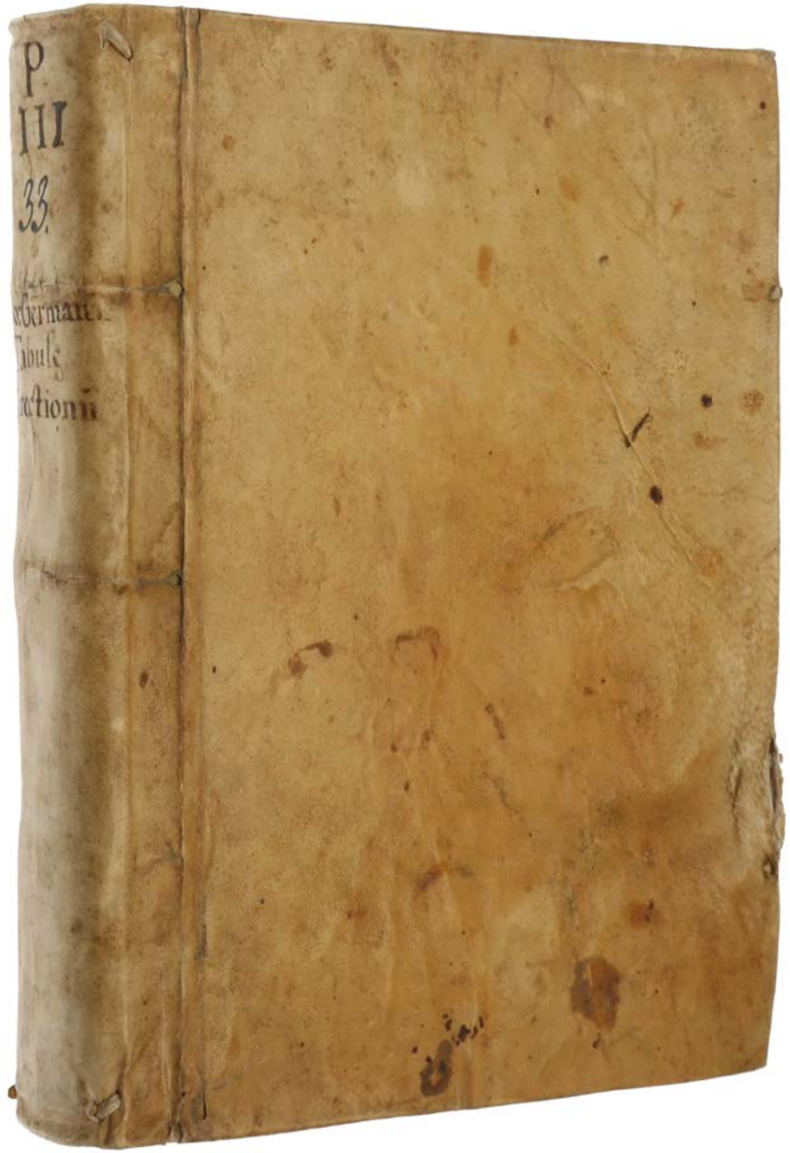
"Poor news though the unsolvability of the *Entscheidungsproblem* was for the Hilbert school, it was very welcome news in other quarters, for a reason that Hilbert's illustrious pupil von Neumann had given in 1927: 'If undecidability were to fail then mathematics, in today's sense, would cease to exist; its place would be taken by a completely mechanical rule, with the aid of which any man would be able to decide, of any given statement, whether the statement can be proven or not.' As the Cambridge mathematician G. H. Hardy said in a lecture in 1928: 'if there were ... a mechanical set of rules for the solution of all mathematical problems ... our activities as mathematicians would come to an end'" (Copeland, p. 53).

AN IMPORTANT SOURCE FOR COPERNICUS

CÓRDOBA, Alfonso de; REGIOMONTANUS, Johannes. *Tabule Astronomice Elisabeth Regine... [Bound after:] Tabule Directionu[m] profectionu[m] q[ue] famosissimi viri Magistri Joannis Germani de Regiomonte in Natiuitatibus multum vtiles: Una cum Tabella sinus recti...* [Colophon:] Venice; ibid: Petrus Liechtenstein; ibid, 28 December 1503; February 1504.

$17,500

4to (210 x 161mm). Córdoba: ff. [52], E4 blank and present. Woodcut initials, that on A1v being, according to Zinner (p. 174), an image of Regiomontanus; Liechtenstein's woodcut device printed in red and black on E3v (minor marginal worming, not near text); Regiomontanus: ff. [150]. Woodcut initials, that on A3r being an image of the author, Liechtenstein's device on R6v (two small wormholes to title, not near text, dampstain to head margin affecting first half of volume, scattered ink stains, light foxing, soiling to D2-4). Later sixteenth-century limp vellum, titled in manuscript on spine: Io: Germani | Tabule | Directionū (covers somewhat cockled and soiled, slight damage to fore-edge of upper board).



First edition, the fine Doheny copy in an untouched near-contemporary binding, of Alfonso de Córdoba's rare astronomical tables, an important source for Copernicus who referred to them in the *Commentariolus* (the first draft of his planetary theory, which remained unpublished until the late 19th century). They are here bound with the second edition of Regiomontanus's astrological tables, the *Tabulae directionum*, compiled in 1467 and first published in 1490;

according to Zinner (p. 95), these tables were also used by Copernicus. The *Tabulae directionum* contain the first table of tangents for use in astronomy. Córdoba's tables are divided into two parts: the first includes a dedication to Ferdinand V (1452-1516) and Isabella (1451-1504), King and Queen of Spain (who, most famously, sent Columbus on his voyage to discover a route to the East Indies) and a set of canons in sixty chapters explaining the use of the tables, with several examples; the second part contains the tables. "In the *Commentariolus*, Copernicus refers to the length of the year, and mentions the values given by four astronomers: Hipparchus, Ptolemy, al-Battani and a fourth referred to as 'Hispalensis' whose identity remained a mystery until the 20th century, when he was identified as Alfonso de Córdoba, a Spanish astronomer and doctor of arts and medicine probably born in 1458 in Seville" (Chabas). We have almost no information about Alfonso de Córdoba's life, and even the date of his death is unknown. ABPC/RBH lists no other complete copy of the Córdoba since Honeyman (19th century binding), no complete copy of the first edition of the Regiomontanus and no other copy of the second.

Provenance: Quaritch, *Catalogue 1422* (2013) (£15,000); Christie's, The Estelle Doheny Collection from St. Mary's of the Barrens, Perryville, Missouri, 14 December 2001, lot 253 (realized $6,462); (note in Christie's citation): *Given to Western Province by the Roman Province of the Congregation of the Mission, 11 September 1954 – donated by them to SMS, 14 May 1967;* early ownership inscription, cancelled but partly visible, to last page of Córdoba; erased ownership mark to title of Regiomontanus; early monastic inscription 'Prohibitus' to title of Regiomontanus; early unidentified manuscript call number to spine: P | III | 33.

The Alphonsine Tables were the first astronomical tables prepared in Christian Europe. They enabled the calculation of eclipses and the positions of the planets for any given time based on the Ptolemaic theory, which assumed that the Earth was at the centre of the universe. Based on the calculations of the Arab astronomer al-Zarqali (also known as Arzachel, 1029–87), the tables were prepared in Toledo, Spain, for King Alfonso X of León and Castile (1223?–84) under the direction of Jehuda ben Moses Cohen and Isaac ben Sid. The tables were not widely known, however, until a Latin version was prepared in Paris in the 1320s. Copies rapidly spread throughout Europe, and for more than two centuries they were the best astronomical tables available. They were first printed at Venice in 1483.

"As was true for almost all European astronomers at the time, Alfonso de Córdoba faithfully adhered to the Alfonsine Tables and followed a tradition in the framework of Ptolemy's astronomy to the point that several of his tables are taken, whether directly or not, from Ptolemy's *Almagest*. Among the material used by Alfonso de Córdoba we have identified the *editio princeps* (1483) of the Alfonsine Tables … However, Alfonso de Córdoba did not limit himself to reproducing the tables in the 1483 edition, adapting them for the time of Queen Isabella, for there are significant changes in presentation; indeed, several of his tables have very different formats from the standard ones, indicating that he had real insights into astronomy and was able to compute competently using tables. Moreover, he constructed some tables adapted to the latitude of his city, Seville, and this bears witness to his considerable computational skill. In fact, Alfonso de Córdoba's *Tabule astronomice Elisabeth Regine* may be regarded as another form of presenting the Alfonsine Tables without departing from its underlying astronomical content … Alfonso de Córdoba produced astronomy at a level similar to that of the best astronomers of his time. This is probably why his tables were used by astronomers in the 1520s, notably … Nicholas Copernicus …

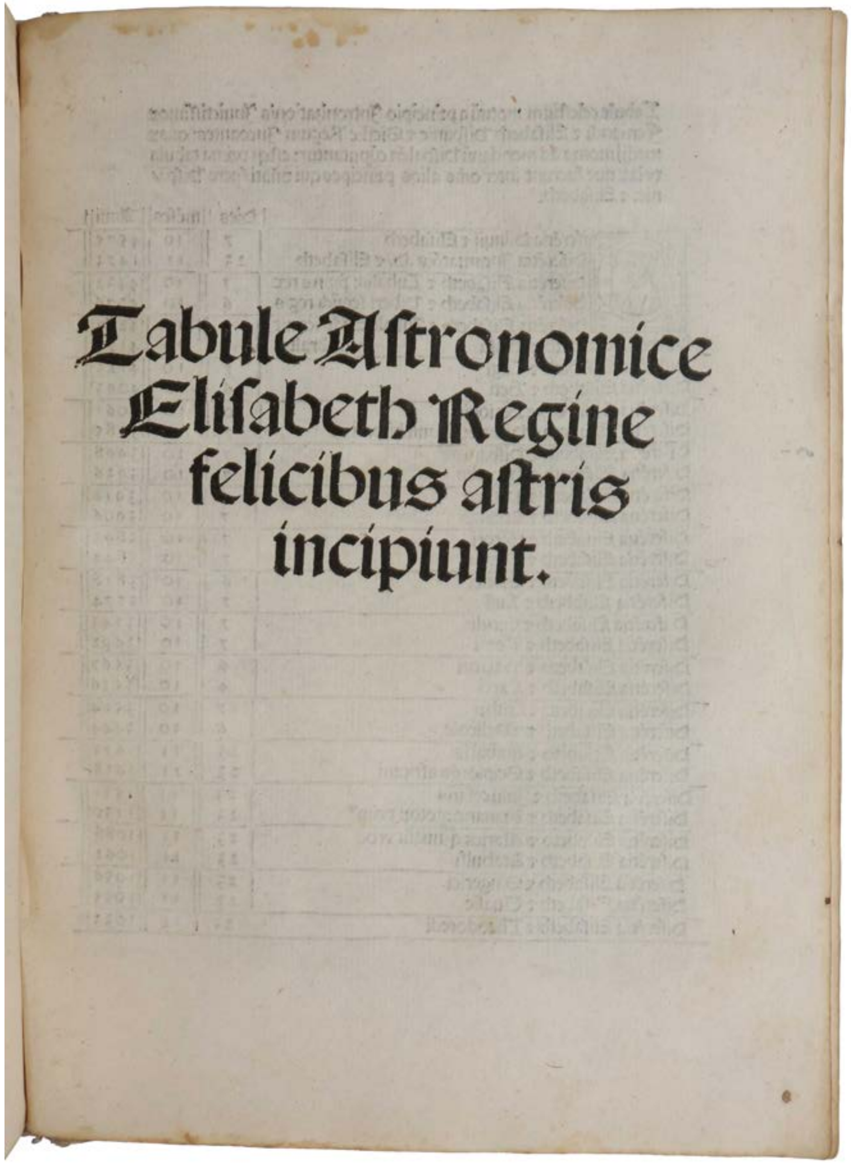
"The text, written in Latin, was printed at least twice. The first edition appeared in Venice in 1503 (December 28), and was printed by Petrus Liechtenstein, the same printer who had published Alfonso de Córdoba's edition of the *Almanach*

Perpetuum one year earlier. The second edition of the tables of Queen Isabella, edited by Luca Gaurico (1476-1558), was printed in 1524 by Lucas Antonius Iunta, also in Venice, in a volume bound with the Alphonsine Tables … The 1524 edition omits the dedication and the canons, and only displays the tables, some of them with short explanatory notes.

"As indicated in the colophon, Alfonso de Córdoba composed his work in Rome. In Chap. 1 (a3r) we are told that the epoch of these tables is noon of the civil day prior to December 24, 1474. This is precisely the date of Queen Isabella's accession to the throne of Castile according to Alfonso de Córdoba … The text does not introduce an 'era of Queen Isabella of Castille'; nevertheless, Alfonso de Córdoba followed a tradition well established in the Alphonsine Tables that goes back far in time: taking some significant moment in the life of a monarch as the starting point for computing planetary positions. For example, in the celebrated Alphonsine Tables, as 'era of Alfonso' was defined as starting on January 1, 1252, the year in which the reign of Alfonso X of Castile and León began" (Chabas).

Johannes Müller (1436-76), called Regiomontanus, was arguably the most important astronomer of the fifteenth century. Born in the Franconian town of Königsberg, he was educated at the Universities of Leipzig and Vienna, and appointed to the Arts Faculty of the latter institution in 1457. In 1461 Regiomontanus went with Cardinal Bessarion to Rome, and accompanied him on various travels around Italy. Association with the Cardinal, a native of Trebizond in Turkey and a great patron of humanist scholarship, gave Regiomontanus access to other texts, and the opportunity for him to become fluent in Greek. Between 1467 and 1471, Regiomontanus worked in Hungary.

"Regiomontanus made these tables in 1467 at the castle in Gran … With this work he was helped by Martin Ilkusz [i.e., Martin Bylica of Olkusz, 1433-93)], a Polish



master from the University of Cracow as well as doctor of theology and medicine. He was probably the one who lectured on astronomy at Bologna during 1463-64, and was later in Rome as Cardinal Barbo's astrologer during the papal election where he met Regiomontanus, who cast him as the Cracower in opposition to the Viennese man in his dialogue on Sabbonieta's planetary theory [*Disputationes contra Cremonensia in planetarum theoricas deliramenta*]" (Zinner, p. 95).

"In 1467, with Bylica's assistance, Regiomontanus computed his *Tables of Directions*, which consisted of the longitudes of the celestial bodies in relation to the apparent daily rotation of the heavens. These *Tables*, computed for observers as far north of the equator as 60°, were first published in 1490 and very frequently thereafter. Regiomontanus wrote accompanying problems and in problem 10 he indicated the desirability of abandoning the sexagesimal character of the table of sides by putting sin 90° = 100,000 instead of 60,000 (the base he had used in *Triangles*, book IV, theorem 25). In that work he had not employed the tangent function; but in *Tables of Directions* he included a table of tangents (although he did not use this term) for angles up to 90°, the interval being 1° and tan 45° = 100,000, thereby providing the model for our modern tables" (DSB).

"For the most part, this work, called *Tabulae directionum,* contained tables for calculating the house boundaries, with accompanying directions for use. In Section 14 he came to speak about the several different manners of calculating the houses. Leaving out the oldest and simplest way, namely dividing the zodiac into twelve equal parts, beginning from the first of Aries — which method was even used by Cardano — he described the three most important divisions of the heavens: (1) The most common division of the zodiac by the six hourly circles, going through the terrestrial North Pole and beginning from the east point; (2) Campanus's division by six circles, the ones through the celestial poles and the perpendicular one through the east and west points being evenly subdivided; (3) The division by six circles, which also go through the celestial North and South Poles, but the equator being evenly subdivided beginning from the east point. Regiomontanus preferred this last method and used it to calculate his tables for latitudes up to 60°. At the same time he supplied all tables that were necessary for casting horoscopes, not including those of the planetary positions, and taught how to use these tables with a number of examples given in the commentary. He also gave instructions for testing and expanding his tables.

"In the commentary to these tables, he referred to a table of sines with sin 90° = 60,000, but remarked in Section 10 that a table of sines with sin 90° = 100,000 would be much more useful. In the same section he introduced his *Tabula secunda*, namely a table of tangents with tan 45° = 100,000 and showed its advantages … Regiomontanus may have been the first to introduce the modern table of tangents and to emphasize its usefulness … In the commentary to his *Tabulae directionum* he pointed out the advantages of both this table [of sines with sin 90° = 100,000] and a table of tangents with tan 45° = 100,000; hence the decimal system had been used throughout.

"He wanted to publish the *Tabulae directionum* in Nuremberg, but this was not to be. It was first printed posthumously by Erhard Ratdolt in Augusburg, and went through eleven editions up to 1626 … Among those who used these tables were Albert von Brudzewo, Nicholas Copernicus, Johannes Werner, J. Cario, Lucas Gauricus, Jacobus Ferdinand Bariensis, H. Altobellus, E. O. Schrekenfuchs, Georg Collimitius Tanstetter, J. Hieber and Kepler" (Zinner, pp. 92-3).

Carrie Estelle Betzold Doheny (1875-1958) married oil tycoon Edward Laurence Doheny (1856-1935) in 1900. Although overshadowed by her husband's fame during her lifetime, she later achieved her own recognition as one of the most renowned American women book collectors of the twentieth century. She first began collecting books in the 1920s: her principal areas of interest included fine bindings, illuminated manuscripts, incunabula, and Western Americana. In 1950, she acquired the "crowning achievement" of her collection, a complete Gutenberg Bible. The collection grew to approximately 7,000 books and 1,300 manuscripts, and was housed in the Doheny mansion in Los Angeles. In 1940, Mrs. Doheny donated a large portion of her book collection to St. John's Seminary in Camarillo, California, to be housed in the Edward Laurence Doheny Memorial Library. However, in 1985, church officials decided to sell the collection and use the proceeds to establish a teaching endowment. It was auctioned by Christie's in a series of six sales from 1987 to 1989. In 1954, Mrs. Doheny donated a further portion of her collection to St. Mary's of the Barrens in Perry County, Missouri, but in 2000 its library was closed and the Doheny treasures were sold, again by Christie's, in the following year. The present volume was included in the latter sale.

Córdoba: Adams C2622; Houzeau & Lancaster 12712; Lalande, p. 31; Palau 61824; José Chabas, 'Astronomy for the Court in the Early Sixteenth Century. Alfonso de Córdoba and his Tabule Astronomice Elisabeth Regine,' *Archive for History of Exact Sciences*, Vol. 58, No. 3 (2004), pp. 183-217. Regiomontanus: Adams R287; BM STC It. p. 455; Zinner, *Regiomontanus*: *His Life and Work*, 1990.

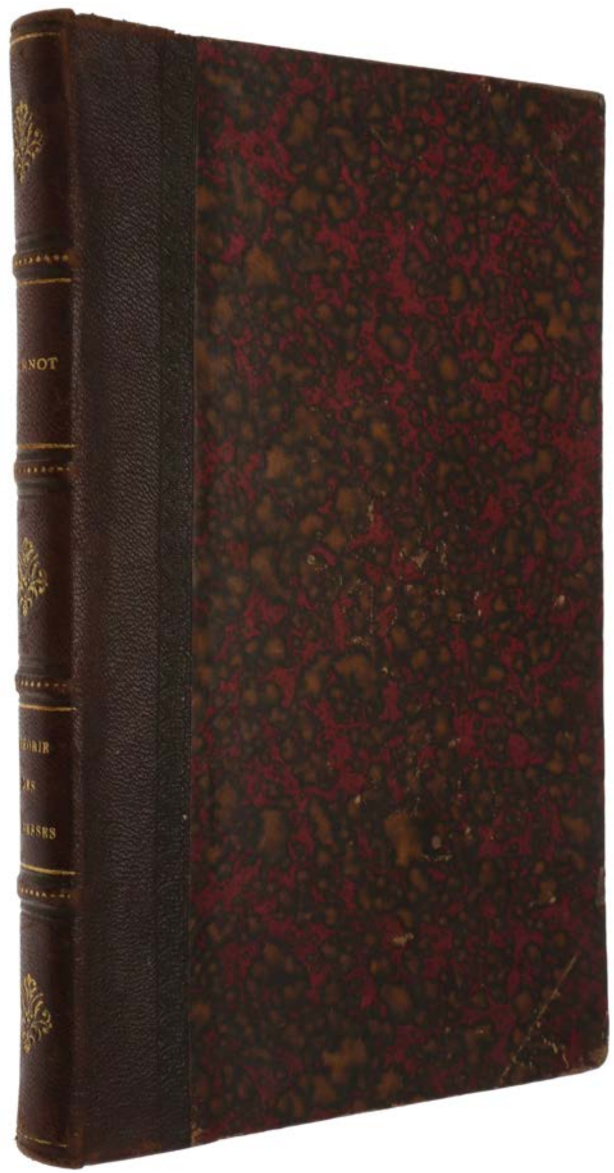
INAUGURATED THE FIELD OF MATHEMATICAL ECONOMICS

COURNOT, Antoine Augustin. *Recherches sur les Principes Mathématiques de la Théorie des Richesses.* Paris: Chez L. Hachette, 1838.

$17,500

8vo (209 x 130 mm), pp. xi (including half-title), 198, [2, contents and errata], with one folding plate, diagrams in text. Contemporary half calf, gilt spine. Some foxing throughout as is always the case with this book.

First edition, rare, of Cournot's masterpiece which inaugurated mathematical economics. "Although neglected in his time, the impact of Cournot's work on modern economics can hardly be overstated" (*The History of Economic Thought*). "With the publication in 1838 of his *Recherches sur les principes mathématiques de la théorie des richesses*, he was a third of a century ahead of Walras and Jevons and must be considered the true founder of mathematical economics. By reducing the problem of price formation in a given market to a question of analysis, he was the first to formulate the data of the diagram of monopolistic competition, thus defining a type of solution that has remained famous as 'Cournot's point' … Undoubtedly, he remains the first of the important pioneers in this field" (DSB). "Cournot, in a book that for sheer originality and boldness of conception has no equal in the history of economic thought, was the very first writer to define and to draw a demand function … To prove the existence and uniqueness of the maximum [of the total profit], Cournot employed the familiar tests of calculus: the first derivative of the total profit function must vanish and the second



derivative must be negative. All this in 1838!" (Blaug, pp. 301-2). Schumpeter (p. 463) places Cournot among "The Men Who Wrote Above Their Time" – that is, men who delivered "important performances, the powerful originality of which was recognized late but which the profession completely, or almost completely, failed to recognize at the time." Cournot himself expected that this work would not be well received – in the preface he writes, "le titre. . . indique . . . que j'ai intention d'y appliquer les formes et les symboles de l'analyse mathématique: or c'est-là, je le confesse, un plan qui doit m'attirer tout d'abord la reprobation des théoriciens accrédités" – and it was not until the 1870s that its importance began to be recognised. Today "it strikes us as an utterly modern work – underlining Schumpeter's view of Cournot as a man above his time. It is not just that Cournot provides us with the now-standard presentations of monopoly and perfect competition much as they are found in basic microeconomics textbooks today; it is that he presents them in a thoroughly modern idiom. The ideas of Smith, Ricardo, Jevons, Marshall, and Walras live on in modern economics, but the dust of an outmoded vocabulary and defunct styles of exposition hang around the original texts. Not so with Cournot. It would hardly raise a student's eyebrow if Cournot's text were included on a modern graduate syllabus. Cournot invented the modern idiom of mathematical economics and remains one of its master expositors. He did not attempt to write a complete treatise on political economy in the mode of Adam Smith. Rather – in the manner of so many recent economists – he extracted from political economy just those portions that were most amenable to mathematical representation and analyzed them concisely and efficiently. In style and substance, the *Recherches* reads very much like graduate textbooks from Samuelson's *Foundations of Economic Analysis* (1947) to the present day" (Wible & Hoover, p. 515). Only four complete copies have sold at British and American auctions in the last 30 years (the folding plate is often lacking).

"Cournot begins with some preliminary remarks on the role of mathematics applied to the social sciences. He announces that his purpose in using mathematics is merely to guide his reasoning and illustrate his argument rather than lead to any numerical calculations. He acknowledges (and disparages) N.F. Canard as his only predecessor. In his first three chapters, Cournot runs through the definition of wealth, absolute vs. relative prices and the law of one price.

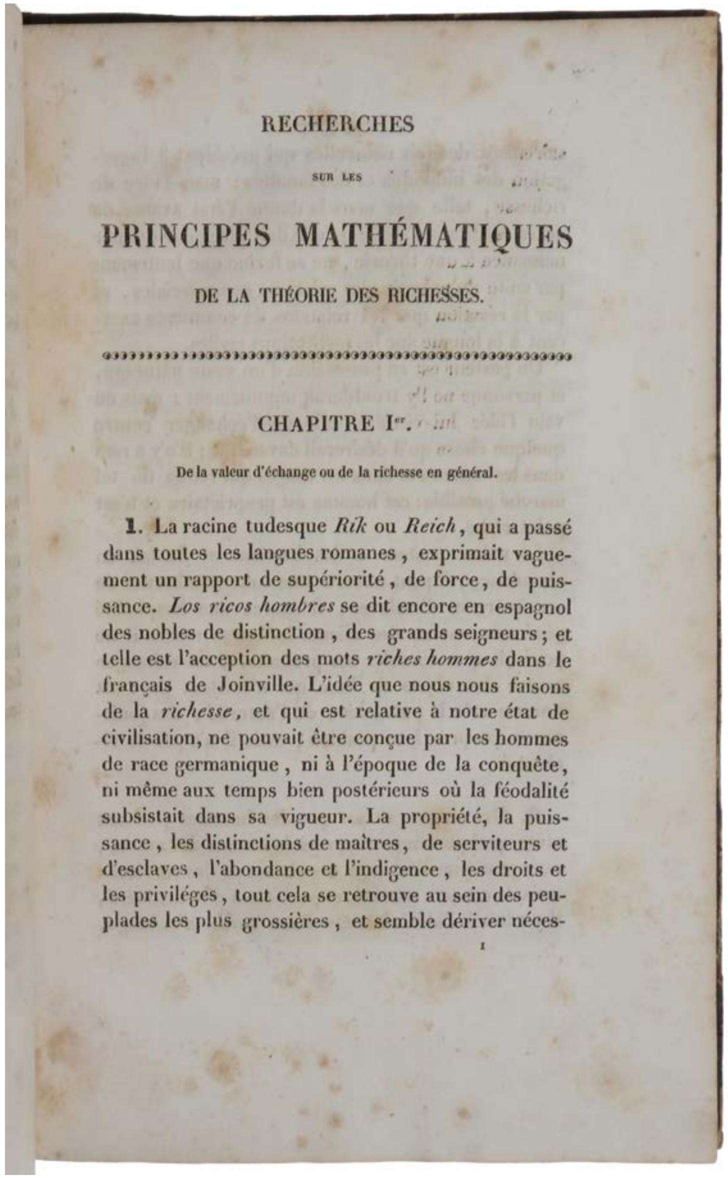
"Then, in Chapter 4, he unveils his demand function. He writes it in general form as $D = F(p)$. He assumes that F is continuous and takes it as an empirical proposition that the demand function is downward-sloping (the *loi de débit*, 'law of demand'). It is important to note that Cournot's 'demand function' is not a demand schedule in the modern sense. His curve, $D = F(p)$ merely summarizes the empirical relationship between price and quantity sold, rather than the conceptual relationship between price and the quantity sought by buyers. Cournot refuses to derive demand from any 'utility'-based theories of individual behavior. As he notes, the 'accessory ideas of utility, scarcity, and suitability to the needs and enjoyments of mankind … are variable and by nature indeterminate, and consequently ill suited for the foundation of a scientific theory' (p. 10). He satisfies himself with merely acknowledging that the functional form of F depends on 'the utility of the article, the nature of the services it can render or the enjoyments it can procure, on the habits and customs of the people, on the average wealth, and on the scale on which wealth is distributed' (p. 47). He proceeds to draw the demand curve in price-quantity space (Fig. 1). He also introduces the idea of 'elasticity' of demand, but does not write it down in a mathematical formula.

"In Chapter 5, Cournot jumps immediately into an analysis of monopoly. Here, Cournot introduces the concept of a profit-maximizing producer. He begins by positing a cost function $f(D)$ and discusses decreasing, constant and increasing costs to scale. He shows, mathematically, how a producer will choose to produce at a quantity where marginal revenue is equal to marginal cost. In Chapter 6, he examines the impact of various forms of taxes and bounties on price and quantity produced, as well as their impact on the income of producers and consumers.

"In Chapter 7, Cournot presents his famous 'duopoly' model. He sets up a mathematical model with two rival producers of a homogeneous product. Each producer is conscious that his rival's quantity decision will also impact the price he faces and thus his profits. Consequently, each producer chooses a quantity that maximizes his profits subject to the quantity reactions of his rival. Cournot mathematically derives a deterministic solution as the quantities chosen by the rival producers are in accordance with each other's anticipated reactions. Cournot showed how this equilibrium can be drawn as the intersection of two 'reaction curves'. He depicts a stable and an unstable equilibrium in Figures 2 and 3 respectively.

"Comparing solutions, Cournot notes that under duopoly, the price is lower and the total quantity produced greater than under monopoly. He runs with this insight, showing that as the number of producers increases, the quantity becomes greater and the price lower. In Chapter 8, he introduces the case of unlimited competition, i.e. where the quantity of producers is so great that the entry or departure of an individual producer has a negligible effect on the total quantity produced. He goes on to derive the prices and quantities in this 'perfectly competitive' situation, in particular showing that, at the solution, price is equal to marginal cost.

"In the remainder of his book, Cournot takes up what he calls the 'communication of markets', or trade of a single good between regions. In Chapter 10, he analyzes two isolated countries and one homogeneous product. He shows that the impact of opening trade between the two countries leads to the equalization of prices, with the lower cost producer exporting to the higher cost country. Cournot



RECHERCHES

SUR LES

PRINCIPES MATHÉMATIQUES

DE LA THÉORIE DES RICHESSES.

CHAPITRE Ier.

De la valeur d'échange ou de la richesse en général.

1. La racine tudesque *Rik* ou *Reich*, qui a passé dans toutes les langues romanes, exprimait vaguement un rapport de supériorité, de force, de puissance. *Los ricos hombres* se dit encore en espagnol des nobles de distinction, des grands seigneurs; et telle est l'acception des mots *riches hommes* dans le français de Joinville. L'idée que nous nous faisons de la *richesse*, et qui est relative à notre état de civilisation, ne pouvait être conçue par les hommes de race germanique, ni à l'époque de la conquête, ni même aux temps bien postérieurs où la féodalité subsistait dans sa vigueur. La propriété, la puissance, les distinctions de maîtres, de serviteurs et d'esclaves, l'abondance et l'indigence, les droits et les priviléges, tout cela se retrouve au sein des peuplades les plus grossières, et semble dériver néces-

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tries to prove that there are conditions where the opening of trade will lead to a decline in the quantity of the good and lower revenue. He then proceeds to discuss the impact of import and export taxes and subsidies. On account of this, Cournot raises doubts in Chapter 12 about the 'gains from trade' and defends the profitability of import duties.

"Finally, Cournot acknowledges that the solutions obtained via his 'partial equilibrium' method are incomplete. He recognizes the need to take multiple markets into account and trying to solve for the general equilibrium, but 'this would surpass the powers of mathematical analysis' (p. 127).

"Cournot's 1838 work received hardly any response when it came out. The denizens of the French Liberal School, who dominated the economics profession in France at the time, took no notice of it. Cournot was left crushed and bitter … Cournot took another stab with his *Principes de la théorie des richesses* (1863), which, on the whole, was merely a restatement of the 1838 *Recherches* in more popular prose and without the mathematics. Once again, it was completely neglected …

"However, by this time the Marginalist Revolution had already started. Léon Walras (*Éléments d'économie politique pure*, 1874), who had read Cournot's work early on, argued that his own theory was but a multi-market generalization of Cournot's partial equilibrium model (indeed, the notation is almost identical). W. Stanley Jevons, who had not read him, nonetheless hailed him as a predecessor in later editions of his *The Theory of Political Economy* (1871). Francis Ysidro Edgeworth (*Mathematical Psychics*, 1881) went to Cournot to pick up his theory of perfect competition. Alfred Marshall claimed to have read him as far back as 1868, and extensively acknowledged Cournot's influence in his 1890 textbook *Principles of Economics*, particularly in his discussion of the theory of the firm.

"Cournot lived long enough to greet the works of Walras and Jevons with a warm sense of vindication. This is evident in Cournot's *Revue sommaire des doctrines économiques* (1877), a long, non-mathematical statement of his earlier work. He seemed particularly grateful that Walras had bravely climbed the steps of the Institute de France and accused the academicians of injustice towards Cournot. He died that same year …

"Cournot's *Recherches* were finally translated into English in 1898. The introduction by Irving Fisher and Henry L. Moore's 1905 biographical pieces helped promote Cournot's work among Anglo-American economists. The development of monopolistic competition in the 1930s drew much inspiration from Cournot's work.

"Cournot's influence grew by leaps and bounds in the second half of the 20th Century. As game theory advanced, Mayberry, Nash and Shubik ('A comparison of treatments of a duopoly situation,' *Econometrica* 21 (1953), 141-54) restated Cournot's duopoly theory as a non-cooperative game with quantities as strategic variables. They showed that Cournot's solution was nothing other than its 'Nash equilibrium' (Nash, 'Non-cooperative games,' *Annals of Mathematics* 54 (1951), 286-95). Cournot's influence on modern theory continues unabated, having been given a particular boost in the attempt to develop non-cooperative foundations for Walrasian general equilibrium theory" (*The History of Economic Thought*).

Antoine Augustin Cournot was born on August 28, 1801, in the small town of Gray (Haute-Saône) in France. He was educated in the schools of Gray until he was 15. At 19, he enrolled in a mathematical preparatory course at a school in Besançon, and subsequently won entry into the École Normale Supérieure in Paris in 1821. In 1822, Cournot transferred to the Sorbonne, obtaining a licentiate in mathematics in 1823. In Paris, he attended seminars at the Académie des Sciences and the salon of the economist Joseph Droz. Among his main intellectual influences were Pierre-Simon Laplace, Joseph-Louis Lagrange and Hachette, a former disciple of Marie-Antoine Condorcet, who started him on the principles of *mathématique sociale,* i.e., the idea that the social sciences, like the natural sciences, could be dealt with mathematically. From 1823, Cournot was employed as a literary advisor to Marshal Gouvoin Saint Cyr and as a tutor to his son. In 1829, Cournot acquired a doctorate in sciences, focusing on mechanics and astronomy. In 1834, Cournot found a permanent appointment as professor of analysis and mechanics at Lyons. A year later, Poisson secured him a rectorship at the Academy of Grenoble. Although his duties were mostly administrative, Cournot excelled at them. In 1838 (again, at the instigation of the loyal Poisson), Cournot was called to Paris as Inspecteur Général des Études. In that same year, he was made a knight of the Légion d'honneur, and he published his masterpiece, the *Recherches*. In 1839, the sickly Poisson asked Cournot to represent him at the *Concours d'agrégation de mathématiques* at the *Conseil Royal*. After Poisson died in 1840, Cournot continued on at the *Conseil* as a deputy to Poisson's successor, the mathematician Louis Poinsot. In 1841, Cournot published his lecture notes on analysis from Lyons, dedicating the resulting *Traité élémentaire de la théorie des fonctions et du calcul infinitésimal* to his long-time benefactor, Poisson. In 1843, Cournot made his first stab at probability theory in his brilliant *Exposition de la théorie des chances et des probabilités*. He differentiated between three types of probabilities: objective, subjective and philosophical. The former two follow their standard ontological and epistemological definitions. The third category refers to probabilities 'which depend mainly on the idea that we have of the simplicity of the laws of nature,' or what modern commentators would call 'credal probabilities'. After the 1848 Revolution, Cournot was appointed to the *Commission des Hautes Études*. It was during this time that he wrote his first treatise on the philosophy of science *Essai sur les fondements de nos connaissances et sur les caractères de la critique philosophique* (1851). In 1854, he became rector of the Academy at Dijon. However, by this time, Cournot's lifelong eye-sight problem began getting worse. In 1859, Cournot wrote his *Souvenirs*, a haunting autobiographical memoir (published posthumously in 1913). Cournot retired from teaching in 1862 and moved back to Paris. Despite the dark pessimism about the decline of his sight and his creative powers, Cournot wasn't quite yet finished. He published two more philosophical treatises in 1861 and 1872 which sealed his fame in the French philosophy community.

Kress C4590. Blaug, *Economic Theory in Retrospect*, 1997. Schumpeter, *History of Economic Analysis*, 1954. Wible & Hoover, 'Mathematical Economics Comes to America: Charles S. Peirce's Engagement with Cournot's *Recherches Sur Les Principes Mathematiques De La Théorie Des Richesses*,' *Journal of the History of Economic Thought* 37 (2015), pp. 511-36. *The History of Economic Thought* (hetwebsite.net/het/profiles/cournot.htm).

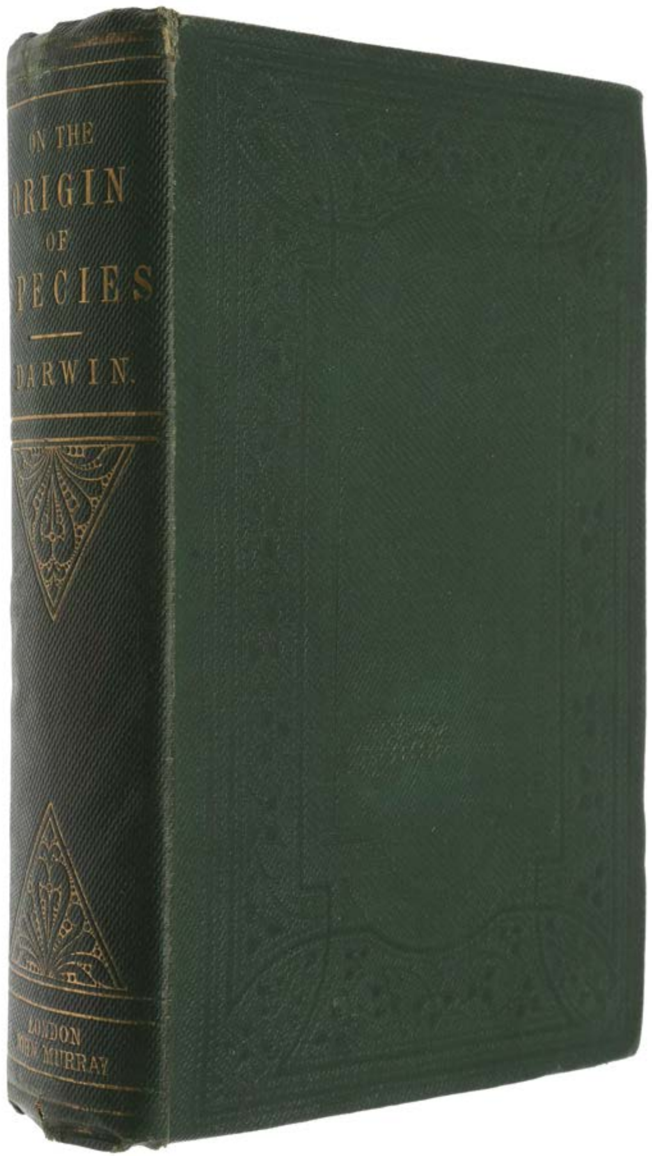
THE MOST IMPORTANT BIOLOGICAL WORK EVER WRITTEN

DARWIN, Charles. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.* London: John Murray, 1859.

$480,000

8vo (198 x 124 mm), pp. ix, [i], 502, [32, publisher's catalogue dated June 1859], with one folding lithographed table. A fine, unrestored copy bound in publisher's green blind-stamped cloth gilt (slightly rubbed at extremities) rear paste-down with binder's ticket, half-title and title with some very small tears. Custom half leather box with gilt spine.

First edition, an unusually fine copy, untouched in its original binding, of "the most influential scientific work of the nineteenth century" (Horblit), "the most important biological work ever written" (Freeman), and "a turning point, not only in the history of science, but in the history of ideas in general" (DSB). "Darwin not only drew an entirely new picture of the workings of organic nature; he revolutionized our methods of thinking and our outlook on the natural order of things. The recognition that constant change is the order of the universe had been finally established and a vast step forward in the uniformity of nature had been taken" (*Printing and the Mind of Man*). Bern Dibner's *Heralds of Science* describes *On the Origin of Species* as "the most important single work in science." When the first edition was published on 24 November 1859, in a print run of 1,250 copies, it created an immediate sensation. Fifty-eight were distributed by Murray for review, promotion, and presentation,



and Darwin reported that the balance was sold out on the first day of publication. Five further editions, each variously corrected and revised, appeared in Darwin's lifetime, as did eleven translations. The *Origin* was actually an 'abstract' of a larger work, tentatively titled Natural Selection, that Darwin never completed, although he salvaged much of the first part of the manuscript for *The Variation of Animals and Plants under Domestication*, published in 1868.

"England became quieter and more prosperous in the 1850s, and by mid-decade the professionals were taking over, instituting exams and establishing a meritocracy. The changing social composition of science—typified by the rise of the freethinking biologist Thomas Henry Huxley—promised a better reception for Darwin. Huxley, the philosopher Herbert Spencer, and other outsiders were opting for a secular nature in the rationalist *Westminster Review* and deriding the influence of "parsondom." Darwin had himself lost the last shreds of his belief in Christianity with the tragic death of his oldest daughter, Annie, from typhoid in 1851 …

"After speaking to Huxley and Hooker at Downe in April 1856, Darwin began writing a triple-volume book, tentatively called *Natural Selection*, which was designed to crush the opposition with a welter of facts. Darwin now had immense scientific and social authority, and his place in the parish was assured when he was sworn in as a justice of the peace in 1857. Encouraged by Lyell, Darwin continued writing through the birth of his 10th and last child, Charles Waring Darwin (born in 1856, when Emma was 48), who was developmentally disabled. Whereas in the 1830s Darwin had thought that species remained perfectly adapted until the environment changed, he now believed that every new variation was imperfect, and that perpetual struggle was the rule. He also explained the evolution of sterile worker bees in 1857. Those could not be selected because they did not breed, so he opted for "family" selection (kin selection, as it is known today): the whole colony benefited from their retention.

"Darwin had finished a quarter of a million words by June 18, 1858. That day he received a letter from Alfred Russel Wallace, an English socialist and specimen collector working in the Malay Archipelago, sketching a similar-looking theory. Darwin, fearing loss of priority, accepted Lyell's and Hooker's solution: they read joint extracts from Darwin's and Wallace's works at the Linnean Society on July 1, 1858. Darwin was away, sick, grieving for his tiny son who had died from scarlet fever, and thus he missed the first public presentation of the theory of natural selection. It was an absenteeism that would mark his later years.

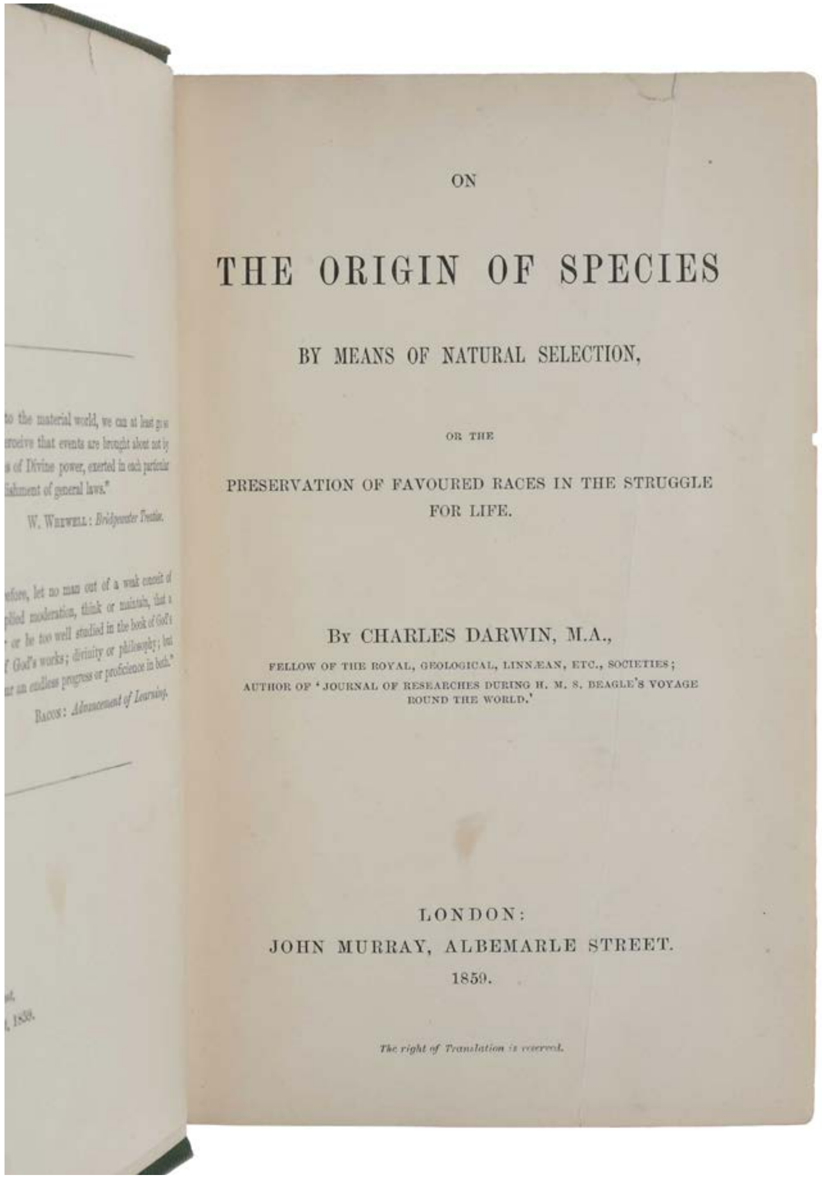
"Darwin hastily began an "abstract" of Natural Selection, which grew into a more-accessible book, *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. Suffering from a terrible bout of nausea, Darwin, now 50, was secreted away at a spa on the desolate Yorkshire moors when the book was sold to the trade on November 22, 1859. He still feared the worst and sent copies to the experts with self-effacing letters ("how you will long to crucify me alive"). It was like "living in Hell," he said about those months.

"The book did distress his Cambridge patrons, but they were marginal to science now. However, radical Dissenters were sympathetic, as were the rising London biologists and geologists, even if few actually adopted Darwin's cost-benefit approach to nature. The newspapers drew the one conclusion that Darwin had specifically avoided: that humans had evolved from apes, and that Darwin was denying mankind's immortality. A sensitive "Darwin, making no personal appearances, let Huxley, by now a good friend, manage that part of the debate. The pugnacious Huxley, who loved public argument as much as Darwin loathed it, had his own reasons for taking up the cause, and did so with enthusiasm. He wrote three reviews of *Origin of Species*, defended human evolution at the Oxford meeting of the British Association for the Advancement of Science in 1860 (when Bishop Samuel Wilberforce jokingly asked whether the apes were on Huxley's grandmother's or grandfather's side), and published his own book on human evolution, *Evidence as to Man's Place in Nature* (1863). What Huxley championed was Darwin's evolutionary naturalism, his non-miraculous assumptions, which pushed biological science into previously taboo areas and increased the power of Huxley's professionals. And it was they who gained the Royal Society's Copley Medal for Darwin in 1864" (Britannica).

"Chapter I covers animal husbandry and plant breeding, going back to ancient Egypt. Darwin discusses contemporary opinions on the origins of different breeds under cultivation to argue that many have been produced from common ancestors by selective breeding. As an illustration of artificial selection, he describes fancy pigeon breeding, noting that '[t]he diversity of the breeds is something astonishing', yet all were descended from one species of rock pigeon. Darwin saw two distinct kinds of variation: (1) rare abrupt changes he called 'sports' or 'monstrosities' (example: Ancon sheep with short legs), and (2) ubiquitous small differences (example: slightly shorter or longer bill of pigeons). Both types of hereditary changes can be used by breeders. However, for Darwin the small changes were most important in evolution.

"In Chapter II, Darwin specifies that the distinction between species and varieties is arbitrary, with experts disagreeing and changing their decisions when new forms were found. He concludes that 'a well-marked variety may be justly called an incipient species" and that "species are only strongly marked and permanent varieties'. He argues for the ubiquity of variation in nature … Darwin and Wallace made variation among individuals of the same species central to understanding the natural world.

"In Chapter III, Darwin asks how varieties 'which I have called incipient species'



become distinct species, and in answer introduces the key concept he calls 'natural selection' ... Owing to this struggle for life, any variation, however slight and from whatever cause proceeding, if it be in any degree profitable to an individual of any species, in its infinitely complex relations to other organic beings and to external nature, will tend to the preservation of that individual, and will generally be inherited by its offspring ... I have called this principle, by which each slight variation, if useful, is preserved, by the term of Natural Selection, in order to mark its relation to man's power of selection' …

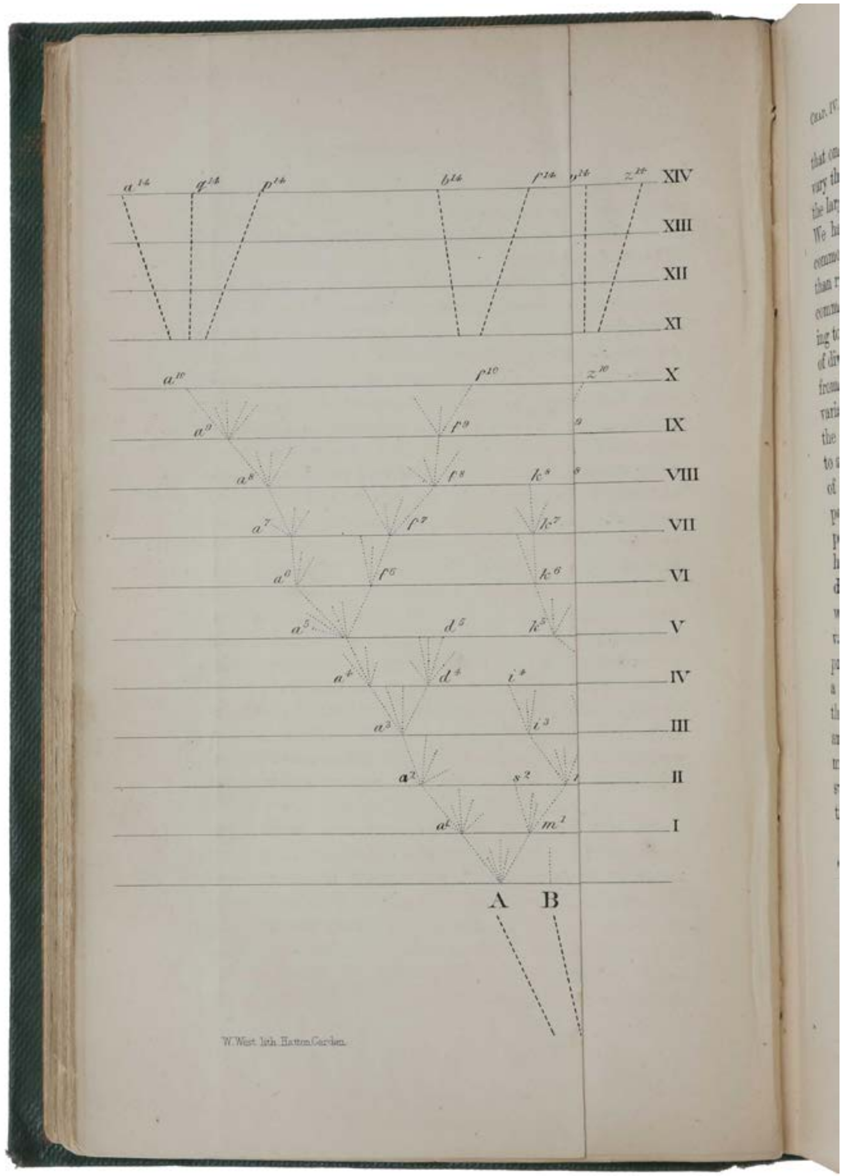
"Chapter IV details natural selection under the 'infinitely complex and close-fitting ... mutual relations of all organic beings to each other and to their physical conditions of life'. Darwin takes as an example a country where a change in conditions led to extinction of some species, immigration of others and, where suitable variations occurred, descendants of some species became adapted to new conditions. He remarks that the artificial selection practised by animal breeders frequently produced sharp divergence in character between breeds, and suggests that natural selection might do the same, saying: 'But how, it may be asked, can any analogous principle apply in nature? I believe it can and does apply most efficiently, from the simple circumstance that the more diversified the descendants from any one species become in structure, constitution, and habits, by so much will they be better enabled to seize on many and widely diversified places in the polity of nature, and so be enabled to increase in numbers' ... Darwin proposes sexual selection, driven by competition between males for mates, to explain sexually dimorphic features such as lion manes, deer antlers, peacock tails, bird songs, and the bright plumage of some male birds ... Using a tree diagram and calculations, he indicates the 'divergence of character' from original species into new species and genera. He describes branches falling off as extinction occurred, while new branches formed in 'the great Tree of life ... with its ever branching and beautiful ramifications' ...
"Chapter V discusses what he called the effects of use and disuse; he wrote that he thought 'there can be little doubt that use in our domestic animals strengthens and enlarges certain parts, and disuse diminishes them; and that such modifications are inherited', and that this also applied in nature. Darwin stated that some changes that were commonly attributed to use and disuse, such as the loss of functional wings in some island dwelling insects, might be produced by natural selection ...

"Chapter VI begins by saying the next three chapters will address possible objections to the theory, the first being that often no intermediate forms between closely related species are found, though the theory implies such forms must have existed. As Darwin noted, 'Firstly, why, if species have descended from other species by insensibly fine gradations, do we not everywhere see innumerable transitional forms? Why is not all nature in confusion, instead of the species being, as we see them, well defined?' Darwin attributed this to the competition between different forms, combined with the small number of individuals of intermediate forms, often leading to extinction of such forms … Another difficulty, related to the first one, is the absence or rarity of transitional varieties in time. Darwin commented that by the theory of natural selection 'innumerable transitional forms must have existed,' and wondered 'why do we not find them embedded in countless numbers in the crust of the earth?' The chapter then deals with whether natural selection could produce complex specialised structures, and the behaviours to use them, when it would be difficult to imagine how intermediate forms could be functional. Darwin said: 'Secondly, is it possible that an animal having, for instance, the structure and habits of a bat, could have been formed by the modification of some animal with wholly different habits? Can we believe that natural selection could produce, on the one hand, organs of trifling importance, such as the tail of a giraffe, which serves as a fly-flapper, and, on the other hand, organs of such wonderful structure, as the eye, of which we hardly as yet fully understand the inimitable perfection?' His answer was that in many cases animals exist with intermediate structures that are functional … Darwin concludes: 'If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down. But I can find out no such case'...

"Chapter VII addresses the evolution of instincts. His examples included two he had investigated experimentally: slave-making ants and the construction of hexagonal cells by honey bees. Darwin noted that some species of slave-making ants were more dependent on slaves than others, and he observed that many ant species will collect and store the pupae of other species as food. He thought it reasonable that species with an extreme dependency on slave workers had evolved in incremental steps. He suggested that bees that make hexagonal cells evolved in steps from bees that made round cells, under pressure from natural selection to economise wax …

"Chapter VIII addresses the idea that species had special characteristics that prevented hybrids from being fertile in order to preserve separately created species. Darwin said that, far from being constant, the difficulty in producing hybrids of related species, and the viability and fertility of the hybrids, varied greatly, especially among plants. Sometimes what were widely considered to be separate species produced fertile hybrid offspring freely, and in other cases what were considered to be mere varieties of the same species could only be crossed with difficulty. Darwin concluded: 'Finally, then, the facts briefly given in this chapter do not seem to me opposed to, but even rather to support the view, that there is no fundamental distinction between species and varieties' ...

"Chapter IX deals with the fact that the geological record appears to show forms of life suddenly arising, without the innumerable transitional fossils expected from gradual changes. Darwin borrowed Charles Lyell's argument in *Principles of Geology* that the record is extremely imperfect as fossilisation is a very rare occurrence,



spread over vast periods of time; since few areas had been geologically explored, there could only be fragmentary knowledge of geological formations, and fossil collections were very poor. Evolved local varieties which migrated into a wider area would seem to be the sudden appearance of a new species ...

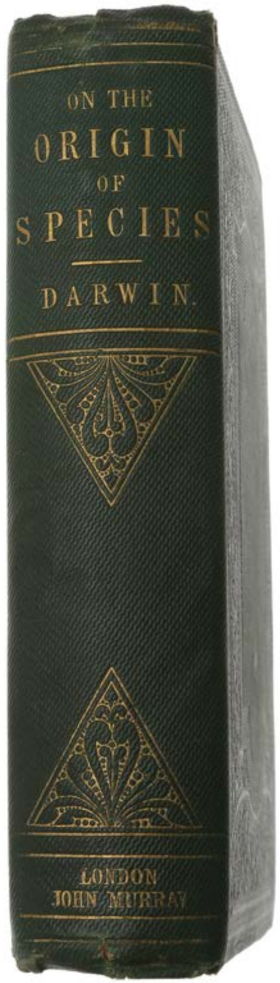
"Chapter X examines whether patterns in the fossil record are better explained by common descent and branching evolution through natural selection, than by the individual creation of fixed species. Darwin expected species to change slowly, but not at the same rate – some organisms such as *Lingula* were unchanged since the earliest fossils. The pace of natural selection would depend on variability and change in the environment. This distanced his theory from Lamarckian laws of inevitable progress ...

"Chapter XI deals with evidence from biogeography, starting with the observation that differences in flora and fauna from separate regions cannot be explained by environmental differences alone; South America, Africa, and Australia all have regions with similar climates at similar latitudes, but those regions have very different plants and animals. The species found in one area of a continent are more closely allied with species found in other regions of that same continent than to species found on other continents ... Chapter XII continues the discussion of biogeography … The summary of both chapters says: 'I think all the grand leading facts of geographical distribution are explicable on the theory of migration (generally of the more dominant forms of life), together with subsequent modification and the multiplication of new forms. We can thus understand the high importance of barriers, whether of land or water, which separate our several zoological and botanical provinces. We can thus understand the localisation of sub-genera, genera, and families; and how it is that under different latitudes, for instance in South America, the inhabitants of the plains and mountains, of the forests, marshes, and deserts, are in so mysterious a manner linked together by affinity, and are likewise linked to the extinct beings which formerly inhabited the same continent ... On these same principles, we can understand, as I have endeavoured to show, why oceanic islands should have few inhabitants, but of these a great number should be endemic or peculiar'.

"Chapter XIII starts by observing that classification depends on species being grouped together in a Taxonomy, a multilevel system of groups and sub groups based on varying degrees of resemblance. After discussing classification issues, Darwin concludes: 'All the foregoing rules and aids and difficulties in classification are explained, if I do not greatly deceive myself, on the view that the natural system is founded on descent with modification; that the characters which naturalists consider as showing true affinity between any two or more species, are those which have been inherited from a common parent, and, in so far, all true classification is genealogical; that community of descent is the hidden bond which naturalists have been unconsciously seeking.' Darwin discusses morphology, including the importance of homologous structures. He says, 'What can be more curious than that the hand of a man, formed for grasping, that of a mole for digging, the leg of the horse, the paddle of the porpoise, and the wing of the bat, should all be constructed on the same pattern, and should include the same bones, in the same relative positions?' This made no sense under doctrines of independent creation of species, as even Richard Owen had admitted, but the 'explanation is manifest on the theory of the natural selection of successive slight modifications' …

"The final chapter 'Recapitulation and Conclusion' reviews points from earlier chapters, and Darwin concludes by hoping that his theory might produce revolutionary changes in many fields of natural history. He suggests that psychology will be put on a new foundation and implies the relevance of his theory to the first appearance of humanity with the sentence that 'Light will be thrown on the origin of man and his history.' Darwin ends with a passage that became well known and much quoted: 'It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us … Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved'" (Wikipedia, accessed 14 May 2018).

Dibner *Heralds of Science* 199; *Heirs of Hippocrates* 1724; Freeman 373; Garrison-Morton 220; Grolier Science 23b; Norman 593; PMM 344b; Sparrow *Milestones* 49; Waller 10786.



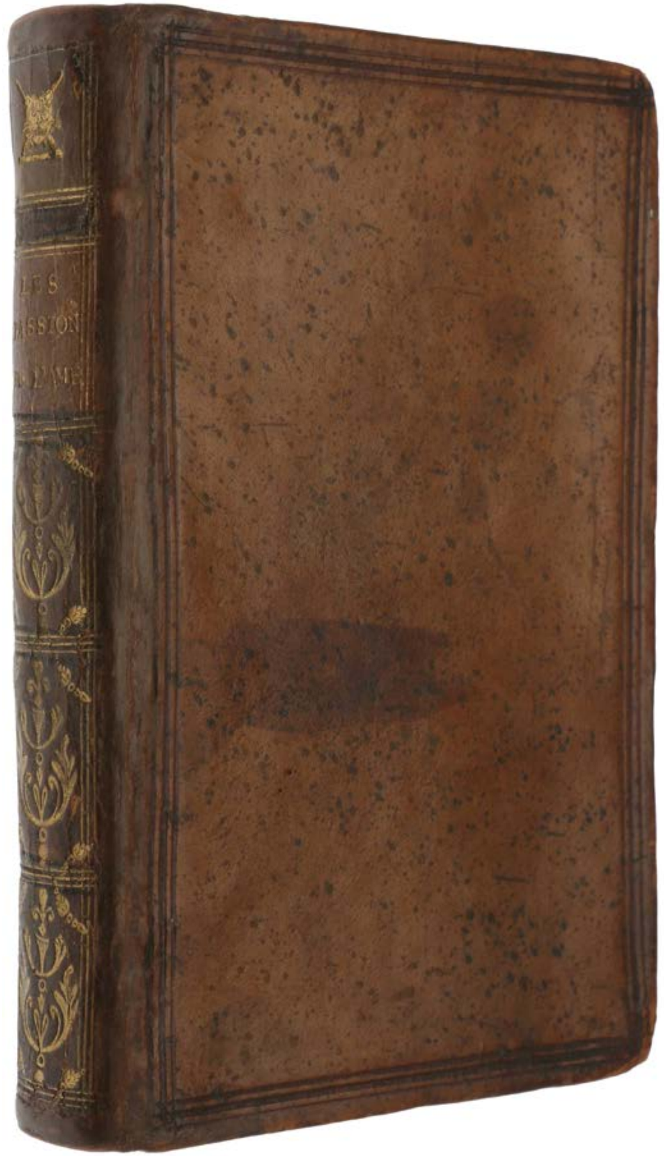
IN CONTEMPORARY ENGLISH BINDING

DESCARTES, René. *Les passions de l'ame.* Amsterdam: chez Henry, 1649.

$11,000

8vo (152 x 96 mm), pp. [xlviii], 286, [2]. Woodcut device on title, woodcut initials and tailpieces. Contemporary English speckled calf, English printer's waste used in binding (joints repaired). The printer's waste contains part of A copy of a letter from the Earle of Essex, by order of the pretended Houses of Parliament, to Prince Rupert: with His Highnesse answer thereunto (Oxford: Leonard Lichfield, 1645), pages 1-4 of 8 (Wing E3310).

First edition of Descartes's important psychological treatise, one of his most influential works, and the last work published before his death in the following year. This copy made its way to England very soon after publication. "*Les passions de l'ame,* which drew heavily on the then-unpublished *Traité de l'homme*, contains the application of Descartes's mechanistic physiology to the relationship between mind and body. Descartes made an essential distinction between the soul as the divinely-endowed seat of consciousness, will and rational thought, and the body as a machine or automaton subject to the laws of physics, and only indirectly controlled by the soul through the nerves. Using this dualistic model, he was able to make the important distinction between voluntary and involuntary actions, a distinction discussed further in the *Traité*. Descartes located the soul in the pineal gland, which thus served as the locus for interaction between soul and body; he had defined the pineal gland's function in the *Traité,* but *Les passions de l'ame* contains his first published account of it. The work also contains the first use of



the word "reflex" in connection with the action of the nervous system" (Norman). "Cartesian dualism . . . gave great impetus to the development of psychology in its own right" (Hunter & Macalpine, *Three Hundred Years of Psychiatry*, p. 133). Cartesian theories had a great deal of influence on the way that mental pathologies were considered throughout the entire 17th century and during much of the 18th century, but the link between the pineal gland and psychiatric disorders was definitively highlighted in the 20th century, with the discovery of melatonin in 1958. The first edition of *Les passions de l'ame* was apportioned between the Elseviers of Amsterdam and Henry le Gras of Paris. There is no priority between the two versions; they are equally rare. Copies in contemporary English bindings are most uncommon; the work was translated into English in the following year as *Passions of the Soul.*

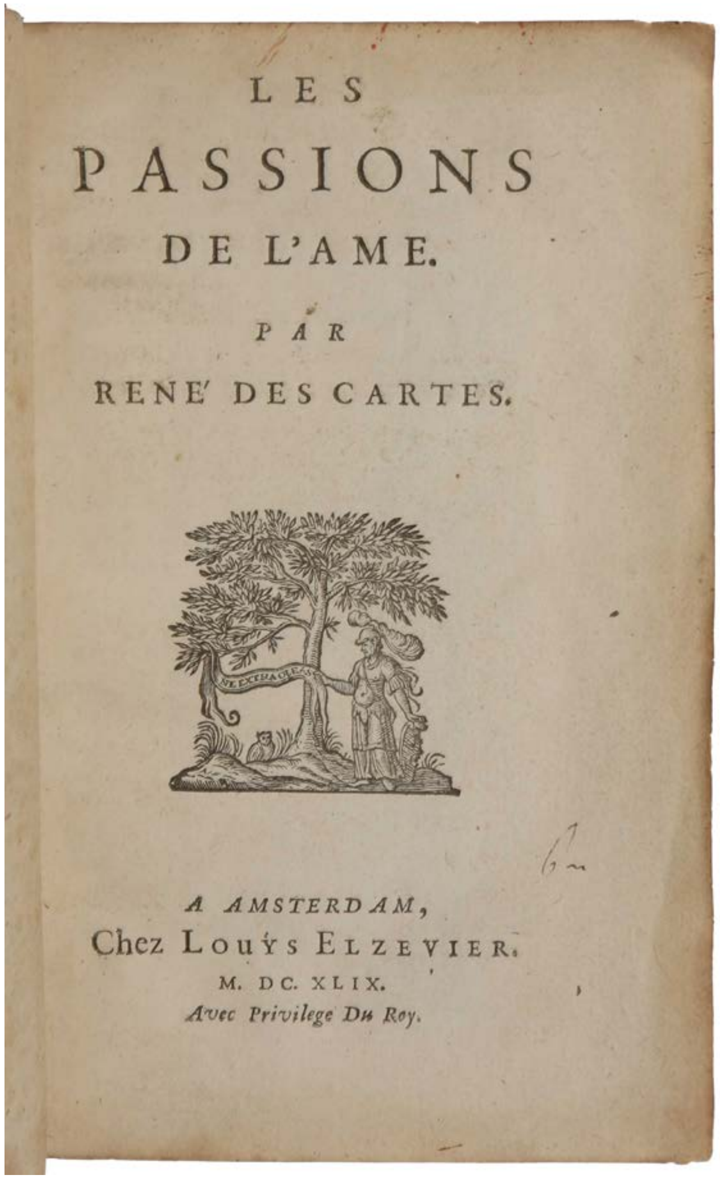
Provenance: Sir Henry Edward Bunbury (1778-1860), armorial bookplate and his crest at head of spine. Son of the famous caricaturist Henry William Bunbury (1750-1811), Henry Edward Bunbury had a successful military career, being responsible in 1815 for informing Napoleon of his sentence of deportation to St Helena. He was the author of several historical works, the most notable being his military memoirs *Narratives of Some Passages in the Great War with France*, first published in 1854.

The origins of *Passions of the Soul* lie partly in Descartes's *Meditations on First Philosophy* (1641): in the Sixth Meditation he had sought to justify the way in which we are equipped to respond to the outside world by experiencing sensations, appetites, and passions. He argued that such perceptions provide guides for maneuvering our bodies through the world, and ultimately for preserving the mind-body union that constitutes the human being. But the main impetus for writing the *Passions* was his correspondence with Princess Elisabeth of Bohemia from 1643 to 1645. Elisabeth, almost twenty years younger than Descartes, was one of the great princesses of Europe, the daughter, granddaughter and great-granddaughter of kings. She was a person of remarkable intelligence and unusually well read at a time when women were generally denied the kind of education their brothers received. Elisabeth asked Descartes most searchingly about his dualistic theory qua theory; she also asked him for advice about her own physical and mental health (she was probably suffering depression owing to the misfortunes of her house both at home and abroad – the English King Charles I was her uncle). Her requests and Descartes' replies frequently bear on the relationship between the body and the mind.

"The *Passions of the Soul* is the last of Descartes's works to be published in his lifetime. It is his fullest account of the interaction between soul and body, and his most significant contribution to moral philosophy. Not that he sets himself up as a moral philosopher: he says that his intention is to explain the passions purely as a natural philosopher (*physicien*), not, as Aristotle had done, from the point of view of rhetoric or moral philosophy. However, he does not confine himself to a purely descriptive approach: his theory opens up a prescriptive dimension. Thus, the first part of the text explains the nature of passion in general, the second describes the principal passions, and the third the further passions that derive from these; but each part ends with some definite recommendations concerning the attitudes or behavior we should adopt in the light of the foregoing explanations …

"Though he dismisses all earlier writings on the subject, Descartes's account of the passions shows continuities with that of earlier thinkers. Like Aristotle and Aquinas, for instance, he sees the passions as involving interaction between body and soul. But his theory does involve a radical break with other aspects of their accounts. Essentially, he argues that the soul is nothing other than the mind: it is not the support of the organic functions of life. These can be explained in purely mechanical terms. To show this, Descartes briefly describes the workings of the body in terms of its key organs and processes: digestion, the circulation of the blood via the veins into the heart and so to the rest of the body through the arteries; and the movement of the muscles by contraction and extension, in response to the action of the nerves, little filaments originating in the brain and responsible also for sensation. The source of all these processes is a kind of fire kept going in the heart by the blood supplied by the veins. This fire dilates or rarefies the blood, so causing it to flow to different parts of the body. But the most rarefied parts of the blood, what Descartes calls the animal spirits, flow into the brain and out again into the nerves and thence into the muscles, where they produce movement. The animal spirits are described as tiny and fast-moving bodies comparable to the particles of a flame (§§7-10). Their movement is closely related to sensation. Sensory stimuli, external or internal, set off movements in the nerves, which are transmitted to the brain. These can cause movements of the animal spirits, and hence of the muscles. Such motions can be accounted for purely mechanically …

"Descartes analyses the passions as perceptions in the soul of a bodily process. To that extent they are akin to sense-perceptions of external objects or internal perceptions of bodily states such as hunger and pain. In sense-perception the light of a torch and the clang of a bell arouse different movements in our nerves, which are then transmitted to the brain, so as to produce different sensations in the soul (note that the sensation, as such, occurs only in the soul; what occurs in the brain is a movement). But there is an element of confusion in the perception. We seem to see the light of the torch in the room, to hear the bell ring in the church tower. Likewise with our internal perceptions: we feel a dryness in our throat, a pain in our injured foot. But in each case, what we are in fact aware of is a sensation representing an external object or a bodily state (the pain we feel 'in' our foot is produced by the same mechanism as the pain an amputee feels 'in' the limb that has been removed). Again, as regards the passions, we feel anger or joy



'in' our soul, whereas we are in fact reacting to a physical process produced by a sense-perception (seeing behavior of which we disapprove or hearing the voice of someone we are fond of).

"The passions, then, can be defined as 'perceptions, or sensations, or emotions of the soul that we refer (*rapportons*) particularly to the soul itself, and that are caused, sustained, and fortified by some movement of the spirits' (§27). 'Perceptions' in the general sense of thoughts rather than volitions, but not the kind of perception involved in evident knowledge; 'sensations' in that they reach the soul by the same path as sense-perceptions; 'emotions' in that, more than any other kind of thought, they are liable to agitate and disturb the soul (§28). Descartes emphasizes the involvement of the animal spirits in order to distinguish passion as such from acts of will, which we also experience as in the soul, but rightly, because they do originate within it (§29).

"The mediating agency between body and soul is identified by Descartes as a part of the brain called the pineal gland. Though undoubtedly erroneous, Descartes's ascription of this function to the gland is a brilliant piece of reasoning. He notes that the other parts of the brain are all doubled, as are our sense-organs; so that we need one single part, like the gland, in which the two-fold impressions received from our sense-organs can be fused into one (§§30-3).

"Descartes is now in a position to reconstruct the whole process of passion. It begins in sensation: to use his example, an animal appears in our field of vision. Light reflected from its body affects our optic nerve, producing two images, one for each eye, on the inner surface of the brain. The surrounding spirits transmit these to the pineal gland, which blends them into a single image. The gland transmits this to the soul, and we see the animal …

"Having explained the general mechanism of the passions, Descartes proceeds, in the second part of the text, to explain how the specific passions are generated. He identifies six basic passions, classified in respect of the various ways in which objects of sense-perception can harm or benefit us: wonderment, love, hate, desire, joy, sadness. This taxonomy differs markedly from two influential earlier schemes, those of the Stoics and of Aquinas. Along with each basic passion, he identifies its major derivatives (§§51-69). He then goes through the basic passions again, defining them in more detail and describing the particular physical processes that accompany each one (§§70-111). Next, he reviews the external manifestations of these passions: movements of the eyes, facial expression, changes of colour, trembling, lethargy, fainting, laughter, tears, groans, and sighs (§§112-35). (His discussion of facial expressions is generally held to have inspired seventeenth-century art theorists' attempts to codify the expression of the passions in painting.) In the third part, he discusses the derivative passions in detail, along the same lines as the principal ones" (Moriarty (tr.), *The Passions of the Soul and Other Late Philosophical Writings*, pp. xviii-xxiv).

"The final essential thread in this account of emotions is the Cartesian theory of conditioning … 'Our soul and our body are so linked that, if we have once joined some bodily action with a certain thought, one of them does not occur subsequently without the other also occurring. We see this, for example, in those who have taken some medicine with great revulsion when they were ill, and cannot afterwards eat or drink anything that has a similar taste without immediately feeling the same revulsion. Likewise, they cannot think of their revulsion from medicines without the same taste returning in their thought.' This innate connection between specific thoughts or feelings and bodily states tends to continue indefinitely unless changed by new connections that displace them. However, the primitive connections can also be expanded to include novel relations between mental states and bodily states, even in the case of stimuli that have no natural connection with the feelings they trigger. Descartes had noticed that animals can be conditioned to respond to novel stimuli, long before Pavlov studied the same phenomenon in the twentieth century and gave his name to it. 'This is so certain that if you whipped a dog five or six times to the sound of a violin, I believe that it would begin to howl and run away when it hears that music again'. Evidently, the same kind of conditioning works in the case of human beings. 'If people have at some time in the past enjoyed dancing while a certain tune was being played, then the desire to dance will return to them as soon as they hear a similar tune again. On the contrary, if others have never heard the music for a galliard without falling into some misfortune, they would infallibly become sad as soon as they heard it again' …

"Descartes' book on human emotions was published in Amsterdam and Paris, toward the end of November 1649. He had drafted a large part of it during the winter of 1645-46 and had sent it to Elisabeth. Elisabeth's reply included suggestions for improvement that, almost out of character, were accepted by the author. Even with additions and corrections, however, this still amounted to only about two-thirds of the final text. Descartes made a clean copy of the revised text and sent it to Chanut [the French ambassador to Sweden], with permission to show it to Queen Christina. At about the same time, he had a request from an unidentified correspondent who had met him on his trip to Paris, had heard about the essay on the passions, and had apparently offered to assist the author in getting the final version into print. Descartes explained that his reluctance to release the manuscript had nothing to do with an unwillingness to serve his reading public. He wanted to keep the essay confidential as long as possible, partly because it had been composed originally 'only to be read by a princess whose mind is so above the norm that she easily understands what seems most difficult to our doctors'. However, Descartes relented and promised 'to revise this writing on the passions, to add what I think is necessary to make it more intelligible. After that, I shall send it to you and you may do what you wish with it.'

"In the spring of 1649, Descartes also sent a copy of the revised manuscript to Clerselier in Paris [Claude Clerselier met Descartes in Paris in 1644 and published the French edition of the *Meditations* in 1647]. Clerselier advised him that it was too difficult for ordinary readers. This prompted a further revision and plans for the addition of most of the material that was published as Part III of the book. When he wrote to Clerselier, in April 1649, he probably still had done little more than think about the additions that remained to be written: 'As regards the *Treatise on the Passions,* I do not expect it to be printed until I have arrived in Sweden. For I neglected to revise it and to add the things that you thought were missing, which would have increased its size by a third. It will contain three parts, of which the first will be about the passions in general and, as required, the nature of the soul, etc.; the second part will be about the six primitive passions, and the third part about all the others.' Descartes seems to have been procrastinating at this stage, and to have been concerned primarily with a decision about going to Sweden – whether he would go at all and, if so, when would be the best time to travel.

"His importunate correspondent of the previous year wrote again, in July 1649, bemoaning the fact that 'it has been such a long time that you have made me wait for your *Treatise on the Passions* that I am beginning to lose hope of getting it'. This correspondent had hoped to facilitate Descartes' ambition to complete the unfinished parts of the *Principles,* and he suggested that, if he were to publish this essay, it might prompt those who had access to public funds or private donors to provide the money required to complete the necessary experiments. One reason for Descartes' reluctance to part with the text of the *Passions,* which his correspondent could not have known about, was that he was worried about publishing a book that he had previously shown to Queen Christina without dedicating it to her and without her permission to make public something that he had shared with her as if with a privileged reader. This scruple was resolved by writing to the queen's librarian and asking him to inquire discreetly about whether she might take offence. Once that was cleared, Descartes replied to his anxious editor that he was not so lazy that he feared the challenge that would result if he had adequate funds for his scientific work. However, he was now able to report that he had worked on the revisions he had promised and was ready to release the work for publication. He thus wrote on 14 August 1649, two weeks before his departure for Sweden: 'I confess that it took more time to revise the little treatise that I am sending you than it previously required to write it. Nonetheless, I added very little to it, and I changed nothing in the argument, which is so simple and brief that it will show that my plan was not to explain the passions as an orator or even as a moral philosopher but only as a natural philosopher. I foresee, therefore, that this treatise will not do any better than my other writings. Although its title may possibly attract more people to read it, only those who take the trouble to study it carefully can find it satisfactory. Such as it is, I place it in your care.'

"The comments in the anonymous letters apparently addressed to Descartes in the Preface to the volume were accurate. They linked the *Treatise on the Passions* with the unfinished *Principles,* in particular with the writing on animals and human nature that Descartes wished to complete. The *Treatise on the Passions* was thus a foretaste of what might have been realized if Descartes had had the financial resources to pursue his research project and if he had made the progress that he thought, less plausibly, was being inhibited only by a lack of observations and experiments. It is difficult to estimate how successful that project might have been had Descartes lived longer, in a more suitable research environment. Apart from such guesswork, the context in which the *Passions* should be read was captured perfectly by Descartes' prefatory letter. There was nothing unusual about a philosopher writing a book on the passions. However, it was distinctive to approach the topic as a '*physicien*', that is, as a natural philosopher or, in today's language, as a scientist. In doing so, Descartes came as close as he had ever come to addressing directly the question of how mind and body interact" (Clarke, *Descartes*, pp. 387-9 & 391-2).

Descartes's connection with Queen Christina began in 1646, when he met her close friend Pierre Chanut. When Chanut showed Christina some of the letters between Descartes and Elisabeth (despite Elisabeth's insistence that their exchanges be kept private), she began a correspondence with Descartes, through Chanut as intermediary. In 1649 she invited him to Sweden; initially reluctant, Descartes eventually agreed and arrived in Stockholm on 4 October 1649, where he resided with Chanut.

Queen Christina at first required very little from Descartes, but after he had some time to settle in, she ordered him to do two things: first, to put all of his papers in order, and secondly, to put together designs for an academy. In January of 1650 Queen Christina began to require Descartes to give her lessons in philosophy. These were given five days a week, would begin at five in the morning and would last for about five hours. During this time Descartes published the *Passions.* He also met and became friends with Vicomte Brégy, the French Ambassador to Poland, who was then visiting Stockholm. In a letter to Brégy, dated 15 January 1650, Descartes expresses reservations about his decision to come to Sweden. He sees himself to be "out of his element," the winter so harsh that "men's thoughts are frozen here, like the water". In early February, less than a month after writing to Brégy, Descartes fell ill. His illness quickly turned into a serious respiratory infection. And, although at the end of a week he appeared to have made some movement towards recovery, things took a turn for the worse and he died in the


ESSE QUAM VIDERI
Henry Edward Bunbury
PRINCE RUPERT

early morning of 11 February 1650. He was fifty-three years old.

Brunet, II, 611; GM 4965; Guibert p. 150, no. 1; Hermstein & Boring (eds.), *A Source Book in the History of Psychology*, pp. 204-210; Norman 626; Rieber 130; Tchemerzine IV, p. 301 ("Cette édition fut imprimée de compte à demi par L. Elzevier avec le libraire parisien Le Gras. Aussi trouve-t-on des exemplaires sous l'adresse de Louis Elzevier à Amsterdam, avec la Minerve comme fleuron. Les deux aspects de cette édition sont d'impression elzévirienne"); Willems 1083 ("L'édition de 1649 est assez rare").

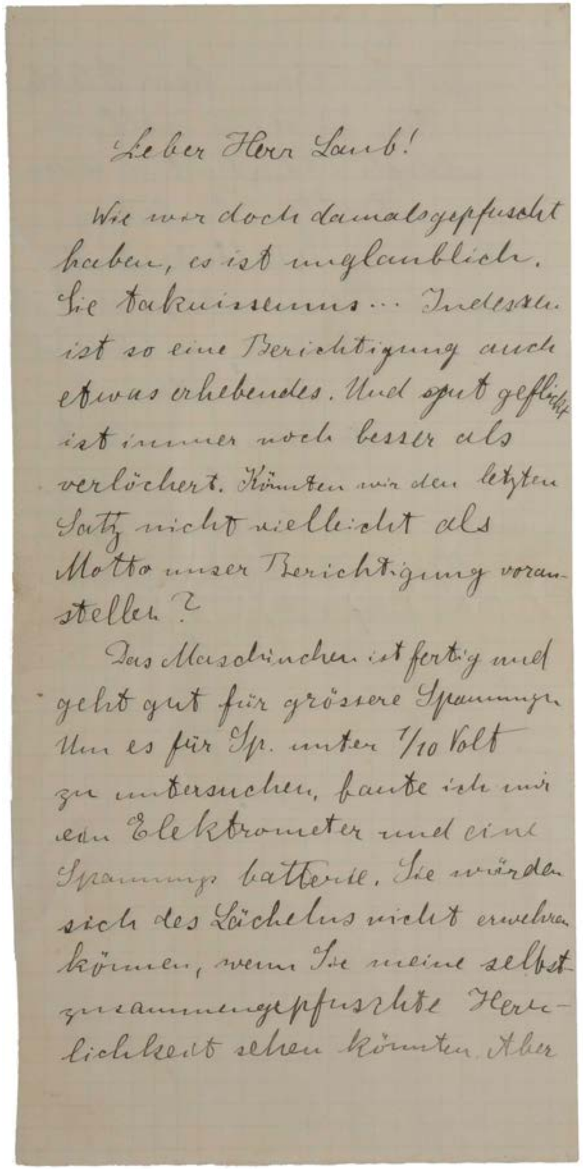
EINSTEIN WRITES TO LAUB ABOUT RELATIVITY AND QUANTUM THEORY

EINSTEIN, Albert. *Autograph scientific letter, signed 'A. Einstein,' to the physicist Jakob Laub, Einstein's first research collaborator.* [Bern: late 1908].

$38,500

Single sheet (210 x 102 mm), written on recto and verso, light horizontal crease from having been folded for postage.

A fascinating, early, and very personal Einstein letter touching on relativity, quantum theory and one of Einstein's very few projects in experimental physics. It was written by Einstein at a time when he was still working at the Patent Office in Bern, but had started his teaching at the University there (but before he secured his first academic post). The recipient, Jakob Laub, then working under Wilhelm Wien at Würzburg, had already written two papers on special relativity, developed by Einstein in his 'annus mirabilis' 1905, and had visited Einstein for three months in the spring of 1908, during which time the two men co-authored two substantial scientific papers – this was Einstein's first scientific collaboration. But the tone of the letter makes it clear that Laub was not just Einstein's collaborator, he was also a close friend. The first part of the letter refers to one of Einstein's joint papers with Laub on a problem in relativity, which was published as 'Über die im elektromagnetischen Grundgleichungen für bewegte Körper' (*Annalen der Physik* 26 (1908), pp. 532-540) – this work required a correction following comments by Max von Laue, to which Einstein refers in the letter and which was



Lieber Herr Laub!

Wie wir doch damals gepfuscht haben, es ist unglaublich. Si tacuissemus… Indessen ist so eine Berichtigung auch etwas erhebendes. Und spät geflickt ist immer noch besser als verlöchert. Könnten wir den letzten Satz nicht vielleicht als Motto unser Berichtigung voranstellen?

Das Maschinchen ist fertig und geht gut für grössere Spannungen. Um es für Sp. unter 1/10 Volt zu untersuchen, baute ich mir ein Elektrometer und eine Spannungsbatterie. Sie würden sich des Lächelns nicht erwehren können, wenn Sie meine selbst zusammengepfuschte Herrlichkeit sehen könnten. Aber published in the following year. At the end of the letter, Einstein refers to a paper by Johannes Stark, who was awarded the Nobel Prize in 1919 for his discovery of the 'Stark effect', which provides support for Planck's quantum theory (then still controversial) – Einstein advises Laub to look at Stark's paper on the Doppler shift of the light emanating from a 'canal ray' tube when observed against the direction of motion of the rays, which Stark believed (and Einstein agreed) could be explained in terms of quantum theory ('canal rays' are streams of protons produced in a discharge tube, although this was not known at the time). Einstein had, of course, provided the first major support for the quantum theory through his application of it in 1905 to explain the photoelectric effect, for which he would be awarded the Nobel Prize in 1921. The third aspect of the letter is its reference to Einstein's work on his 'Maschinchen' ('little machine'). This was an electrostatic device for amplifying small voltage-differences which Einstein was developing with his friends Conrad and Paul Habicht. The correspondence between Einstein and Laub continued until at least 1910 and its importance has been emphasized by historians: "Einstein, at least in his early years, possessed such extraordinary creative powers, enabling him to reshape his tentative conceptions so quickly, that it was impossible for the present author to do justice to the evolution of Einstein's ideas in view of the meagre facts at hand. This situation might change when Einstein's many early letters to Jacob Johann Laub are made available to historical research. Today we must still be content to accept Einstein's fully developed conceptions as they appeared between 1905 and 1909" (Hermann, p. 51).

Lieber Herr Laub!

Wie wir doch damals gepfuscht haben, es ist unglaublich. Sic takuissemus ... Indessen ist so eine Berichtigung auch etwas erhebendes. Und gut geflickt ist immer noch besser als verlöchert. Könnten wir den letzten Satz nicht vielleicht als Motto unser[er] Berichtigung voranstellen?

Das Maschinchen ist fertig und geht gut für grössere Spannungen. Um es für Sp[annungen] unter 1/10 Volt zu untersuchen, baute ich mir ein Elektrometer und eine Spannungsbatterie. Sie würden sich des Lächelns nicht erwehren können, wenn Sie meine selbstzusammengepfuschte Herrlichkeit sehen könnten. Aber es gibt in Bern kein Elektrometer, und ich will nun endlich Klarheit in dieser Frage erhalten. Die bisher erlangten Resultate sind jedenfalls ermutigend ...

Die Geschichte von J. Stark müssen Sie ansehen; ich halte diese Anwendung der Quantentheorie für sehr wichtig.

Dear Mr. Laub!

How we messed up then, it's incredible. Sic takuissemus ... However, such a correction is also something uplifting. And well mended is still better than full of holes. Could not we insert the last sentence as a motto at the beginning of our correction?

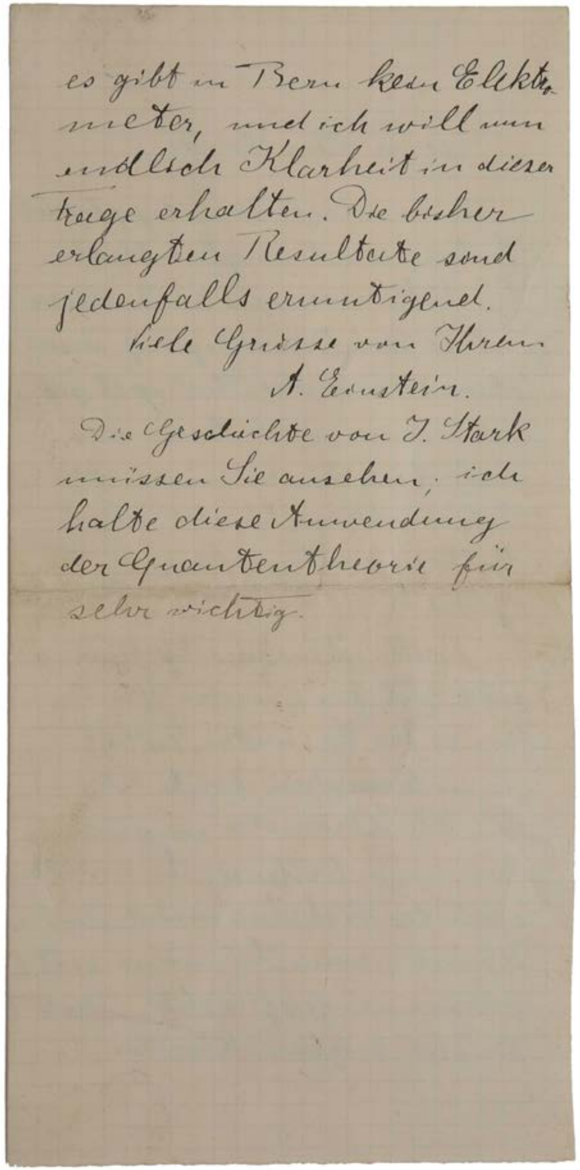
The little machine is finished and works well for greater voltages. To investigate it for potential differences under 1/10 volt, I built myself an electrometer and a voltage battery. You would not be able to resist the smile if you could see my self-clasped glory. But there is no electrometer in Bern, and I want to finally get clarity on this question. Anyway, the results obtained so far are encouraging ... "

You must look at the paper of J. Stark; I consider this application of quantum theory to be very important.

The Austro-Hungarian physicist Jakob Johann Laub (1884-1962) studied mathematics at Göttingen, and in 1905 moved to the University of Würzburg, where he worked under Wilhelm Wien (1864-1928), famous for his 1893 'displacement law' for the distribution of energy in the spectrum of radiation emitted by a black body, and for which he was awarded the 1911 Nobel Prize in physics. It was the failure of this law to accurately account for the observed spectrum at long wavelengths that led Max Planck (1858-1947) to put forward his famous quantum hypothesis in 1900. In 1907 Laub obtained his doctorate (three years after Einstein) on the investigation of secondary cathode ray emission. “During his oral examination, Laub referred to Einstein’s new relativity theory … [this] fuelled a heated discussion on several points that could not be clarified, so, upon Wien’s advice, Laub intended to visit the author of the theory in person” (Weinstein, pp. 75-76). After his doctorate, Laub directed the major part of his work toward Einstein’s special theory of relativity. In June 1907 Laub published his first paper on relativity, a discussion of Fresnel’s drag coefficients (‘Zur Optik der bewegten Körper,’ *Annalen der Physik* 23 (1907), pp. 738-744 – a sequel was published in *ibid*. 25 (1908), pp. 175-184).

“In early February 1908, Laub wrote to Einstein (1879-1955), who was then at the patent office in Bern, to inquire if it would be possible for him to spend three months in Bern to work on the theory of relativity. Laub assured Einstein of his great interest in the theory: he considered Einstein’s work fundamental not only for electrodynamics but for all of physics. Einstein’s reply to Laub is lost, but it must have been favourable. Over the next three months, he and Laub collaborated on two articles on the special theory of relativity. These were the first papers Einstein wrote with another person” (Pyenson, p. 94). During Laub’s visit, “Einstein informed [his wife] Mileva, ‘I’ve just come home from a long walk with Laub. I work with him a great deal … Nowadays I always take my meals with him’” (Weinstein, p. 76).

In the paper with Laub to which Einstein refers in the present letter, they “criticized Minkowski’s 1908 paper on the basic equations of electromagnetic processes, where he first discussed in print his ideas on space-time [‘Die


es gibt in Bern kein Elektrometer, und ich will nun endlich Klarheit in dieser Frage erhalten. Die bisher erlangten Resultate sind jedenfalls ermutigend.
Viele Grüsse von Ihrem
A. Einstein.
Die Geschichte von J. Stark müssen Sie ansehen, ich halte diese Anwendung der Quantentheorie für sehr wichtig.

Grundgleichungen für die elektromagnetischen Vorgänge in bewegten Körpern,' *Göttingen Nachrichten*, pp. 53-111]: 'In a recently published study Mr. Minkowski has presented the fundamental equations for the electromagnetic processes in moving bodies. In view of the fact that this study makes rather great demands on the reader in its mathematical aspects, we do not consider it superfluous to derive here these important equations in an elementary way, which is, by the way, essentially in agreement with that of Minkowski.' Einstein's objection was to the four-dimensional space-time viewpoint Minkowski introduced; his objection is ironic, since this point of view proved to be essential for his later development of general relativity.

In the second part of their paper, Einstein and Laub wrote that they 'use a simple special case to show how moving dielectrics behave according to the theory of relativity and how the results differ from those obtained using the Lorentz theory.' "Einstein and Laub were concerned with explaining a puzzling effect discovered by H. A. Wilson (1874-1964): when a dielectric is rotated in the gap between the plates of a connected capacitor in the presence of a magnetic field, an equal and opposite charge collects on the plates. For convenience, Einstein and Laub assumed that each particle of the dielectric, although actually in rotation, is only in linear motion. They used Minkowski's equations of motion with appropriate boundary conditions to arrive at the observed charge separation on the two capacitor plates. Einstein and Laub claimed that their calculation differs from one based on Lorentz's electron theory and that the Wilson experiment gives identical results for the two theories because the magnetic permeability is unity in each case. Einstein and Laub carried out a theoretical study that appealed to experimental physics. When Max von Laue (1879-1960) objected to the way in which Einstein and Laub used boundary conditions in the article, for example, they responded by affirming the physical nature of their calculation" (*ibid*., pp. 95-97).

The error in the treatment of boundary conditions pointed out by Laue is what Einstein refers to in the letter:

How we messed up then, it's incredible. Sic takuissemus ... However, such a correction is also something uplifting. And well mended is still better than full of holes. Could we not insert the last sentence as a motto at the beginning of our correction?

The error was to assume that the electromagnetic boundary conditions at the surface separating two different media remain the same, whether the bodies are at rest or in motion. The correction, which was made by a method originally used by Heinrich Hertz (1857-94), was published the following year as 'Bemerkungen zu unserer Arbeit: Elektromagnetische Grundgleichungen für bewegte Körper' (*Annalen der Physik* 28 (1909), pp. 445-7). 'Sic takuissemus' may be Einstein's reference to the Latin proverb *Si tacuisses, philosophus mansisses*, often attributed to Boethius, which translates literally as, 'If you had been silent, you would have remained a philosopher.'

The next part of the letter refers to Einstein's Maschinchen:

The little machine is finished and works well for greater voltages. To investigate it for potential differences under 1/10 volt, I built myself an electrometer and a voltage battery. You would not be able to resist a smile if you could see my self-clasped glory. But there is no electrometer in Bern, and I want to finally get clarity on this question. Anyway, the results obtained so far are encouraging.

"As the result of a note on voltage fluctuations in a condensor, 'a phenomenon similar to Brownian motion,' that Einstein wrote in 1907 ['Theoretische Bemerkungen über die Brownsche Bewegung,' *Zeitschrift für Electrochemie* 13, pp. 41-42], he became interested in the possibility of amplifying small voltage differences. He conceived the idea of using for this purpose a condensor with variable capacity which is charged at low voltage and maximum capacity, then discharged at a higher voltage and at minimum capacity into another condensor. This process was to be repeated with the help of a set of condensors coupled in series. It was his hope that this electrostatic device might be of use for research in radioactivity. In December 1907 Einstein wrote to Conrad [Habicht] (1876-1958) that Paul [Habicht] (1884-1948) planned to build this 'Maschinchen,' as Einstein affectionately called it, in his own laboratory. Einstein was quite excited about his invention and at one time must have even considered patenting it. 'I am very curious how much can be achieved – I have rather high hopes. I have dropped the patent, mainly because of the lack of interest of the manufacturer.' A few months later, he published his proposal ['Eine neue elektrostatische Methode zur Messung kleiner Elektricitätsmengen,' *Physikalische Zeitschrift* 9 (1908), pp. 216-7] and in 1908 tried to construct his own Maschinchen. In 1910 the Habicht brothers published the results of experiments 'performed with A. Einstein in the laboratory of the University of Zürich,' in which Einstein's idea was realized with the help of a set of six rotating condensors. Einstein still continued to take a lively interest in the project after his own work had gone in other directions. In 1911 he wrote from Prague to Besso about the great success Paul had had in demonstrating the apparatus in Berlin.

"Rapid advances in amplification technology overtook Einstein's design, however. After Paul's death in 1948, Einstein wrote to Conrad, 'The memory awakens of old days in which I worked with your brother on the … little machine … It was wonderful, even though nothing useful came of it" (Pais, pp. 484-5).

Today only three specimens of the Maschinchen are known to exist; these are preserved at the Zürcher Hochschule Winterthur, Switzerland, in the Physics Institute of the University of Tübingen, Germany, and in the Museum Boerhaave in Leiden, The Netherlands.

At the end of the letter, Einstein writes:

You must look at the paper of J. Stark; I consider this application of quantum theory to be very important.

In 1907 Johannes Stark (1874-1957), as the editor of *Jahrbuch der Radioaktivität und Elektronik*, had asked the then still rather unknown Albert Einstein to write a review article on the principle of relativity. In preparing this article, which was published in the same year in Stark's journal as 'Über das Relativitätsprinzip und die aus demselb gezogenen Folgerungen' (*Jahrbuch* 4, pp. 411-62), Einstein began a line of thought that would eventually lead to his general theory of relativity.

"Stark was an extremely skilful experimentalist and had a high degree of cognitive imagination … The first major success of the 30-year-old physicist was the discovery late in 1905 of the Doppler effect of canal rays … Stark designated the Doppler effect in 1907 as the 'third possibility for an experimental verification of Planck's elemental law.'

"In the spectral analysis of light emanting from a canal ray tube, the Doppler bands ('moving intensity,' as Stark called it), displaced toward shorter wavelengths when observed against the direction of motion, can be seen in addition to the unshifted spectral line. A definite intensity mimimum is located between the 'intensity at rest' and the broad 'moving intensity' …

"When Stark published his detailed study concerning the Doppler effect ['Der Doppler-Effekt bei den Kanalstrahlen und die Spektra der positiven Atomionen,' *Physikalische Zeitschrift* 6 (1905), pp. 892-7], he clearly raised the question of the origin of this intensity minimum. In October 1907, he felt that he had found a solution to the problem in Planck's quantum law ['Beziehung des Doppler-Effektes bei Kanalstrahlen zur Planckschen Strahlungstheorie,' *Physikalische Zeitschrift* 8 (1907), pp. 913-9]: in collisions between moving canal ray particles and gas particles at rest, inelastic deformation energy can be transferred to the canal ray particles only if the energy available for this purpose is at least equal to *hv*, where *v* is the frequency of the optical vibration [and *h* is Planck's constant]. Thus the kinetic energy of the canal ray particles must exceed a definite value. This explanation was accepted by Albert Einstein, Hendrik Antoon Lorentz, Peter Debye, and Arnold Sommerfeld. Einstein, for example, wrote the following postcard to Stark on December 2, 1908: 'Many thanks for sending me your paper. I was particularly pleased with the application of light-quantum theory to the curve for the Doppler effect'" (Hermann, pp. 72-75).

Much of Einstein's correspondence with Laub remains in private hands, due to Laub's difficult circumstances in later life. In 1911 he moved to Argentina, returning permanently to Germany only in 1947. "In his new home town Freiburg he went into economic troubles and therefore sold a part of his correspondence with Einstein" (Wikipedia, accessed 19 March 2018).

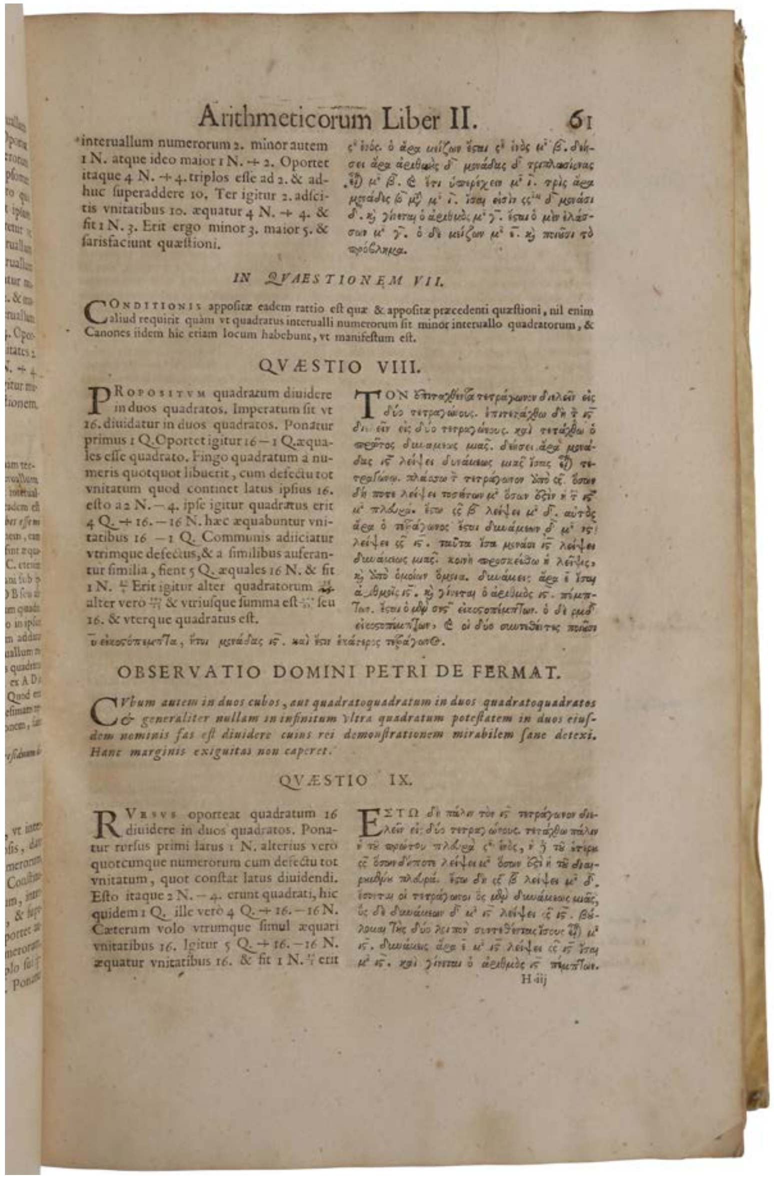
Hermann, *The Genesis of Quantum Theory* (1899-1913), 1971. Pais, *Subtle is the Lord*, 1982. Pyenson, 'Einstein's early scientific collaboration,' *Historical Studies in the Physical Sciences* 7 (1976), pp. 83-123. Weinstein, *Einstein's Pathway to the Special Theory of Relativity*, 2015. On the Maschinchen, see Maas, 'Einstein as Engineer: The Case of the Little Machine,' *Physics in Perspective* 9 (2007), pp. 305–328. See *The Collected Papers of Albert Einstein*, *Vol. 2*: *The Swiss Years*: *Writings, 1900-1909* (*English translation supplement*), for Einstein and Laub's paper (pp. 329-338) and its correction (pp. 350-356), and Einstein's paper on the Maschinchen (pp. 312-315) (available online: einsteinpapers.press.princeton.edu/vol2-trans/).

FERMAT'S LAST THEOREM

[FERMAT, Pierre de] DIOPHANTUS of Alexandria. *Arithmeticorum libri sex, et de numeris multangulis liber unus. Cum commentariis C.G. Bacheti V.C. & observationibus D.P. de Fermat senatoris Tolosani.* Toulouse: Bernard Bosc, 1670.

$50,000

Folio (344 x 223 mm), contemporary vellum, red title label, richly gilt spine, pp [12] 64; 341 [i.e., 343, pp 337-343 mispaginated 335-341]; 48. Contemporary marginal annotations to several leaves. Corner of title page with old paper repair. Corners with light wear. Custom slip case.



First edition of Fermat's annotated edition of Diophantus' *Arithmetica.* This is the first printing of Fermat's contributions to the theory of numbers, of which he is the undisputed founder, including his famous statement of 'Fermat's last theorem.' Since most of Fermat's work in number theory remained unpublished in his lifetime, "it was neither understood nor appreciated until Euler revived it and initiated the line of continuous research that culminated in the work of Gauss and Kummer in the early nineteenth century" (DSB). Fermat showed little interest in publishing his work, which remained confined to his correspondence, personal notes, and to marginal jottings in his copy of the 1621 *editio princeps*, edited by Claude Bachet, of Diophantus' *Arithmetica*. Fermat's marginalia included not only arguments against some of Bachet's conclusions, but also new problems inspired by Diophantus. After his death, Fermat's eldest son Clement-Samuel published his father's marginalia in this new edition. Most famous of the 48 observations by Fermat included here is the tantalizing note that appears on fol. H3r "regarding the impossibility of finding a positive integer $n > 2$ for which the equation $x^n + y^n = z^n$ holds true for the positive integers *x*, *y*, and *z*" (Norman). Fermat noted that he had discovered a "truly marvellous demonstration" of this proposition, but that the margin was too narrow to transcribe it. This simple statement became known as the single most difficult problem in mathematics, and for over 300 years no mathematician succeeded in either proving or disproving it. In 1995 Andrew Wiles, professor of mathematics at Princeton, who had been obsessed with Fermat's last theorem since the age of 10, completed a 130-page proof (first presented in 1993, with a flaw that required revision), using the most advanced techniques of modern mathematics. His achievement was described by fellow mathematicians as the mathematical equivalent "of splitting the atom or finding the structure of DNA" (Singh, *Fermat's Enigma* (1997), p. 279). Although Fermat's marginal jottings in Diophantus hold a special place in the history of mathematics, much of what we know of Fermat's methods of proof is found in his letters to the French Jesuit Jacques de Billy, a pupil of Bachet, printed for the first time in the present work as *Doctrinae Analyticae Inventum Novum*.

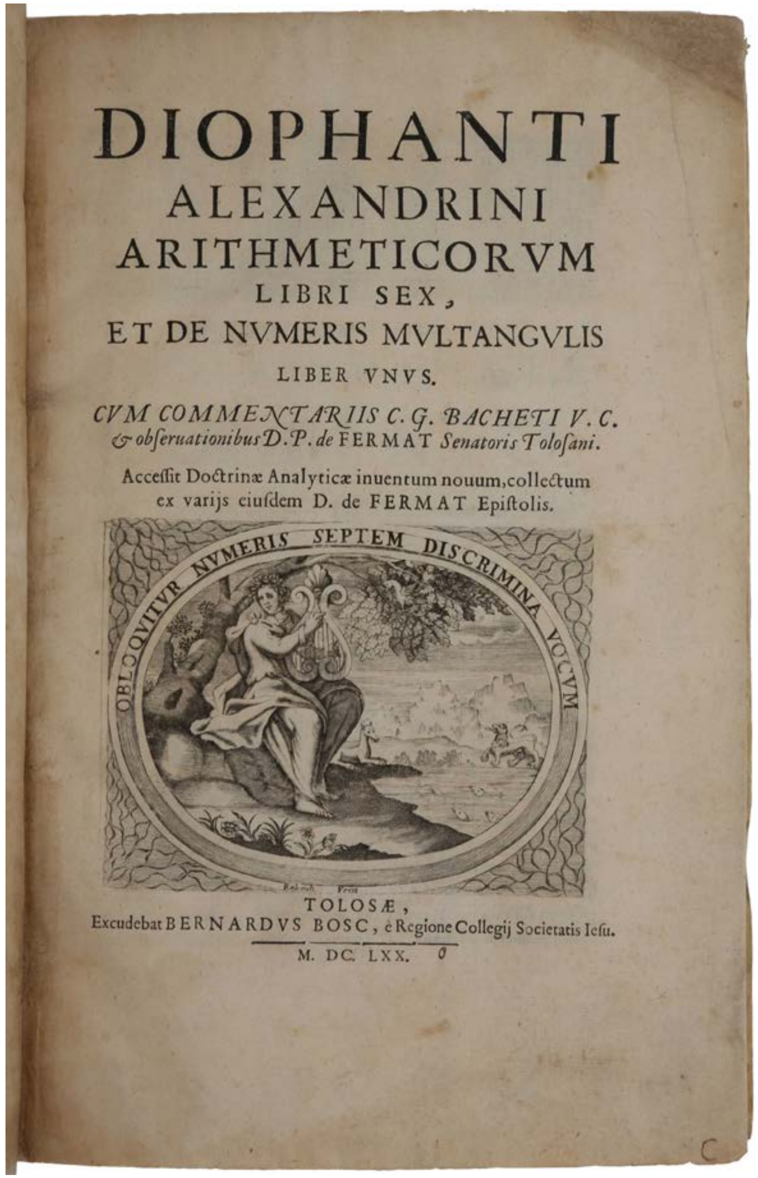
"The *Arithmetica* begins with an introduction addressed to Dionysius—arguably St. Dionysius of Alexandria. After some generalities about numbers, Diophantus explains his symbolism—he uses symbols for the unknown (corresponding to our x) and its powers, positive or negative, as well as for some arithmetic operations—most of these symbols are clearly scribal abbreviations. This is the first and only occurrence of algebraic symbolism before the 15th century. After teaching multiplication of the powers of the unknown, Diophantus explains the multiplication of positive and negative terms and then how to reduce an equation to one with only positive terms (the standard form preferred in antiquity). With these preliminaries out of the way, Diophantus proceeds to the problems. Indeed, the *Arithmetica* is essentially a collection of problems with solutions, about 260 in the part still extant.

The introduction also states that the work is divided into 13 books. Six of these books were known in Europe in the late 15th century, transmitted in Greek by Byzantine scholars and numbered from I to VI; four other books were discovered in 1968 in a 9th-century Arabic translation by Qusṭā ibn Lūqā. However, the Arabic text lacks mathematical symbolism, and it appears to be based on a later Greek commentary—perhaps that of Hypatia (c. 370–415)—that diluted Diophantus's exposition. We now know that the numbering of the Greek books must be modified: *Arithmetica* thus consists of Books I to III in Greek, Books IV to VII in Arabic, and, presumably, Books VIII to X in Greek (the former Greek Books IV to VI). Further renumbering is unlikely; it is fairly certain that the Byzantines only knew the six books they transmitted and the Arabs no more than Books I to VII in the commented version.

"The problems of Book I are not characteristic, being mostly simple problems used to illustrate algebraic reckoning. The distinctive features of Diophantus's problems appear in the later books: they are indeterminate (having more than one solution), are of the second degree or are reducible to the second degree (the highest power on variable terms is 2, i.e., x^2), and end with the determination of a positive rational value for the unknown that will make a given algebraic expression a numerical square or sometimes a cube. (Throughout his book Diophantus uses "number" to refer to what are now called positive, rational numbers; thus, a square number is the square of some positive, rational number.) Books II and III also teach general methods. In three problems of Book II it is explained how to represent: (1) any given square number as a sum of the squares of two rational numbers; (2) any given non-square number, which is the sum of two known squares, as a sum of two other squares; and (3) any given rational number as the difference of two squares. While the first and third problems are stated generally, the assumed knowledge of one solution in the second problem suggests that not every rational number is the sum of two squares. Diophantus later gives the condition for an integer: the given number must not contain any prime factor of the form $4n + 3$ raised to an odd power, where n is a non-negative integer. Such examples motivated the rebirth of number theory. Although Diophantus is typically satisfied to obtain one solution to a problem, he occasionally mentions in problems that an infinite number of solutions exists.

"In Books IV to VII Diophantus extends basic methods such as those outlined above to problems of higher degrees that can be reduced to a binomial equation of the first- or second-degree. The prefaces to these books state that their purpose is to provide the reader with "experience and skill." While this recent discovery does not increase knowledge of Diophantus's mathematics, it does alter the appraisal of his pedagogical ability. Books VIII and IX (presumably Greek Books IV and V) solve more difficult problems, even if the basic methods remain the same. For instance, one problem involves decomposing a given integer into the sum of two squares that are arbitrarily close to one another. A similar problem involves decomposing a given integer into the sum of three squares; in it, Diophantus excludes the impossible case of integers of the form $8n + 7$ (again, n is a non-negative integer). Book X (presumably Greek Book VI) deals with right-angled triangles with rational sides and subject to various further conditions" (Britannica).

"For a mathematician of the sixteenth century, Diophantus was no easy text to decipher, and no small share of the credit for its re-discovery must go to Rafael Bombelli (1526-72) and to Xylander (1532-76). Bombelli read and translated most of it in Rome, for his own use, about 1570, and then incorporated this into his Italian *Algebra* of 1572; Xylander was the first to attempt a complete translation, and published the fruit of his efforts in Basel in 1575. Of course the substantial difficulties of such undertakings were greatly increased by the comparatively poor condition of the available manuscript texts. As has been the case with virtually all Greek classical authors, these were all derived from a single codex (the so-called "archetype", now lost) marred by copying mistakes and omissions. Worst of all, in


DIOPHANTI
ALEXANDRINI
ARITHMETICORVM
LIBRI SEX,
ET DE NVMERIS MVLTANGVLIS
LIBER VNVS.
CVM COMMENTARIIS C. G. BACHETI V. C.
& obseruationibus D. P. de FERMAT Senatoris Tolosani.
Accessit Doctrinæ Analyticæ inuentum nouum, collectum
ex varijs eiusdem D. de FERMAT Epistolis.
OBLOQVITVR NVMERIS SEPTEM DISCRIMINA VOCVM
TOLOSÆ,
Excudebat BERNARDVS BOSC, è Regione Collegij Societatis Iesu.
M. DC. LXX.

the case of Diophantus, were the numerical errors. Undoubtedly the copying had been done by professional scribes, not by mathematicians; but perhaps this was just as well; would-be mathematicians might have made things even worse.

"The first translator, [Wilhelm] Holzmann, who hellenized his name as Xylander, was a humanist and a classical scholar who took up algebra as a hobby. Bombelli was a busy engineer, designing canals, desiccating marshes, and he dedicated to mathematics little more than those periods of leisure which were granted to him by his munificent employer and patron, the bishop of Melfi … Thus it was still a huge task that awaited the future editor, translator and commentator of Diophantus, even after all the work done by his predecessors. As Fermat's son Samuel expressed it in his preface to the *Diophantus* of 1670 (echoing, no doubt, his father's sentiments, perhaps his very words): "Bombelli, in his *Algebra,* was not acting as a translator for Diophantus, since he mixed his own problems with those of the Greek author; neither was Viete, who, as he was opening up new roads for algebra, was concerned with bringing his own inventions into the limelight rather than with serving as a torch-bearer for those of Diophantus. Thus it took Xylander's unremitting labors and Bachet's admirable acumen to supply us with the translation and interpretation of Diophantus's great work".

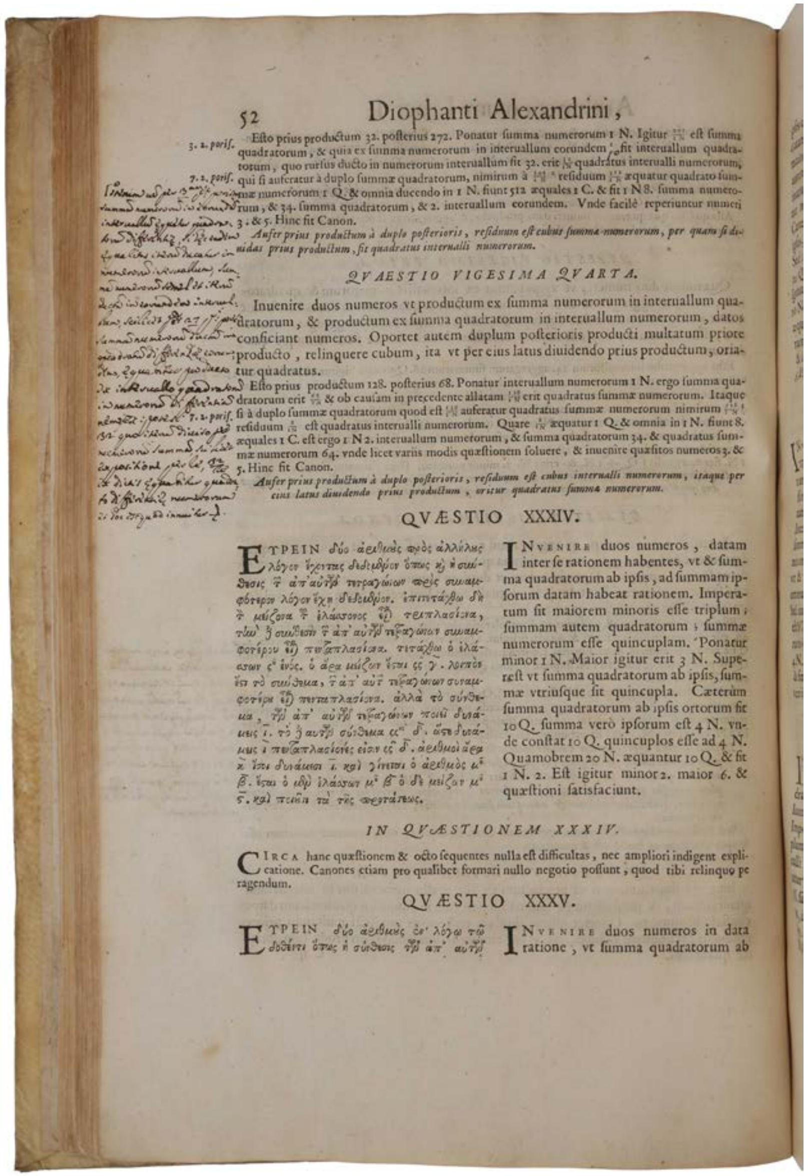
"Claude Gaspar Bachet, sieur de Meziriac, was a country gentleman of independent means, with classical tastes, and no mathematician. Somehow he developed an interest for mathematical recreations and puzzles of the kind found in many epigrams of the Greek Anthology as well as in medieval and Renaissance mathematical texts, or nowadays in the puzzle columns of our newspapers and magazines. In 1612 he published in Lyon a collection of such puzzles under the title *Problèmes plaisants et délectable qui se font par les nombres.* As this indicates, he was thus led to number theory, and so to Diophantus. The latter must have occupied him for several years prior to its publication in 1621; after seeing it through the press he retired to his country estate, got married, and apparently gave up all mathematical activity, except that he prepared a second edition of his *Problèmes* of 1612, incorporating into it some of the materials he had intended for a treatise on arithmetic which never saw the light of day.

"Samuel Fermat's praise of Bachet was by no means excessive. No mere philologist would have made sense out of ever so many corrupt passages in the manuscripts; Xylander had all too often failed to do so. Bachet never tires of drawing attention to the defects of Xylander's translation and comments, while naively extolling his own merits. He even ventures to speak disparagingly of Viète's algebraic methods, which he neither appreciated nor understood; this did not stop him from lifting two Porisms and some important problems about cubes out of Viète's *Zetetica* without a word of acknowledgment. Nevertheless, his is the merit of having provided his successors and notably Fermat with a reliable text of Diophantus along with a mathematically sound translation and commentary. Even his lack of understanding for the new algebra may be said to have benefited number theory in the end … he invariably laid the emphasis on those aspects of the text which were more properly arithmetical, and, prominently among these, on all questions regarding the decomposition of integers into sums of squares. He asked for the conditions for an integer to be a sum of two or of three squares; he extracted from Diophantus the conjecture that every integer is a sum of four squares, and asked for a proof. The curtain could rise; the stage was set. Fermat could make his entrance" (Weil, *Number Theory*, pp. 31-34).

Fermat's marginal notes in his copy of Bachet's Diophantus probably date from the late 1630s. We mention only four. "In a note in his copy of Diophantus and in a letter to Mersenne, Fermat generalized on the well-known 3, 4, 5 right triangle relationship by asserting the following theorems: A prime of the form $4n + 1$ is the hypotenuse of one and only one right triangle with integral arms; the square of $4n + 1$ is the hypotenuse of two and only two such right triangles; its cube, of three; its biquadrate, of 4; and so on, ad infinitum. As an example, consider the case of $n = 1$. Then $4n + 1 = 5$ and 3, 4, 5 are the sides of the one and only right triangle with 5 as hypotenuse. However, 5^2 is the hypotenuse of two, and only two, right triangles 15, 20, 25 and 7, 24, 25. Also 5^3 is the hypotenuse of three, and only three, right triangles 75, 100, 125; 35, 120, 125; and 44, 117, 125" (Kline, *Mathematical Thought from Ancient to Modern Times*, p. 275).

A further theorem on right-angled triangles with integer sides stated by Fermat is that the area of such a triangle cannot be a square. Just in this one case Fermat did find room in the margin for the proof, next to the very last proposition of Diophantus (pp. 338-9). The proof, which is by a method Fermat called "infinite descent," is explained, in modern terminology, in Weil, *Number Theory*, p. 77.

A second set of problems concerns polygonal numbers, the numbers of dots which can be arranged in the shape of a regular polygon. For example, the triangular numbers are the numbers $n(n + 1)/2$ for $n = 1, 2, 3, \ldots$; the square numbers are (of course) the squares; the pentagonal numbers are $n(3n - 1)/2$, etc. "On polygonal numbers Fermat stated in his copy of Diophantus the important theorem that every positive integer is itself triangular or the sum of 2 or 3 triangular numbers; every positive integer is itself square or a sum of 2, 3, or 4 squares; every positive integer is either pentagonal or a sum of 2, 3, 4, or 5 pentagonal numbers; and so on for higher polygonal numbers" (Kline, p. 277). Weil is doubtful that Fermat could have proved these assertion: "no suggestion can be offered at present as to how Fermat could possibly have proved that every integer is a sum of three triangular numbers, and one cannot help thinking that on this point he may have deceived himself" (Weil, Review, p. 1148).


52 Diophanti Alexandrini,

Eſto prius productum 32. poſterius 272. Ponatur ſumma numerorum 1 N. Igitur eſt ſumma quadratorum, & quia ex ſumma numerorum in interuallum eorundem fit interuallum quadratorum, quo rurſus ducto in numerorum interuallum fit 32. erit quadratus interualli numerorum, qui ſi auferatur à duplo ſummæ quadratorum, nimirum à residuum æquatur quadrato ſummæ numerorum 1 Q. & omnia ducendo in 1 N. fiunt 512 æquales 1 C. & fit 1 N 8. ſumma numerorum, & 34. ſumma quadratorum, & 2. interuallum eorundem. Vnde facilè reperiuntur numeri 3. & 5. Hinc fit Canon.

Aufer prius productum à duplo poſterioris, reſiduum eſt cubus ſummæ numerorum, per quam ſi diuidas prius productum, fit quadratus interualli numerorum.

QVAESTIO VIGESIMA QVARTA.

Inuenire duos numeros vt productum ex ſumma numerorum in interuallum quadratorum, & productum ex ſumma quadratorum in interuallum numerorum, datos conficiant numeros. Oportet autem duplum poſterioris producti multatum priore producto, relinquere cubum, ita vt per eius latus diuidendo prius productum, oriatur quadratus.

Eſto prius productum 128. poſterius 68. Ponatur interuallum numerorum 1 N. ergo ſumma quadratorum erit & ob cauſam in precedente allatam erit quadratus ſummæ numerorum. Itaque ſi à duplo ſummæ quadratorum quod eſt auferatur quadratus ſummæ numerorum nimirum residuum eſt quadratus interualli numerorum. Quare æquatur 1 Q. & omnia in 1 N. fiunt 8. æquales 1 C. eſt ergo 1 N 2. interuallum numerorum, & ſumma quadratorum 34. & quadratus ſummæ numerorum 64. vnde licet variis modis quæſtionem ſoluere, & inuenire quæſitos numeros 3. & 5. Hinc fit Canon.

Aufer prius productum à duplo poſterioris, reſiduum eſt cubus interualli numerorum, itaque per eius latus diuidendo prius productum, oritur quadratus ſummæ numerorum.

QVÆSTIO XXXIV.

INVENIRE duos numeros, datam inter ſe rationem habentes, vt & ſumma quadratorum ab ipſis, ad ſummam ipſorum datam habeat rationem. Imperatum ſit maiorem minoris eſſe triplum; ſummam autem quadratorum ſummæ numerorum eſſe quincuplam. Ponatur minor 1 N. Maior igitur erit 3 N. Supereſt vt ſumma quadratorum ab ipſis, ſummæ vtriuſque ſit quincupla. Cæterùm ſumma quadratorum ab ipſis ortorum fit 10 Q. ſumma verò ipſorum eſt 4 N. vnde conſtat 10 Q. quincuplos eſſe ad 4 N. Quamobrem 20 N. æquantur 10 Q. & fit 1 N. 2. Eſt igitur minor 2. maior 6. & quæſtioni ſatisfaciunt.

IN QVÆSTIONEM XXXIV.

CIRCA hanc quæſtionem & octo ſequentes nulla eſt difficultas, nec ampliori indigent explicatione. Canones etiam pro qualibet formari nullo negotio poſſunt, quod tibi relinquo peragendum.

QVÆSTIO XXXV.

INVENIRE duos numeros in data ratione, vt ſumma quadratorum ab

The most famous marginal note is, of course, that which accompanies Diophantus' Proposition II, 8 (p. 61), "To divide a given square number into two squares," for which Diophantus gives the answer (in our notation)

$[a(m^2 + 1)]^2 = (2am)^2 + [a(m^2 - 1)]^2$.

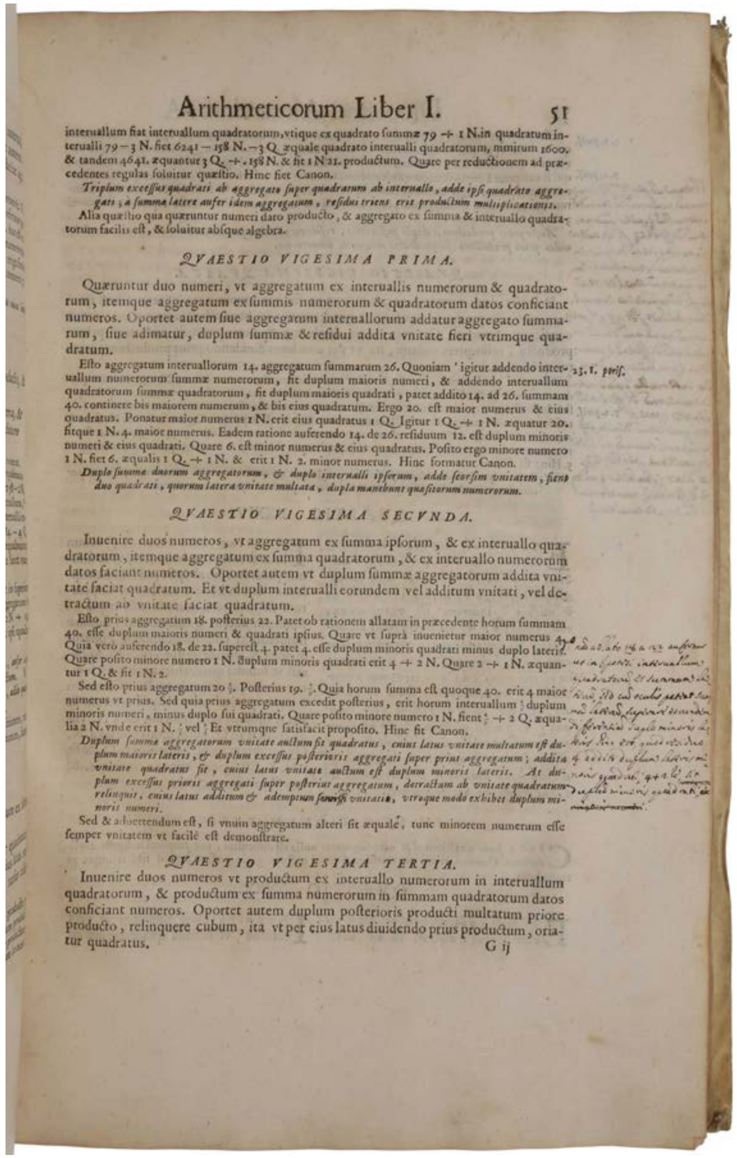
Fermat adds: "In contrast, it is impossible to divide a cube into two cubes, or a fourth power into two fourth powers, or in general any power beyond the square into powers of the same degree; of this I have discovered a very wonderful demonstration. This margin is too narrow to contain it."

In other words, the equation $x^n + y^n = z^n$ has no solution with x, y, z being positive integers and n an integer greater than 2. Fermat gave the proof for $n = 4$ using infinite descent: in fact, it is an easy consequence of his result about the area of right-angled triangles with integer sides described above. To prove the result in general it is now sufficient to prove it when n is an odd prime number (if x, y, z is a solution with $n = pq$, then x^p, y^p, z^p is a solution with $n = q$). The case $n = 3$ was proved by Euler by infinite descent, and Weil suggests that Euler's proof may have been within Fermat's compass. Fermat had in fact posed these two cases as a challenge to the English mathematicians (notably Brouncker and Wallis) in 1657, so it may be reasonable to suppose that he had proofs at that time.

Over the next two centuries (1637–1839), the conjecture was proved for only the primes 3, 5, and 7, although Sophie Germain devised an approach that was relevant to an entire class of primes. In the mid-19th century, Ernst Kummer extended this and proved the theorem for all 'regular' primes, leaving irregular primes to be analyzed individually. Building on Kummer's work and using sophisticated computer studies, other mathematicians were able to extend the proof to cover all prime exponents up to four million.

In 1908, the German industrialist and amateur mathematician Paul Wolfskehl bequeathed 100,000 marks to the Göttingen Academy of Sciences to be offered as a prize for a complete proof of Fermat's Last Theorem. On 27 June 1908, the Academy published nine rules for awarding the prize. Among other things, these rules required that the proof be published in a peer-reviewed journal; the prize would not be awarded until two years after the publication; and that no prize would be given after 13 September 2007, roughly a century after the competition was begun. In the first year alone (1907–1908), 621 attempted proofs were submitted, although by the 1970s, the rate of submission had decreased to roughly 3–4 attempted proofs per month. According to F. Schlichting, a Wolfskehl reviewer, most of the proofs were based on elementary methods taught in schools, and often submitted by "people with a technical education but a failed career." In the words of mathematical historian Howard Eves, "Fermat's Last Theorem has the peculiar distinction of being the mathematical problem for which the greatest number of incorrect proofs have been published."

Around 1955, Japanese mathematicians Goro Shimura and Yutaka Taniyama suspected a link might exist between elliptic curves and modular forms, two completely different areas of mathematics. Known at the time as the Taniyama–Shimura-Weil conjecture, and (eventually) as the modularity theorem. In 1984, Gerhard Frey noticed an apparent link between the modularity theorem and Fermat's Last Theorem. This potential link was confirmed two years later by Ken Ribet, who gave a conditional proof of Fermat's Last Theorem that depended on the modularity theorem. On hearing this, English mathematician Andrew Wiles decided to try to prove the modularity theorem as a way to prove Fermat's Last Theorem. In 1993, after six years working secretly on the problem, Wiles succeeded in proving enough of the modularity theorem to prove Fermat's Last Theorem for odd prime exponents. A flaw was discovered in one part of his


Arithmeticorum Liber I. 51

interuallum fiat interuallum quadratorum, vtique ex quadrato summæ 79 + 1 N. in quadratum interualli 79 − 3 N. fiet 6241 − 158 N. − 3 Q. æquale quadrato interualli quadratorum, nimirum 1600. & tandem 4641. æquantur 3 Q. + 158 N. & fit 1 N 21. productum. Quare per reductionem ad præcedentes regulas soluitur quæstio. Hinc fiet Canon.

Triplum excessus quadrati ab aggregato super quadratum ab interuallo, adde ipsi quadrato aggregati; à summa latere aufer idem aggregatum, residui triens erit productum multiplicationis.

Alia quæstio qua quæruntur numeri dato producto, & aggregato ex summa & interuallo quadratorum facilis est, & soluitur absque algebra.

QVAESTIO VIGESIMA PRIMA.

Quæruntur duo numeri, vt aggregatum ex interuallis numerorum & quadratorum, itemque aggregatum ex summis numerorum & quadratorum datos conficiant numeros. Oportet autem siue aggregatum interuallorum addatur aggregato summarum, siue adimatur, duplum summæ & residui addita vnitate fieri vtrimque quadratum.

Esto aggregatum interuallorum 14. aggregatum summarum 26. Quoniam igitur addendo interuallum numerorum summæ numerorum, fit duplum maioris numeri, & addendo interuallum quadratorum summæ quadratorum, fit duplum maioris quadrati, patet addito 14. ad 26. summam 40. continere bis maiorem numerum, & bis eius quadratum. Ergo 20. est maior numerus & eius quadratus. Ponatur maior numerus 1 N. erit eius quadratus 1 Q. Igitur 1 Q. + 1 N. æquatur 20. fitque 1 N. 4. maior numerus. Eadem ratione auferendo 14. de 26. residuum 12. est duplum minoris numeri & eius quadrati. Quare 6. est minor numerus & eius quadratus. Posito ergo minore numero 1 N. fiet 6. æqualis 1 Q. + 1 N. & erit 1 N. 2. minor numerus. Hinc formatur Canon. 23.1. [illegible]

Duplo summæ duorum aggregatorum, & duplo interualli ipsorum, adde seorsim vnitatem, fient duo quadrati, quorum latera vnitate multata, dupla manebunt quæsitorum numerorum.

QVAESTIO VIGESIMA SECVNDA.

Inuenire duos numeros, vt aggregatum ex summa ipsorum, & ex interuallo quadratorum, itemque aggregatum ex summa quadratorum, & ex interuallo numerorum datos faciant numeros. Oportet autem vt duplum summæ aggregatorum addita vnitate faciat quadratum. Et vt duplum interualli eorundem vel additum vnitati, vel detractum ab vnitate faciat quadratum.

Esto prius aggregatum 18. posterius 22. Patet ob rationem allatam in præcedente horum summam 40. esse duplum maioris numeri & quadrati ipsius. Quare vt suprà inuenietur maior numerus 4. Quia verò auferendo 18. de 22. superest 4. patet 4. esse duplum minoris quadrati minus duplo lateris. Quare posito minore numero 1 N. duplum minoris quadrati erit 4 + 2 N. Quare 2 + 1 N. æquantur 1 Q. & fit 1 N. 2.

Sed esto prius aggregatum 20 ½. Posterius 19. ½. Quia horum summa est quoque 40. erit 4 maior numerus vt prius. Sed quia prius aggregatum excedit posterius, erit horum interuallum ½ duplum minoris numeri, minus duplo sui quadrati. Quare posito minore numero 1 N. fient ½ + 2 Q. æqualia 2 N. vnde erit 1 N. ½ vel ½. Et vtrumque satisfacit proposito. Hinc fit Canon.

Duplum summæ aggregatorum vnitate auctum fit quadratus, cuius latus vnitate multatum est duplum maioris lateris, & duplum excessus posterioris aggregati super prius aggregatum; addita vnitate quadratus fit, cuius latus vnitate auctum est duplum minoris lateris. At duplum excessus prioris aggregati super posterius aggregatum, detractum ab vnitate quadratum relinquit, cuius latus additum & ademptum [illegible] vnitatis, vtroque modo exhibet duplum minoris numeri.

Sed & aduertendum est, si vnum aggregatum alteri sit æquale, tunc minorem numerum esse semper vnitatem vt facilè est demonstrare.

QVAESTIO VIGESIMA TERTIA.

Inuenire duos numeros vt productum ex interuallo numerorum in interuallum quadratorum, & productum ex summa numerorum in summam quadratorum datos conficiant numeros. Oportet autem duplum posterioris producti multatum priore producto, relinquere cubum, ita vt per eius latus diuidendo prius productum, oriatur quadratus.

G ij

original paper during peer review and required a further year and collaboration with a past student, Richard Taylor, to resolve. As a result, the final proof in 1995 was accompanied by a second smaller joint paper. Wiles collected the Wolfskehl prize money, then worth $50,000, on 27 June 1997.

Honeyman 893; Hoffman II, p.109; Macclesfield 638; Norman 777; Smith, *Rara arithmetica*, p. 348. Weil, Review of Mahoney (ibid.), *Bulletin of the American Mathematical Society* 79 (1973), pp. 1138-49. Weil, *Number Theory*: *An Approach Through History from Hammurapi to Legendre*, 1984.

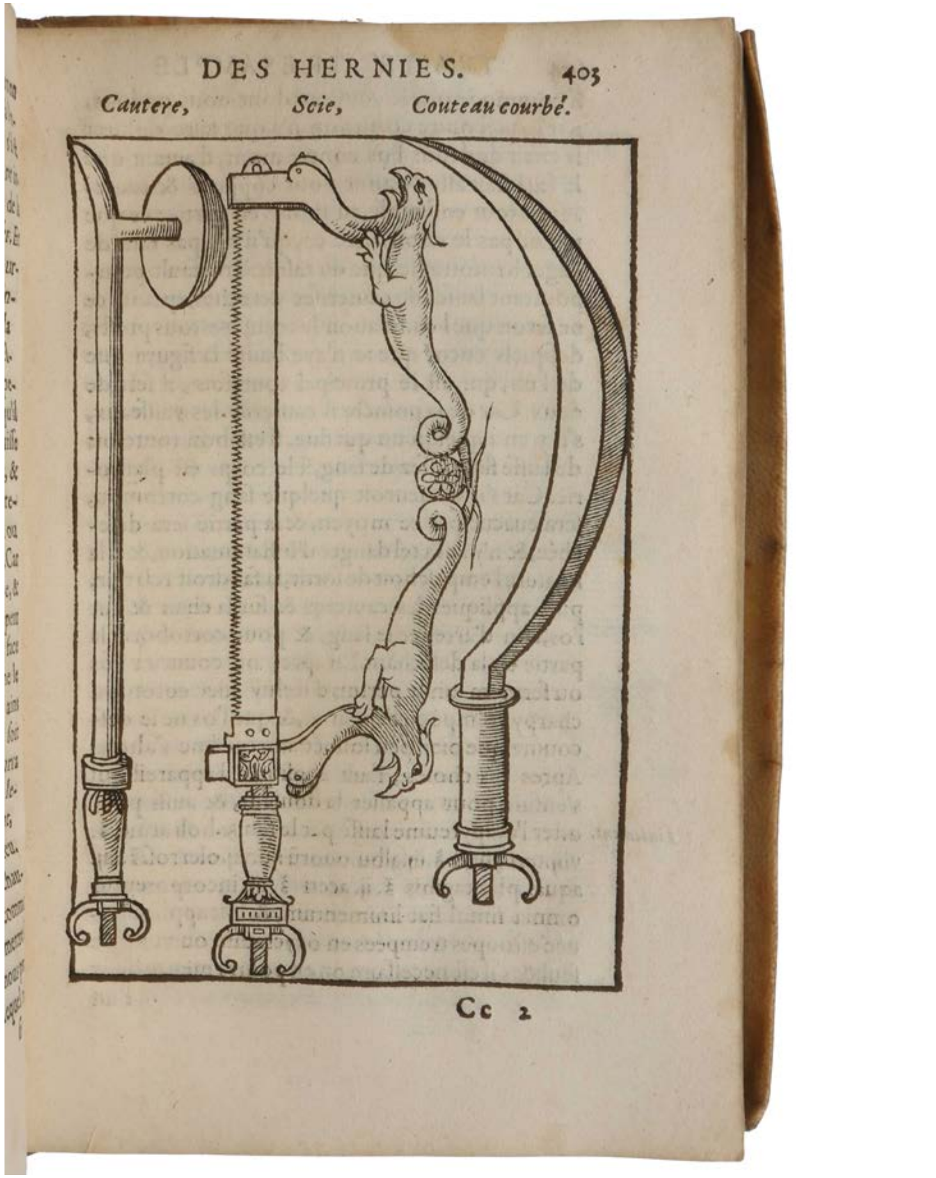
ONE OF THE GREATEST SURGEONS OF THE RENAISSANCE

FRANCO, Pierre. *Traité des hernies: contenant une ample declaration de toutes leurs especes, & autres excellentes parties de la chirurgie, assavoir de la pierre, des cataractes, des yeux, & autres maladies, desquelles comme la cure est perilleuse, aussi est elle de peu dhommes bien exercée avec leurs causes, signes, accidens, anatomie des parties affectées, & leur entiere guarison...* Lyon: Thibauld Payan, 1561.

$38,500

8vo (168 x 108 mm), pp. [16], 554, [2], with woodcuts in text showing a variety of surgical instruments for the procedures discussed and a series of three full skeletons at the end. Contemporary vellum, upper margin of rear board with some wear, remains of ties. A few leaves with light water stains. An entirely unrestored copy. Provenance: from the library of great medical collector Jean Blondelet.

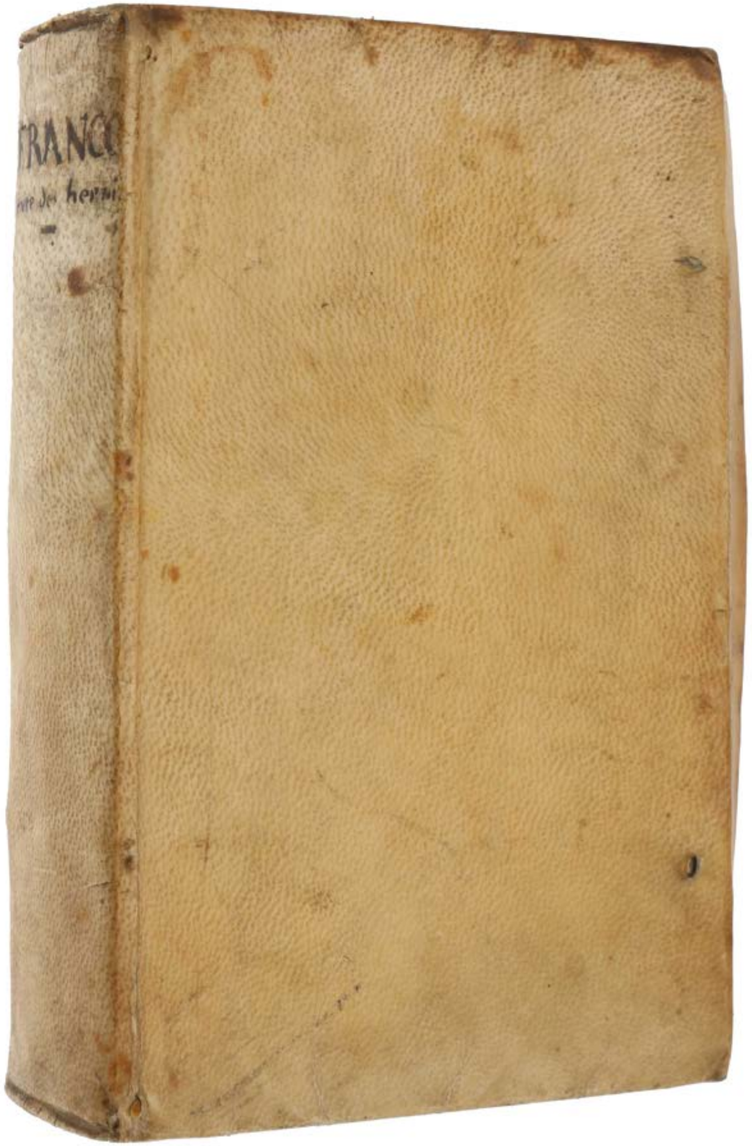
Second edition, almost four times the length of the first (1556), with 25 new illustrations including 22 instruments and three full skeletons. This is Franco's major work, very rare, a copy in an untouched contemporary binding and with a fine provenance. "Pierre Franco, creator of suprapubic lithotomy cataract operation and surgical repair of hernia with preservation of the testis, is considered to be one of the greatest surgeons of the Renaissance and a forerunner of urology" (Androutsos, p. 255). "Franco was influential in bringing operative surgery back into the realm of regular surgical practice, recapturing it from the ignorant hands of charlatans and itinerant "cutters." His major interest was in hernia surgery, to which he introduced several important innovations including an operation preserving the testicle (which was usually removed), a less risky incision at the



base of the scrotum and methods for the surgical release of strangulated hernia. Franco was also the first surgeon to address himself seriously to the removal of bladder stones; he gave an account of perineal lithotomy and was the earliest to describe and perform the suprapubic incision" (Norman). Only two copies recorded on ABPC/RBH in the last 80 years. The only other copy we have located in commerce is in Ernst Weil's catalogue 5 (ca. 1947), no. 93 ("of great rarity", £100). OCLC lists copies in US at Chicago, Harvard, Indiana and West Virginia.

"A less well known French-born contemporary of Paré, but one who well deserves our recognition as a shining star of Renaissance surgery, was Pierre Franco (?1500-1561). He was born in Provence of humble parents and had little schooling, but was early apprenticed to a barber-surgeon. As a Protestant, he was forced to flee from France and practiced his calling in Lausanne in Switzerland, although he eventually returned to Orange in France and his major work, *Treatise on Hernias*, was published in Lyon in 1561, just before his death. He deplored the fact that surgeons of his day rejected the use of open operations. This was because of the risks involved in such procedures, which they would often leave in the hands of charlatans. Franco was obviously a bold surgeon who carried out a wide range of the operative procedures known at that time. He describes in great detail his method of radical surgery for strangulated hernia, devising an incision at the base of the scrotum which he claimed was less dangerous than the higher incision. He also carried out cataract surgery and plastic operations on the face and described a new method for operating on cleft lip. In the surgery for bladder stone he was equally inventive … [he was] the first surgeon to remove a bladder stone successfully via an abdominal approach" (Ellis, p. 44).

"'Considered especially from the point of view of the performance of operations,' wrote Nicaise, "Franco is the premier surgeon of the 16th century." Hernial surgery constituted his principal field of interest. He describes, in minute detail, the



technique of radical operation for inguinal hernia. Like all who preceded him (except for William of Salicet) after the time of Celsus, he removed the testicle as part of his usual procedure. However, for patients who had but one testis he devised an operation in which the organ was spared. Considering the usual incision at the level of the pubis to be unduly dangerous, he "invented" a low incision at the base of the scrotum which, he claims, was used in more than 200 persons by others and himself in the twelve or fifteen years since he first devised it. The clinical picture of strangulated hernia is clearly and vividly described, and methods for the surgical release of strangulation, both with and without opening the sac, are presented. Thus, for the first time, this life-saving procedure became part of the surgical armamentarium.

"In the surgery for bladder stone he was equally enterprising and inventive. He described and pictured a number of instruments for catheterization and lithotomy, and pioneered in the introduction of several incisions, including the suprapubic approach.

"Ophthalmic surgery and facial plastic operations also came within his scope, and he developed a new technique for certain forms of harelip. Whatever subject he dealt with was enriched and advanced through his ingenuity. It is with perfect justification that Nicaise said, "Where Franco appeared with all his genius, it was in operative therapeutics; it suffices for us to recall successively his operations to make evident the role that he has played, and to show that no surgeon has attached his name to so many lasting discovered" (Zimmerman & Veith, pp. 194-5).

"The suprapubic approach to the bladder via a low mid-line abdominal incision, with the bladder distended to push away the peritoneum, is the usual open method employed in the removal of bladder stone today … The first recorded operation of this kind was carried out by Pierre Franco … In the year of his death he gave an

account of an operation on a child of about three years of age who had a stone in the bladder the size of a hen's egg. He was unable to remove the stone via the perineal approach because the enormous stone could not be pushed down into the neck of the bladder. The child's parents begged him to try to relieve the small patient of his sufferings so he therefore pushed the stone up into the groin with his fingers in the rectum, got his assistant to fix the stone in this situation and then cut down immediately above the pubis into the calculus. The little patient recovered, but Franco advised others not to follow his example! … Indeed, it was not until the 18th century that Johann Bonnet was reported to have carried out the suprapubic operation frequently and with success at the Hôtel Dieu in Paris" (Ellis, p. 189).

"Although not an academic, Franco decided to write a surgical text based on his many years of experience, which he modestly called a *Petit Traité* [*Petit traité, contenant une des parties principales de chirurgie, laquelle les chirurgiens hernieres exercent*, … Lyon, 1556] … His second book, *Traité des hernies*, was published in 1561 and includes chapters on anatomy, medicine and pharmacology. While in his first book Franco only cites Avicenna, Albucasis and Guy de Chauliac, *Traité des hernies* contains no less than 356 citations from a wide range of authorities, testifying to the remarkable learning of the supposedly unschooled author. Franco discusses the cleft lip in ample detail, devoting two chapters to the subject. He was the first to state the congenital nature of the malformation clearly, and referred to the unilateral harelip as the "lièvre fendu de nativité" (cleft lip present from birth). He provides a meticulous classification of various types of clefts, calling the bilateral harelip the "dent de lièvre" (hare's tooth) presumably because this condition was frequently accompanied by a marked protrusion of the premaxilla bone with its teeth.

"Franco gave a meticulous description of his surgical technique. He used dry sutures, pins and a triangular bandage. He emphasized that an accurate repair produced an unobtrusive scar, an outcome which was "particularly desirable when the patient was a girl".

"Surgery on the bilateral harelip was carried out in two stages due to the difficulty of closing an extremely wide cleft, often complicated by a protruding premaxilla. Franco recommended that the cheeks be mobilized in the repair, but did not hesitate to resect the premaxilla. As he wrote: "To extirpate this turpitude, we must first proceed in the manner described above, except when the teeth and maxillary segments are outside and cannot be covered by the mouth. There is no danger in cutting too much of that which serves no purpose, so one uses cutting forceps, or a saw or other instrument suitable for this, leaving the flesh which is over these teeth, if there is any, as it helps when sewing to the other parts on each side. And if there is such a distance between these lips that one cannot bring them together, it will be necessary to use dissection in the mouth similar to those on the preceding case, and proceed with the remainder of the closure as we have described" [Chapter XCVI]. This passage could not be more lucid and illustrates why Franco has been called *The Father of Lip Repairs*. Like Paré, he passed a pin or fibula across the repair and held this in place with a figure-of-eight thread, a technique invented by Henry de Mondeville (1260-1320) in 1306 for many wounds" (Santoni-Rugiu & Sykes, pp. 222-3).

BM/STC French p.187; Garrison-Morton 3574; Waller 3223; Wellcome 2409 (imperfect); Norman 828 (modern binding, upper margin of title and final leaf repaired, $9200). Androutsos, 'Pierre Franco (1505-1578): famous surgeon and lithotomist of the 16th century,' *Progress in Urology* 14 (2004), 255-9; Ellis, *A History of Surgery*, 2002; Santoni-Rugiu & Sykes, *A History of Plastic Surgery*, 2007; Zimmerman & Veith, *Great Ideas in the History of Surgery*, 1993.

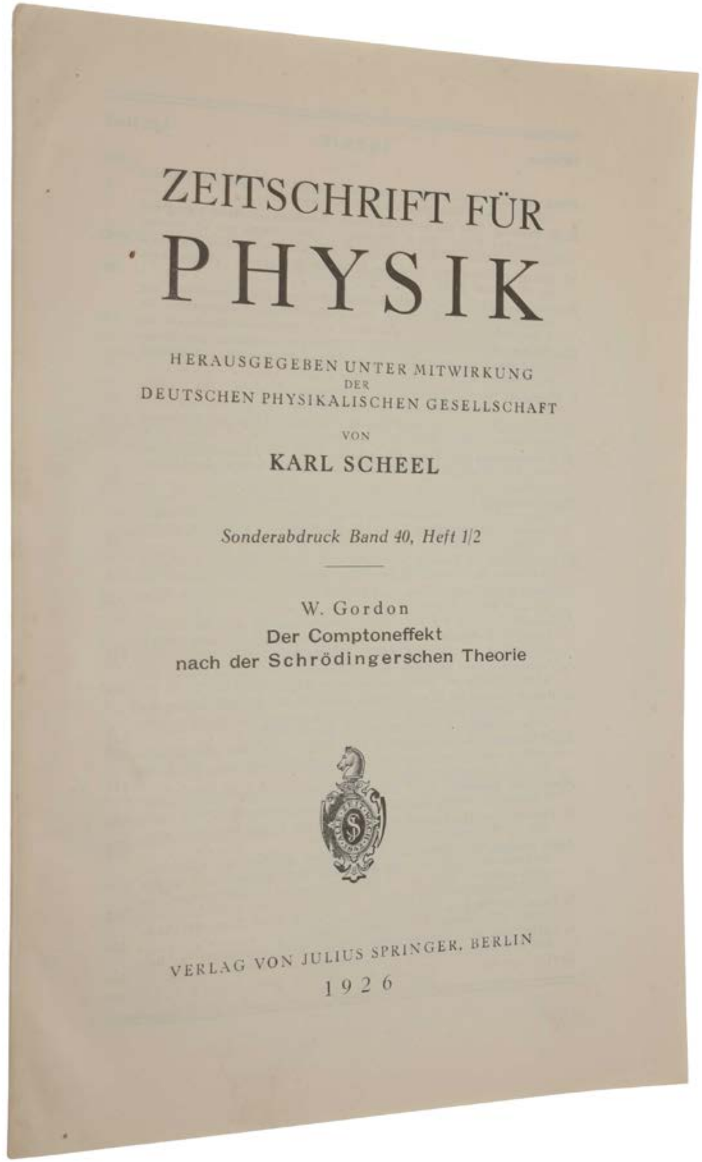
THE KLEIN-GORDON EQUATION

GORDON, Walter. *Der Comptoneffekt nach der Schrödingerschen Theorie.* Berlin: Springer, 1926.

$2,800

Offprint from: Zeitschrift für Physik, Band 40, Heft 1/2, 29 November 1926. 8vo (230 x 155 mm), pp. 117-133. Original printed wrappers. A very fine copy.

First edition of Gordon's account of the 'Klein-Gordon equation' ('KG equation' in what follows), the first attempt at unifying wave mechanics with special relativity. The KG equation was discovered by several authors independently, the first being the Swedish physicist Oskar Klein, although the equation appeared only incidentally in his paper. Gordon gave a detailed account of the KG equation in the present paper, and he was the first to apply it to a concrete physical problem – the Compton effect (the decrease in energy of photons when scattered from electrons). "Soon after Erwin Schrödinger's publication of his first papers on wave mechanics in 1926, Gordon made several important contributions to the relativistic generalization of non-relativistic quantum mechanics: the current-density vector of the scalar wave equation, and the quantitative formula for the Compton effect. That these results were not applicable to the electron—as was generally believed at that time—but to particles obeying Bose statistics, which, however, were discovered later, does not detract from the quality of this work" (DSB). "Since the mid-thirties the KG equation had been recognised to belong to the fundamental equations of quantum field theory" (Kragh 1984, p. 1031). "The work of Walter Gordon provided the most condensed mathematical presentation of the various versions of Schrödinger's equation, especially of the fully relativistic



form. Although he was nearly the last to publish the results, this fact justifies the association of his name with [the KG equation]. Finally, Gordon did not stop at the relativistic wave equation, but went on to use it in a crucial problem: to calculate the Compton effect in wave mechanics. We conclude, therefore, that Oskar Klein – who, besides Schrödinger, first worked on the relativistic wave equation – and Walter Gordon are indeed the appropriate 'patrons' of the equation that bears their names" (Mehra & Rechenberg, pp. 819-820). "The Klein-Gordon equation and its applications led to many further important developments … in particular, the relativistic equation is connected with the physical interpretation of quantum mechanics and with the origin of quantum field theory" (Mehra & Rechenberg, p. 808, n. 271). In addition, the KG equation was later shown to correctly describe spin-zero particles, such as mesons. "On July 4, 2012 CERN announced the discovery of the Higgs boson. Since the Higgs boson is a spin-zero particle, it is the first observed ostensibly elementary particle to be described by the Klein–Gordon equation" (Wikipedia). Not on OCLC. No copies in auction records.

The KG equation is a relativistic wave equation, a quantized version of the relativistic energy-momentum relation. Like the Schrödinger equation, it is second order in space and time, but unlike the Schrödinger equation it is manifestly relativistically covariant. Another difference from the Schrödinger equation is that the wave function in the KG equation cannot be interpreted as a probability amplitude – the norm squared of the wave function must be interpreted as a charge density rather than a probability. The equation describes all spinless particles with positive, negative as well as zero charge.

"On Schrödinger's original road to wave mechanics, relativistic considerations were of crucial importance. In fact, he first derived a relativistic eigenvalue equation, which he did not publish, mainly because he realized that it did not reproduce the hydrogen spectrum with acceptable accuracy … Consequently, Schrödinger reported only the non-relativistic approximation of [the KG equation] in his first publication on wave mechanics.

"Independently of Schrödinger, the relativistic second-order equation was found in the spring of 1926 by Oskar Klein, who was the first to publish it. During the next half year, it was investigated by several other physicists, including Fock, Gordon, de Broglie, Schrödinger, and Kudar, and eventually became known as the Klein-Gordon equation" (Kragh 1990, pp. 51-2).

Klein (1894–1977) was the first to publish the KG equation, in April 1926, in his 'Quantentheorie und fünfdimensionale Relativitätstheorie' (*Zeitschrift für Physik* 37, pp. 895-906). This work was a development of Theodor Kaluza's five-dimensional 'unified' theory of gravity and electromagnetism presented in 'Zum Unitätsproblem der Physik' (*Sitzungsberichte der Preussischen Akademie der Wissenschaften* (*Berlin*) (1921), pp. 966-972). The KG equation appeared only incidentally in Klein's paper and no applications of it were given. In December Klein published a second paper, 'Elektrodynamik und Wellenmechanik vom Standpunkt der Korrespondenzprincips' (*Zeitschrift für Physik* 41 (1927), pp. 407-442), which was principally designed to support Bohr's physical interpretation of quantum mechanics. But in Section 1 of the paper Klein stated the KG equation explicitly, and in Section 4 gave applications of it to the Zeeman effect and dispersion phenomena. (See Mehra & Rechenberg, pp. 810-813.)

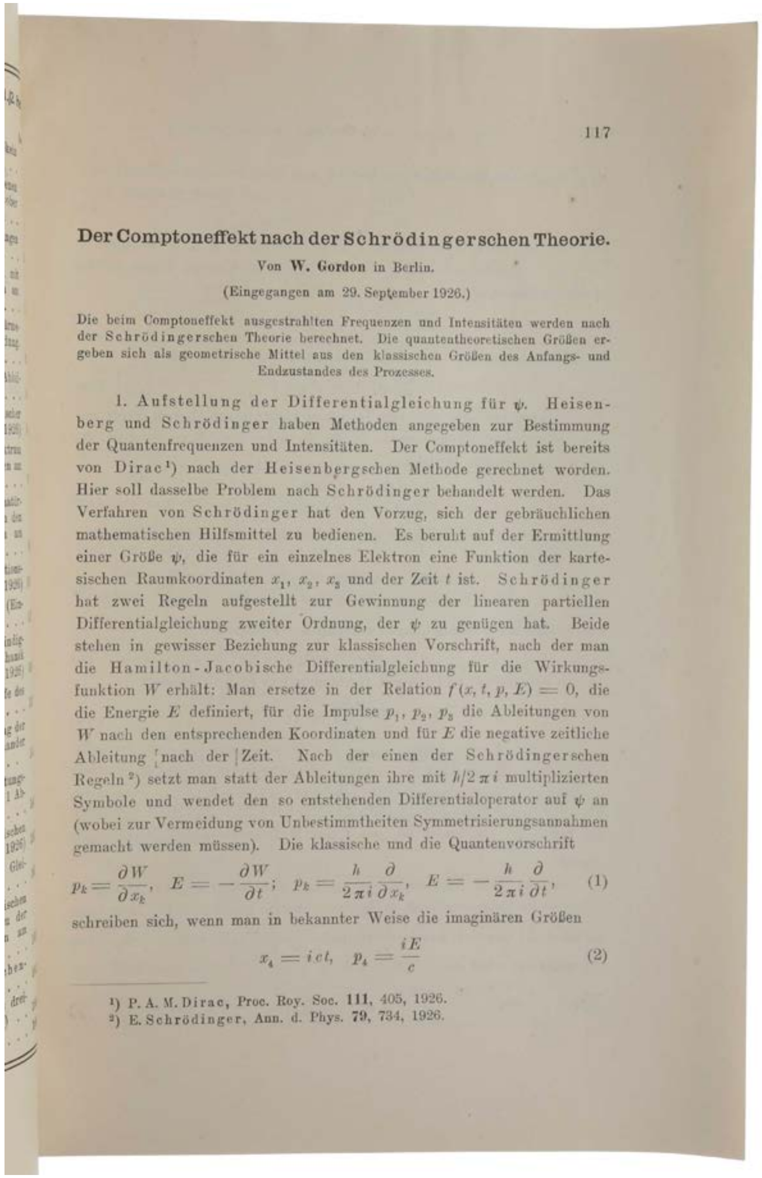
"The fact that Schrödinger had abandoned his relativistic wave equation to avoid disagreement with experiment was commented on extensively by Dirac … The disagreement between [the KG equation] and the hydrogen spectrum was, Dirac said,

'most disappointing to Schrödinger. It was an example of a research worker who is hot on the trail and finding all his worst fears realized. A theory which was so beautiful, so promising, just did not work out in practice. What did Schrödinger do? He was most unhappy. He abandoned the thing for some months, as he told me … Schrödinger had really been too timid in giving up his first relativistic wave equation … Klein and Gordon published the relativistic equation which was really the same as the equation which Schrödinger had discovered previously. The only contribution of Klein and Gordon in this respect was that they were sufficiently bold not to be perturbed by the lack of agreement of the equation with observations'" (Kragh 1990, pp. 50-1).

"It was Dirac's preoccupation with the general principles of quantum mechanics, and the transformation theory in particular, that led him to realize that the formal structure of the Schrödinger equation had to be retained even in a future unification of quantum theory and relativity. Since the KG equation is of second order in d/d*t*, it seemed to Dirac to be in conflict with the general formalism of quantum mechanics … During the Solvay Congress in October 1927, Dirac mentioned to Bohr his concern about a relativistic wave equation:

'Then Bohr answered that the problem had already been solved by Klein. I tried to explain to Bohr that I was not satisfied with the solution of Klein, and I wanted to give him reasons, but I was not able to do so because the lecture started just then and our discussion was cut short. But it rather opened my eyes to the fact that so many physicists were quite complacent with a theory that involved a radical departure from the basic laws of quantum mechanics, and they did not feel the necessity of keeping to these basic laws in the way that I felt.'

"After his return from Brussels, Dirac concentrated on the problem of formulating a first-order relativistic theory of the electron. Within two months he had solved the whole matter" (Kragh 1990, pp. 54-7). This was the famous 'Dirac equation'.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Der Comptoneffekt nach der Schrödingerschen Theorie.

Von **W. Gordon** in Berlin.

(Eingegangen am 29. September 1926.)

Die beim Comptoneffekt ausgestrahlten Frequenzen und Intensitäten werden nach der Schrödingerschen Theorie berechnet. Die quantentheoretischen Größen ergeben sich als geometrische Mittel aus den klassischen Größen des Anfangs- und Endzustandes des Prozesses.

1. Aufstellung der Differentialgleichung für ψ. Heisenberg und Schrödinger haben Methoden angegeben zur Bestimmung der Quantenfrequenzen und Intensitäten. Der Comptoneffekt ist bereits von Dirac[1]) nach der Heisenbergschen Methode gerechnet worden. Hier soll dasselbe Problem nach Schrödinger behandelt werden. Das Verfahren von Schrödinger hat den Vorzug, sich der gebräuchlichen mathematischen Hilfsmittel zu bedienen. Es beruht auf der Ermittlung einer Größe ψ, die für ein einzelnes Elektron eine Funktion der kartesischen Raumkoordinaten x_1, x_2, x_3 und der Zeit t ist. Schrödinger hat zwei Regeln aufgestellt zur Gewinnung der linearen partiellen Differentialgleichung zweiter Ordnung, der ψ zu genügen hat. Beide stehen in gewisser Beziehung zur klassischen Vorschrift, nach der man die Hamilton-Jacobische Differentialgleichung für die Wirkungsfunktion W erhält: Man ersetze in der Relation $f(x, t, p, E) = 0$, die die Energie E definiert, für die Impulse p_1, p_2, p_3 die Ableitungen von W nach den entsprechenden Koordinaten und für E die negative zeitliche Ableitung nach der Zeit. Nach der einen der Schrödingerschen Regeln[2]) setzt man statt der Ableitungen ihre mit $h/2\pi i$ multiplizierten Symbole und wendet den so entstehenden Differentialoperator auf ψ an (wobei zur Vermeidung von Unbestimmtheiten Symmetrisierungsannahmen gemacht werden müssen). Die klassische und die Quantenvorschrift

$$p_k = \frac{\partial W}{\partial x_k}, \quad E = -\frac{\partial W}{\partial t}; \quad p_k = \frac{h}{2\pi i}\frac{\partial}{\partial x_k}, \quad E = -\frac{h}{2\pi i}\frac{\partial}{\partial t}, \qquad (1)$$

schreiben sich, wenn man in bekannter Weise die imaginären Größen

$$x_4 = ict, \quad p_4 = \frac{iE}{c} \qquad (2)$$

[1]) P. A. M. Dirac, Proc. Roy. Soc. **111**, 405, 1926.
[2]) E. Schrödinger, Ann. d. Phys. **79**, 734, 1926.

"Although the KG theory virtually disappeared from the scene of physics after Dirac's alternative theory made its entry, it reappeared some years later. In 1934 Pauli and Weisskopf reconsidered the KG equation in the light of current theories of quantization of wave fields. They emphasized that their new interpretation of the KG equation allowed them to account for the existence of anti-particles in a much more natural way than Dirac's questionable hole theory which was, they said, based on *a priori* arguments. Indeed, Pauli referred to the work as the 'anti-Dirac paper'. However, the Pauli-Weisskopf version of the KG equation applies to bosons only and is thus not truly an alternative to Dirac's theory [of the electron]. In 1934 no elementary particles of spine zero were known. It was only later, with the discovery of mesons, that the KG equation proved to apply to reality. In Yukawa's classic theory of 1935 in which the meson was predicted, he made use of a version of the KG equation. Since the mid-thirties the KG equation had been recognised to belong to the fundamental equations of quantum field theory" (Kragh 1984, p. 1031).

Walter Gordon (1893–1940) obtained his PhD from the University of Berlin in 1921. He remained there until 1929, when he became Privatdozent—and later associate professor—at the University of Hamburg. He lost his position there, like other professors of Jewish origin, in the spring of 1933. He became a member of the Institute of Mathematical Physics at the University of Stockholm in the fall of the same year, but poor conditions for science at the University of Stockholm, together with a general lack of understanding of existing German political conditions, prevented his obtaining a regular position. During almost all of his stay in Sweden, Gordon participated eagerly in the seminars at the Institute of Mathematical Physics, to which his erudition, not merely in physics and mathematics, and his caustic but friendly humour gave a characteristic touch. He also gave lectures, among them a valuable course in group theory. But Gordon's forced exile, taking him from the congenial and inspiring circle at the Hamburg Institute of Physics, and the uncertainty of his future brought an end to his creative powers. Early in 1937 his health declined, and inoperable stomach cancer was diagnosed. Good medical treatment and the care of his wife enabled him to live a reasonably normal life until the last months of 1940.

Kragh, 'Equation with many fathers: The Klein-Gordon equation in 1926,' *American Journal of Physics* 52 (1984), pp. 1024-1033. Kragh, *Dirac: A Scientific Biography*, 1990. Mehra & Rechenberg, *The Historical Development of Quantum theory*, Vol. 5, 1987.

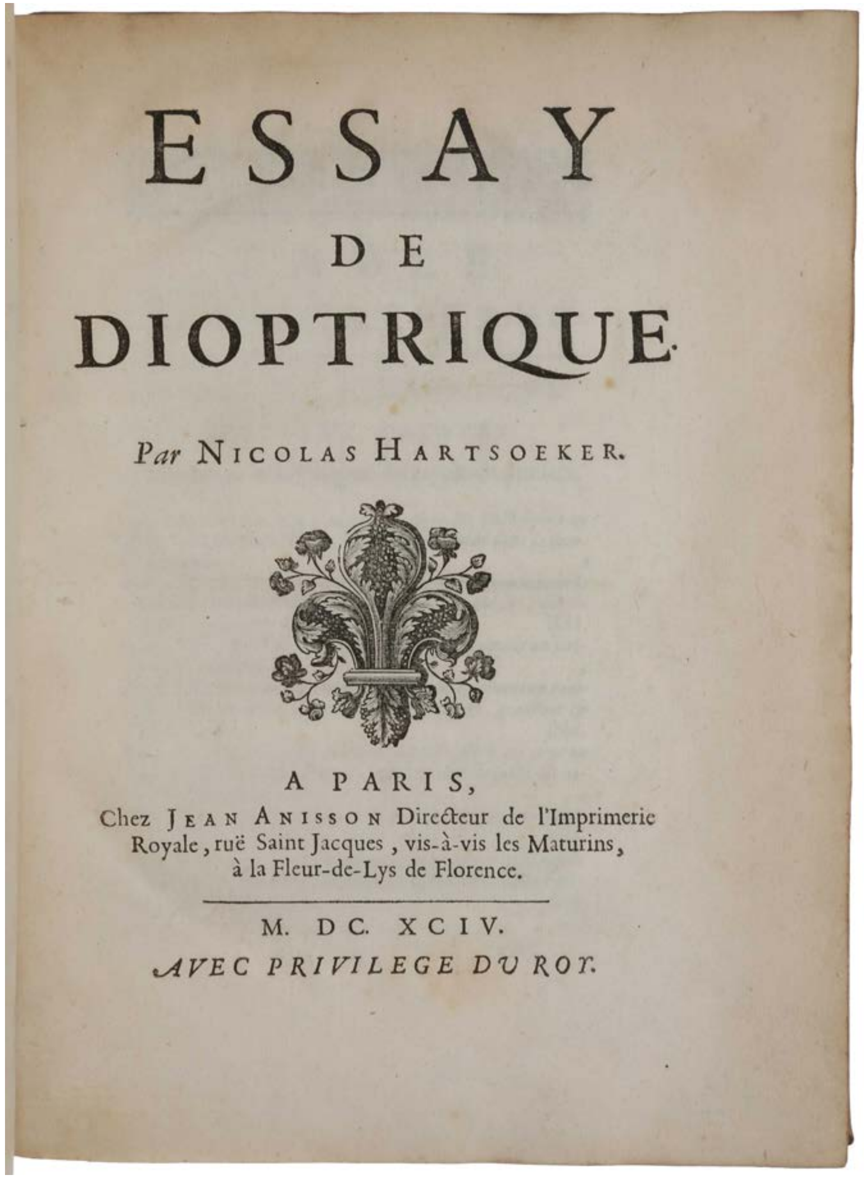
ANATOMY OF THE EYE, PHYSICS OF VISION, THEORY OF COLOR, AND OPTICAL LENSES

HARTSOEKER, Nicolas. *Essay de dioptrique.* Paris: J. Anisson, 1694.

$9,500

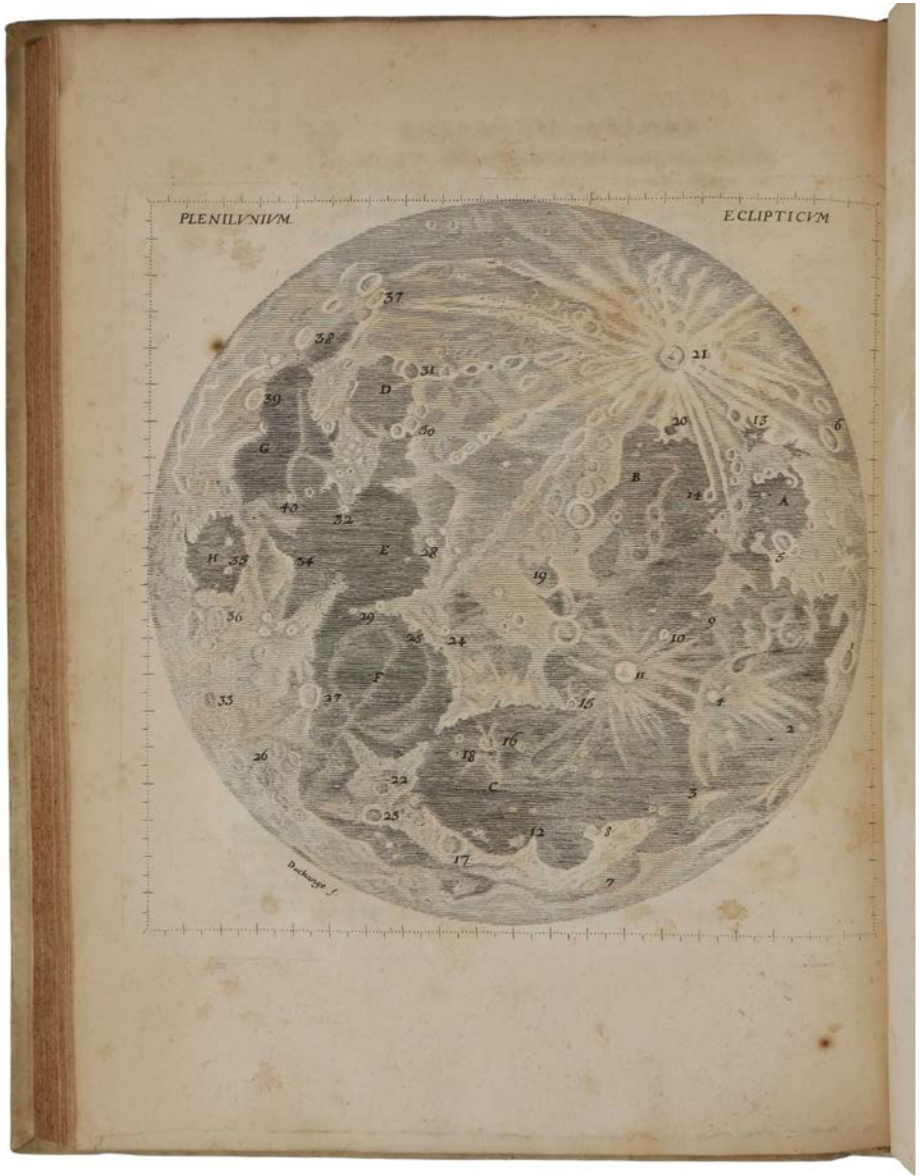
4to (254 x 192 mm), pp. [xxiv], 178, [2], 179-233, [1], with one folding engraved plate of the Moon and numerous woodcut diagrams in the text. Contemporary vellum, a very fine copy.

First edition, rare, of Hartsoeker's first and most important work, in which he reviewed the principles of optics as far as they were known by the end of the 17th century. In addition to the physics of light and the physiology of vision, the book also treats in great detail techniques for the production of lenses for microscopes and telescopes. "Hartsoeker was always interested in optical instruments. He claimed to have developed a method of making small glass globules for microscopes, though his priority in this is doubted. He definitely made lenses of different focal lengths, some of which survive; one lens is said to have had a focal length of 600 feet. He made a number of instruments, not just optical instruments, for the Paris observatory. He constructed a burning glass of great size" (Galileo Project). The *Essay* also documents many observations Hartsoeker made with these instruments. Like Leeuwenhoek, Malpighi and others, Hartsoeker was a preformationist at a time when explanations of animal reproduction were a confused blend of Aristotelian theory, religious orthodoxy, and pure speculation.



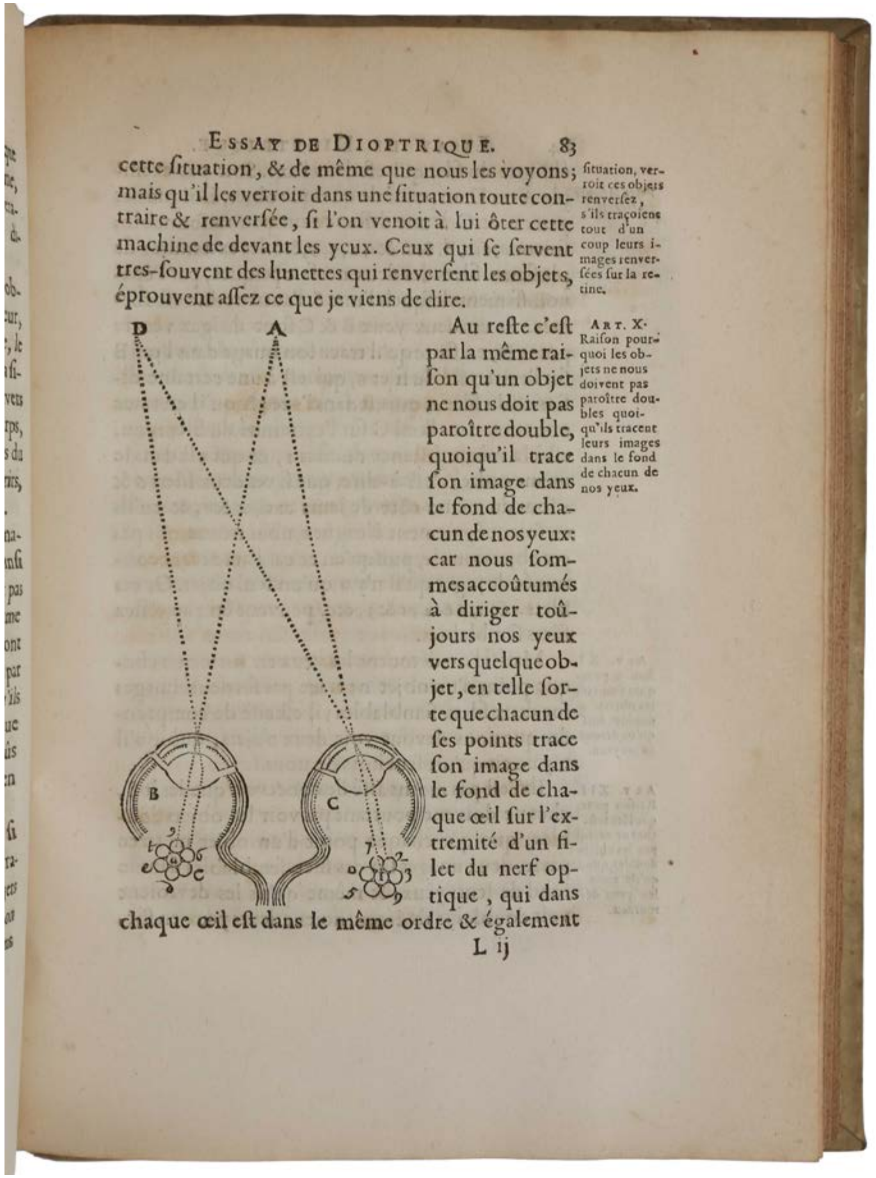
Towards the end of the book, on p. 230, he presented a picture of a little preformed human figure in the head of a spermatozoon. This picture has since become famous and more than a little notorious as an example of observations biased by theoretical prejudice. Hartsoeker's reputation has been forever linked to this picture and if his name appears today at all, he is usually held up as an example of a scientist who saw what he wanted to see. That was not, in fact, the case. In the text accompanying this famous picture he says: 'si l'on pouvoit voir le petit animal au travers de la peau qui le cache, nous le verrions peut-etre comme cette figure le represente, sinon que la tete seroit peut-etre plus grande a proportion du reste du corps, qu'on ne l'a deffinee ici,' i.e., if one's instruments were good enough, here is a suggestion of what one *might* see. ABPC/RBH record only two copies in the past 35 years (Burgersdijk & Niermans, 2003, €3240 (modern binding); Christie's 1999, $3680).

Born in Gouda, "Hartsoeker (1656-1725) was the son of Christiaan Hartsoeker, an evangelical minister, and Anna van der Mey. Although his father wished him to study theology, Hartsoeker preferred science; he secretly learned mathematics and lens grinding. Most sources suggest that he may have studied anatomy and philosophy at the University of Leiden in 1674; a letter from Constantijn Huygens to his brother Christiaan, however, refers to him as having had no higher education, so it is possible that he was largely self-educated in his chosen fields. It is known that by 1672 he had visited Leeuwenhoek and that in 1678 he accompanied Christiaan Huygens to Paris, where he met some of the French scientists and worked for a time at the Paris observatory. In his correspondence with Christiaan Huygens from about this period, Hartsoeker claimed to have invented the technique of making small globules of glass for use as lenses for microscopes, but it is more probable that priority in this belongs to Johann Hudde" (DSB).



“What distinguished Hartsoeker from other opticians was how candid he was about his lens craft and other technical inventions. Unlike Van Leeuwenhoek and the Campani brothers who warily shrouded their lens making methods, Hartsoeker did not keep trade secrets. In fact, his treatise on dioptrics explained in great detail what kind of glass to use, how best to grind lenses, and how to configure them most effectively. Even before his *Essay de dioptrique* came out in 1694, he shared with Huygens his idea of the simple microscope. He then collaborated with Huygens and Rømer on the design that was eventually published in the *Journal des Sçavans* in 1678. Only when Huygens appropriated Hartsoeker’s design of the simple microscope and passed it off as his own in the *Journal des Sçavans*, did Hartsoeker react with indignation. He wanted authorial credit for his invention. But when he began manufacturing telescope lenses, he continued to share his techniques and lenses with Huygens and others at the Academy … To some extent, it appears he deliberately capitalized on transparency when he first asked Huygens to be his benefactor. After the debacle with Huygens in 1678, he conducted himself more prudently. He learnt to protect his ideas and inventions in print” (Abou-Nemeh, pp. 9-10).

“In this treatise [i.e., the *Essay*], Hartsoeker not only explained how to work lenses but also made some natural philosophical claims on generation. For instance, he argued for pre-formation based on his observations with a microscope. The theory stipulated that parts of an organism, for example the fly, were already present in miniature forms in the maggot and merely grew as the organism further developed. The way in which he did this shows nicely how his philosophical hypotheses complemented his observations. For many years he had been observing the sperm of quadrupeds and human beings, which he thought resembled tadpoles. Ever since he had made these observations, he realized that birds, flies and butterflies, were born out of these “worms which enclose them inside and hide them from our view.” No doubt the idea of pre-formation influenced Hartsoeker’s observations.



Essay de Dioptrique. 83

cette ſituation, & de même que nous les voyons; mais qu'il les verroit dans une ſituation toute contraire & renverſée, ſi l'on venoit à lui ôter cette machine de devant les yeux. Ceux qui ſe ſervent tres-ſouvent des lunettes qui renverſent les objets, éprouvent aſſez ce que je viens de dire.

ſituation, verroit ces objets renverſez, s'ils traçoient tout d'un coup leurs images renverſées ſur la retine.

Au reſte c'eſt par la même raiſon qu'un objet ne nous doit pas paroître double, quoiqu'il trace ſon image dans le fond de chacun de nos yeux: car nous ſommes accoûtumés à diriger toûjours nos yeux vers quelque objet, en telle ſorte que chacun de ſes points trace ſon image dans le fond de chaque œil ſur l'extremité d'un filet du nerf optique, qui dans chaque œil eſt dans le même ordre & également

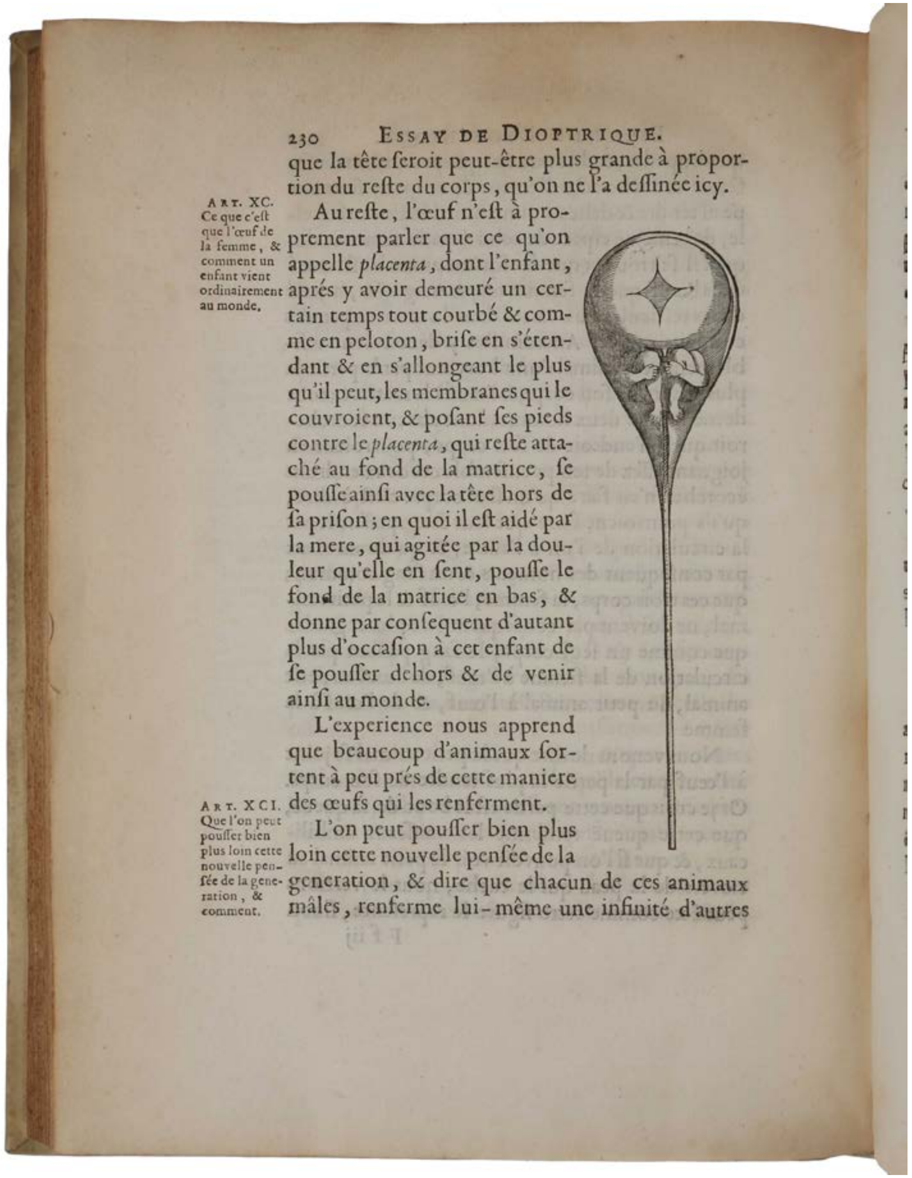
Art. X. Raiſon pourquoi les objets ne nous doivent pas paroître doubles quoiqu'ils tracent leurs images dans le fond de chacun de nos yeux.

L ij

For instance, be believed "that each worm that one sees in the semen of birds encloses actually a male or female [organism] of the same species" as the parent. He presupposed "the same thing of the … [little animals] that there are found in the semen of men and quadrupeds." Namely, "each animalcule contains and for the moment conceals … either a male or female animal from the same species."

"In his *Essay de dioptrique*, Hartsoeker speculated that for man, the spermatic animalcule would look a "little animal", popularly coined as a homunculus. That is, he only *supposed* it would resemble a tiny replica of a human being, with a head that is larger than his body, crouching in a foetal position inside the delicate membrane of the spermatozoon. Yet he never explicitly stated that he *had seen* a homunculus precisely like the one he described: it was a presumption rather than an observation …

"By 1692, Huygens was curious about Hartsoeker's philosophical ideas, all the while anticipating controversy. Huygens and Marquis de L'Hôpital remained in the know about Hartsoeker's optical and philosophical ideas throughout the 1690s … During this time, Hartsoeker persistently tried to convince Huygens of his method for grinding telescopic lenses with long focal lengths. Hartsoeker's lens making method and accompanying system of the world eventually resulted in the *Essay de dioptrique*, in which he advertised for the first time all the aforementioned observations and suppositions. Christiaan Huygens, his brother Constantijn, L'Hôpital and other savants eagerly awaited the publication of the treatise. They expected it to contain details of Hartsoeker's microscopes and, more importantly, his lens making method. L'Hôpital received the treatise with mixed feelings: on the one hand he was thrilled about its possible novelties; but on the other hand, he reacted indignantly to the ideas it contained. Although the book dealt with optics and lens manufacture, it also offered Hartsoeker's microscopical

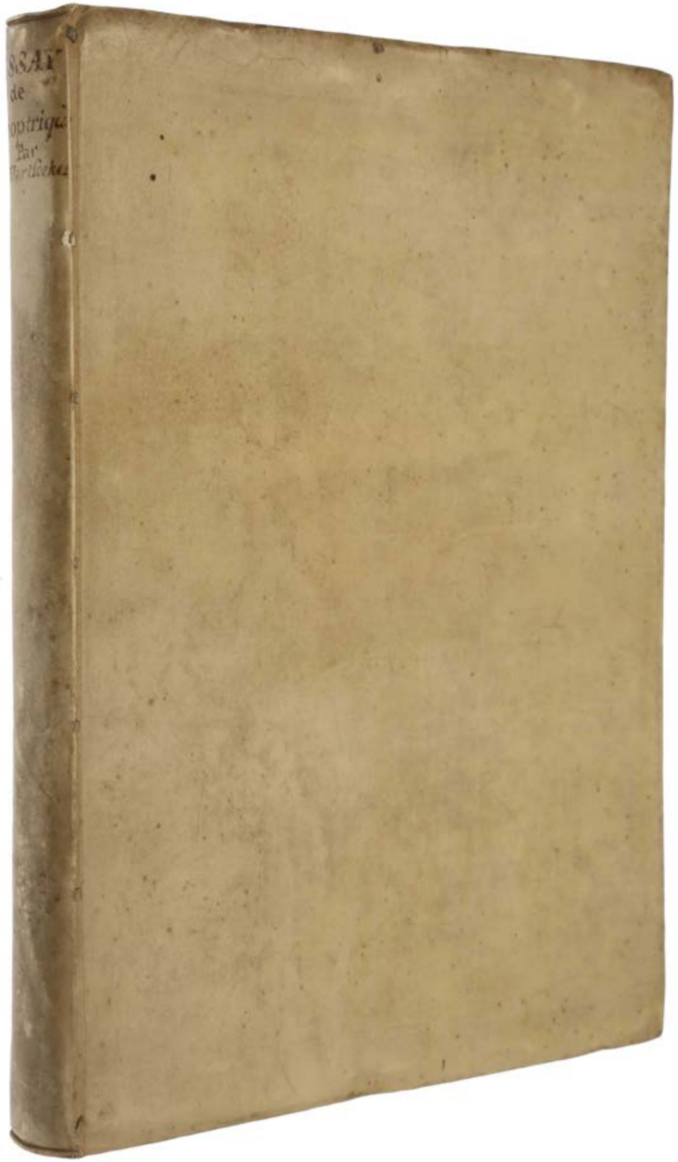


observations and ideas on generation. L'Hôpital and Huygens had looked forward to Hartsoeker's lens-making secrets with bated breath, but they did not expect him to publish his ideas on natural philosophy in the book as well … In the eyes of Huygens and L'Hôpital, [Hartsoeker] was a skilled, educated craftsman who made a living by grinding lenses for the Academy and not yet a full-fledged philosopher who could make knowledge claims about nature. What set the two men apart from Hartsoeker and his ilk even further was the importance they granted mathematics" (*ibid.*, pp. 16-19).

"Of Hartsoeker's lenses, two known to be by his hand are preserved, one signed "Nicolaas Hartsoeker, pro Academia Ludg. Batav: Parisiorum 1688" in the museum of natural history in Leiden, and the other in the museum of the University of Utrecht. It is known, however, that he made three telescopes for the Utrecht observatory at the time of Pieter van Musschenbroek's arrival in 1723.

"Hartsoeker was elected a foreign member of the Académie des Sciences in 1699 and was later also a member of the Berlin Royal Society. His work may be said to have been more honored in France than in his native Holland" (DSB).

Bierens de Haan, 1925; British Optical Association Library I, 91; Hirsch III, 77; Poggendorff I, 1026; Wellcome II, 217. Abou-Nemeh, 'The Natural Philosopher and the Microscope: Nicolas Hartsoeker Unravels Nature's "Admirable Œconomy"', *History of Science* 51 (2015), pp. 1-32.



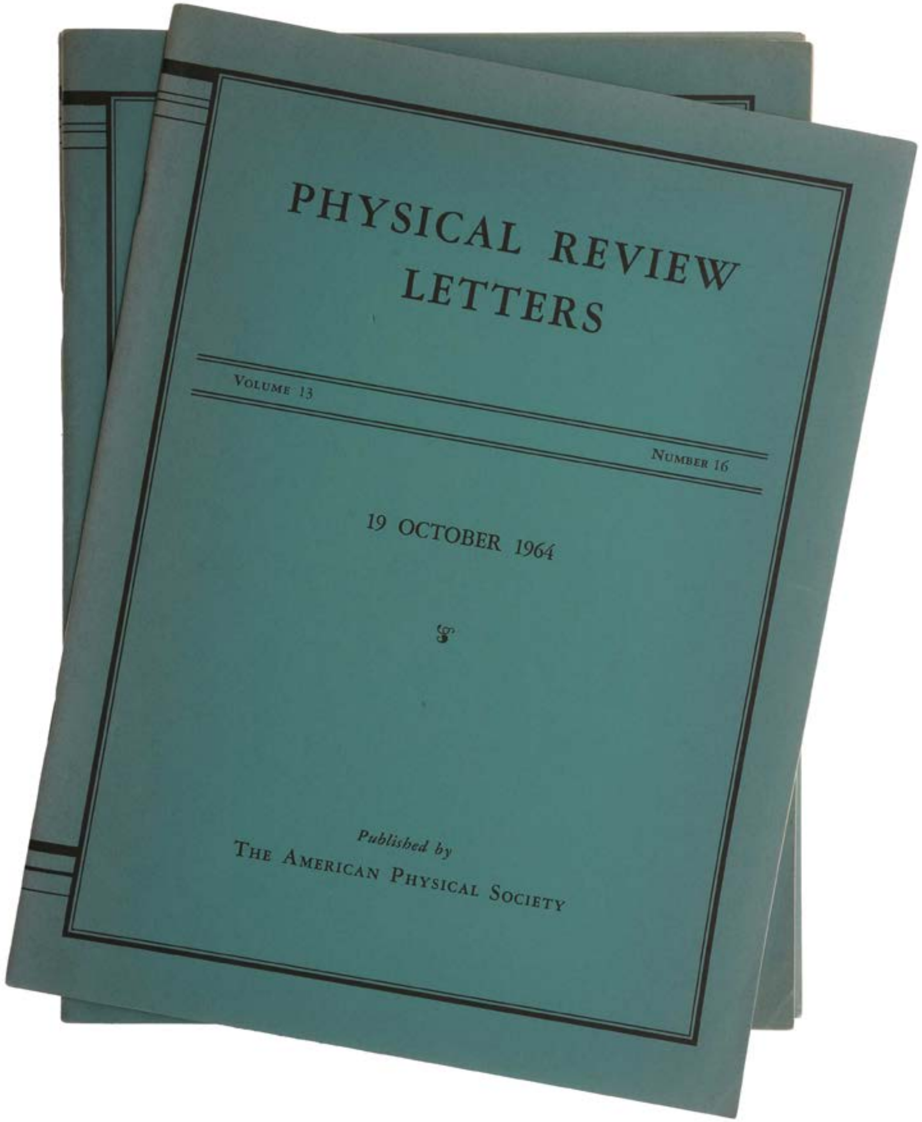
THE HIGGS BOSON AND HIGGS MECHANISM

HIGGS, Peter. 'Broken Symmetries and the Masses of Gauge Bosons,' pp. 508-9 in *Physical Review Letters*, Vol. 13, No. 16, 19 October 1964. [Offered with:] **ENGLERT, François & BROUT, Robert.** 'Broken Symmetry and the Mass of Gauge Vector Mesons,' pp. 321-3 in *ibid.*, Vol. 13, No. 9, 31 August 1964. [Offered with:] **GURALNIK, Gerald, HAGEN, Carl & and KIBBLE, Tom.** 'Global Conservation Laws and Massless Particles,' pp. 585-587 in *ibid.*, Vol. 13, No. 20,

16 November 1964. New York: The American Physical Society, 1964.

$5,500

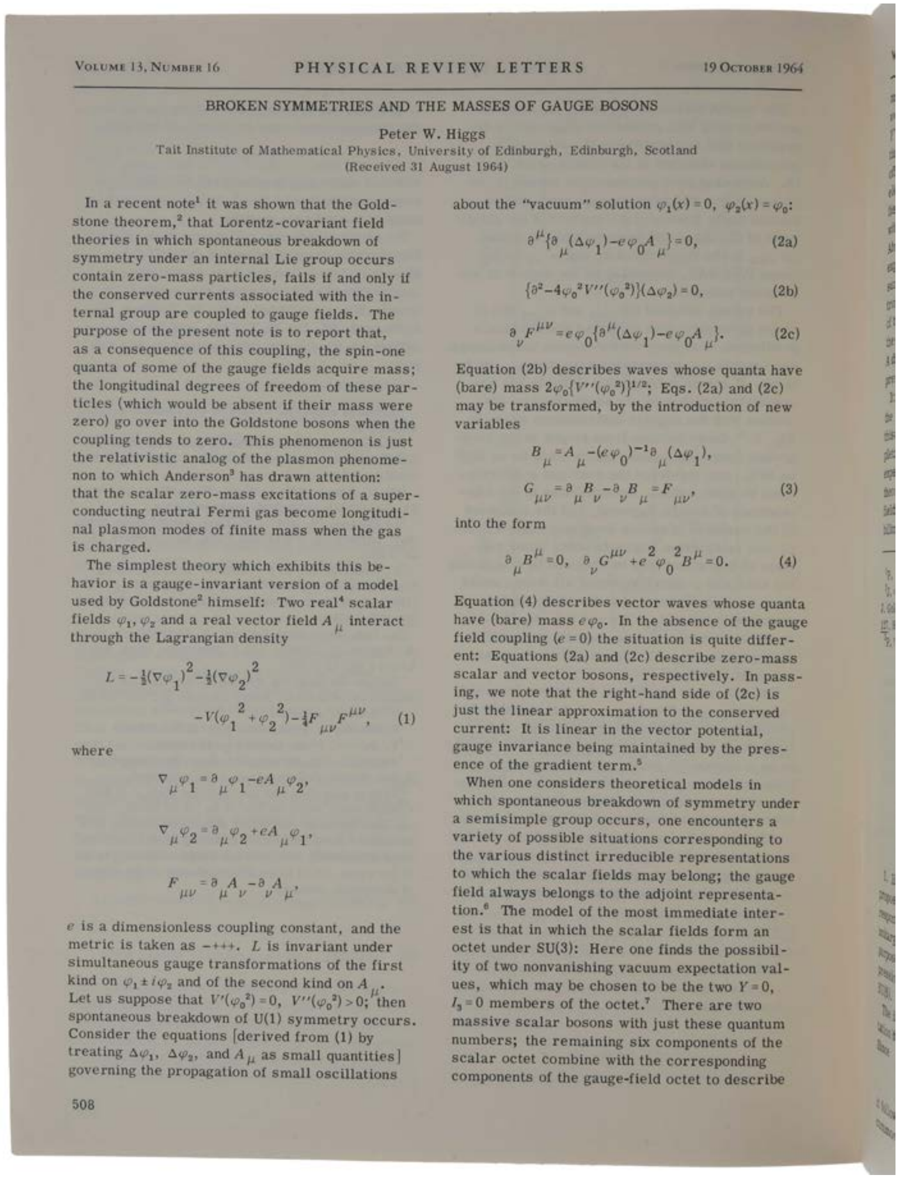
Three vols, 8vo (267 x 199 mm).Original printed wrappers (former owners' address labels on rear covers, No. 20 with some damp-staining to outer edges of rear cover).



First editions of the first published papers to propose the existence of what are now known as the 'Higgs mechanism' and the 'Higgs boson', "the key element of the electroweak theory that forms part of the Standard Model of particle physics, and of many models, such as the Grand Unified Theory, that go beyond it" (http://en.wikipedia.org/wiki/1964_PRL_symmetry_breaking_papers). All three papers introduce a version of the Higgs mechanism, that of Englert & Brout being the first to appear, but only Higgs' paper took the further step of predicting the existence of the Higgs boson. In 2013 Englert and Higgs received the Nobel Prize in Physics "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which was recently confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider" (Brout could not be awarded the prize as he had passed away in 2011).

"Particle physicists study matter made from fundamental particles whose interactions are mediated by exchange particles known as force carriers. At the beginning of the 1960s a number of these particles had been discovered or proposed, along with theories suggesting how they relate to each other, some of which had already been reformulated as field theories in which the objects of study are not particles and forces, but quantum fields and their symmetries. However, attempts to unify known fundamental forces such as the electromagnetic force and the weak nuclear force were known to be incomplete … Goldstone's theorem … also appeared to rule out many obvious solutions, since it appeared to show that zero-mass particles would have to exist that were "simply not seen."

"The Higgs mechanism is a process by which vector bosons can get rest mass *without* explicitly breaking gauge invariance, as a byproduct of spontaneous symmetry breaking. The mathematical theory behind spontaneous symmetry breaking was initially conceived and published within particle physics by Yoichiro Nambu in 1960, the concept that such a mechanism could offer a possible solution for the "mass problem" was originally suggested in 1962 by Phillip Anderson, and Abraham Klein and Benjamin Lee showed in March 1964 that Goldstone's theorem could be avoided this way in at least some non-relativistic cases and speculated it might be possible in truly relativistic cases. These approaches were quickly developed into a full relativistic model, independently and almost simultaneously, by three groups of physicists: by François Englert and Robert Brout in August 1964; by Peter Higgs in October 1964; and by Gerald Guralnik,



VOLUME 13, NUMBER 16 PHYSICAL REVIEW LETTERS 19 OCTOBER 1964

BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

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(Received 31 August 1964)

In a recent note[1] it was shown that the Goldstone theorem,[2] that Lorentz-covariant field theories in which spontaneous breakdown of symmetry under an internal Lie group occurs contain zero-mass particles, fails if and only if the conserved currents associated with the internal group are coupled to gauge fields. The purpose of the present note is to report that, as a consequence of this coupling, the spin-one quanta of some of the gauge fields acquire mass; the longitudinal degrees of freedom of these particles (which would be absent if their mass were zero) go over into the Goldstone bosons when the coupling tends to zero. This phenomenon is just the relativistic analog of the plasmon phenomenon to which Anderson[3] has drawn attention: that the scalar zero-mass excitations of a superconducting neutral Fermi gas become longitudinal plasmon modes of finite mass when the gas is charged.

The simplest theory which exhibits this behavior is a gauge-invariant version of a model used by Goldstone[2] himself: Two real[4] scalar fields φ_1, φ_2 and a real vector field A_μ interact through the Lagrangian density

$$L = -\tfrac{1}{2}(\nabla\varphi_1)^2 - \tfrac{1}{2}(\nabla\varphi_2)^2 - V(\varphi_1^2+\varphi_2^2) - \tfrac{1}{4}F_{\mu\nu}F^{\mu\nu}, \qquad (1)$$

where

$$\nabla_\mu\varphi_1 = \partial_\mu\varphi_1 - eA_\mu\varphi_2,$$

$$\nabla_\mu\varphi_2 = \partial_\mu\varphi_2 + eA_\mu\varphi_1,$$

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu,$$

e is a dimensionless coupling constant, and the metric is taken as $-+++$. L is invariant under simultaneous gauge transformations of the first kind on $\varphi_1 \pm i\varphi_2$ and of the second kind on A_μ. Let us suppose that $V'(\varphi_0^2)=0$, $V''(\varphi_0^2)>0$; then spontaneous breakdown of U(1) symmetry occurs. Consider the equations [derived from (1) by treating $\Delta\varphi_1$, $\Delta\varphi_2$, and A_μ as small quantities] governing the propagation of small oscillations about the "vacuum" solution $\varphi_1(x)=0$, $\varphi_2(x)=\varphi_0$:

$$\partial^\mu\{\partial_\mu(\Delta\varphi_1) - e\varphi_0 A_\mu\} = 0, \qquad (2a)$$

$$\{\partial^2 - 4\varphi_0^2 V''(\varphi_0^2)\}(\Delta\varphi_2) = 0, \qquad (2b)$$

$$\partial_\nu F^{\mu\nu} = e\varphi_0\{\partial^\mu(\Delta\varphi_1) - e\varphi_0 A^\mu\}. \qquad (2c)$$

Equation (2b) describes waves whose quanta have (bare) mass $2\varphi_0\{V''(\varphi_0^2)\}^{1/2}$; Eqs. (2a) and (2c) may be transformed, by the introduction of new variables

$$B_\mu = A_\mu - (e\varphi_0)^{-1}\partial_\mu(\Delta\varphi_1),$$

$$G_{\mu\nu} = \partial_\mu B_\nu - \partial_\nu B_\mu = F_{\mu\nu}, \qquad (3)$$

into the form

$$\partial_\mu B^\mu = 0, \quad \partial_\nu G^{\mu\nu} + e^2\varphi_0^2 B^\mu = 0. \qquad (4)$$

Equation (4) describes vector waves whose quanta have (bare) mass $e\varphi_0$. In the absence of the gauge field coupling ($e=0$) the situation is quite different: Equations (2a) and (2c) describe zero-mass scalar and vector bosons, respectively. In passing, we note that the right-hand side of (2c) is just the linear approximation to the conserved current: It is linear in the vector potential, gauge invariance being maintained by the presence of the gradient term.[5]

When one considers theoretical models in which spontaneous breakdown of symmetry under a semisimple group occurs, one encounters a variety of possible situations corresponding to the various distinct irreducible representations to which the scalar fields may belong; the gauge field always belongs to the adjoint representation.[6] The model of the most immediate interest is that in which the scalar fields form an octet under SU(3): Here one finds the possibility of two nonvanishing vacuum expectation values, which may be chosen to be the two $Y=0$, $I_3=0$ members of the octet.[7] There are two massive scalar bosons with just these quantum numbers; the remaining six components of the scalar octet combine with the corresponding components of the gauge-field octet to describe

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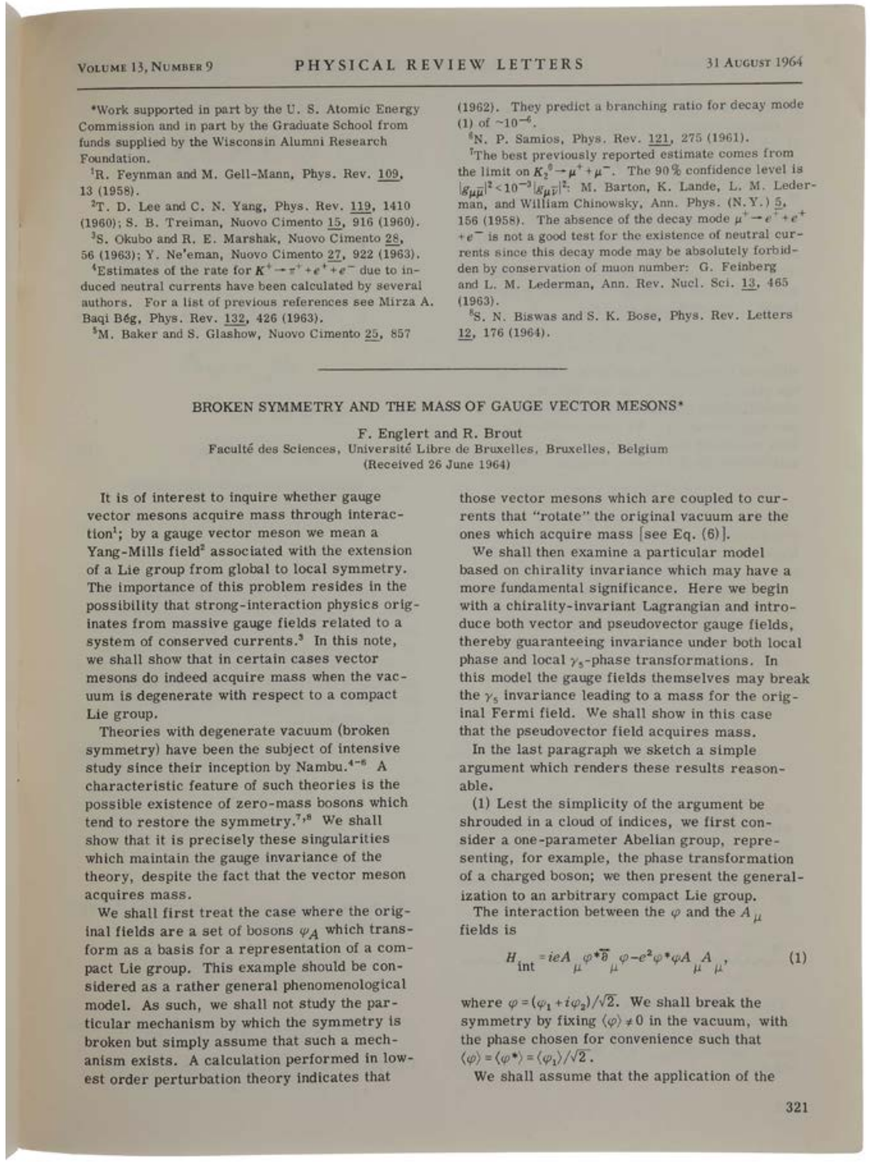
Carl Hagen and Tom Kibble in November 1964" (http://en.wikipedia.org/wiki/1964_PRL_symmetry_breaking_papers).

Higgs' paper was completed on 31 July 1964 and submitted to *Physics Letters*; it was rejected, "the editor saying 'If you develop this work and write a longer paper, you might consider sending it to *Il Nuovo Cimento*'. This suggestion carried mixed messages, as *Il Nuovo Cimento* had a reputation at that time for not using referees at all. Higgs took the first piece of advice, adding some practical consequences, which took his 'extra week'. He added some sentences at the end, alluding to the presence of scalar bosons, which together with an equation describing their behaviour form the first hints of what has become known as the Higgs boson. Feeling that *Physics Letters* was unreceptive, and dis-favouring *Il Nuovo Cimento*, Higgs then sent this revised paper to *Physical Review Letters* …

"In another of the coincidences in this tale, the editor of *Physical Review Letters* received Higgs' manuscript on the very same day that Brout and Englert's paper was published. When Higgs' paper finally appeared in print, on 19 October, Brout and Englert were surprised to see that it included a reference to their own: "He couldn't have seen our paper, so how did he know of it?" Higgs explained: Nambu had been the referee of both papers and "had drawn attention to the work of Brout and Englert. I added a remark about their work." Their researches were truly independent …

"There is no dispute that Brout and Englert were first to complete, and first to publish. So why is it that Higgs' name is associated with the massive boson and not those of Englert or Brout? The answer is that so far everyone had been addressing what happened to Goldstone's massless boson. However, there remained the issue of Goldstone's other massive boson. This is what Higgs had uniquely included in his revised paper, the one that appeared in *Physical Review Letters*" (Close, pp.



Volume 13, Number 9 PHYSICAL REVIEW LETTERS 31 August 1964

*Work supported in part by the U. S. Atomic Energy Commission and in part by the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation.

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BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

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(Received 26 June 1964)

It is of interest to inquire whether gauge vector mesons acquire mass through interaction[1]; by a gauge vector meson we mean a Yang-Mills field[2] associated with the extension of a Lie group from global to local symmetry. The importance of this problem resides in the possibility that strong-interaction physics originates from massive gauge fields related to a system of conserved currents.[3] In this note, we shall show that in certain cases vector mesons do indeed acquire mass when the vacuum is degenerate with respect to a compact Lie group.

Theories with degenerate vacuum (broken symmetry) have been the subject of intensive study since their inception by Nambu.[4-6] A characteristic feature of such theories is the possible existence of zero-mass bosons which tend to restore the symmetry.[7,8] We shall show that it is precisely these singularities which maintain the gauge invariance of the theory, despite the fact that the vector meson acquires mass.

We shall first treat the case where the original fields are a set of bosons φ_A which transform as a basis for a representation of a compact Lie group. This example should be considered as a rather general phenomenological model. As such, we shall not study the particular mechanism by which the symmetry is broken but simply assume that such a mechanism exists. A calculation performed in lowest order perturbation theory indicates that those vector mesons which are coupled to currents that "rotate" the original vacuum are the ones which acquire mass [see Eq. (6)].

We shall then examine a particular model based on chirality invariance which may have a more fundamental significance. Here we begin with a chirality-invariant Lagrangian and introduce both vector and pseudovector gauge fields, thereby guaranteeing invariance under both local phase and local γ_5-phase transformations. In this model the gauge fields themselves may break the γ_5 invariance leading to a mass for the original Fermi field. We shall show in this case that the pseudovector field acquires mass.

In the last paragraph we sketch a simple argument which renders these results reasonable.

(1) Lest the simplicity of the argument be shrouded in a cloud of indices, we first consider a one-parameter Abelian group, representing, for example, the phase transformation of a charged boson; we then present the generalization to an arbitrary compact Lie group.

The interaction between the φ and the A_μ fields is

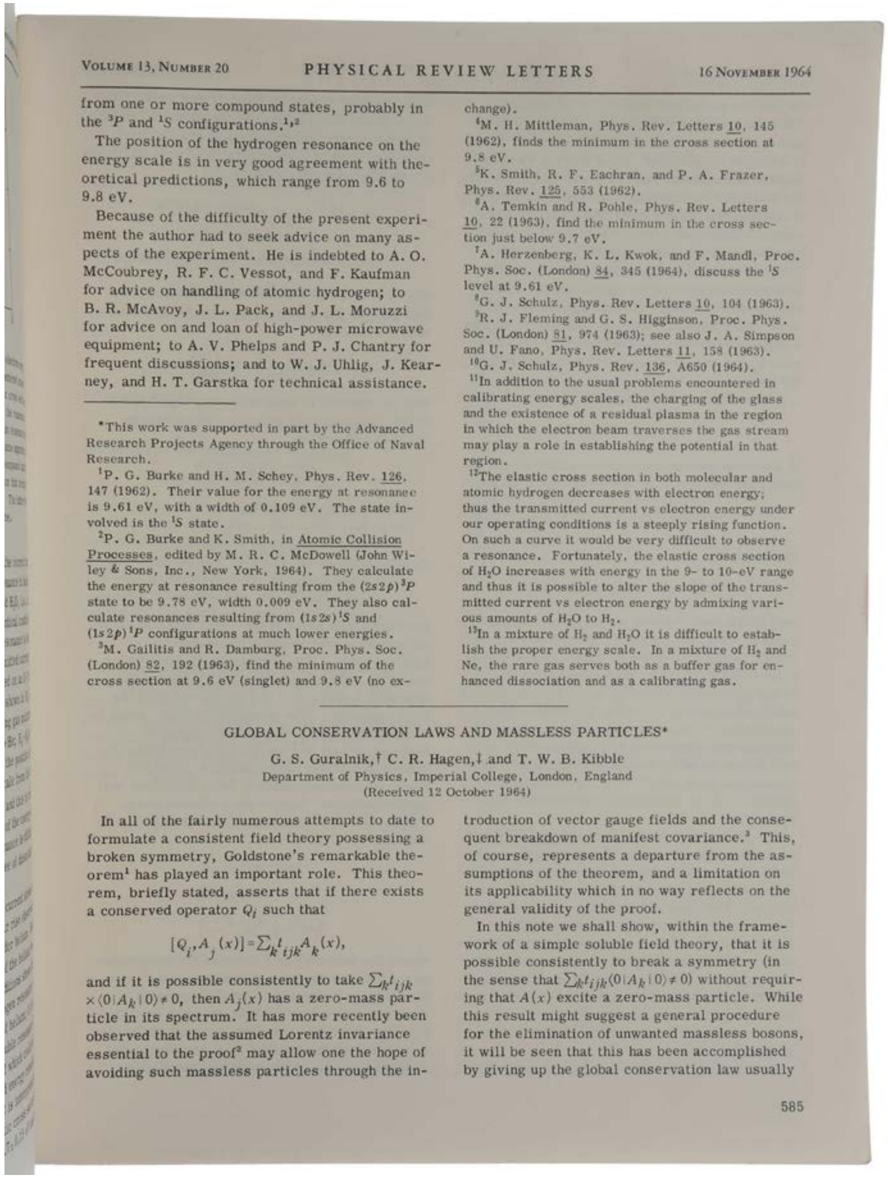
$$H_{\text{int}} = ieA_\mu \varphi^* \overleftrightarrow{\partial}_\mu \varphi - e^2 \varphi^* \varphi A_\mu A_\mu, \tag{1}$$

where $\varphi = (\varphi_1 + i\varphi_2)/\sqrt{2}$. We shall break the symmetry by fixing $\langle\varphi\rangle \neq 0$ in the vacuum, with the phase chosen for convenience such that $\langle\varphi\rangle = \langle\varphi^*\rangle = \langle\varphi_1\rangle/\sqrt{2}$.

We shall assume that the application of the

161-3). "Within the community of particle physicists it is Higgs' name that is freely associated with the "Boson that has been named after [him]." That is how it is likely to remain" (Close, p. 168).

Guralnik, Hagen and Kibble, all then at Imperial College, London, had been working independently on the same problem as Brout & Englert and Higgs, and received copies of their papers just as they were about to send their own paper to *Physical Review Letters*. "Guralnik, Hagen and Kibble's work was tightly argued, and contained unique insights towards understanding the depth of these new ideas. However, the sad fact was that they had been scooped. They added references to those papers into the text, but changed nothing, nor did they add anything as a result of what had happened. They sent the manuscript to *Physical Review Letters*, where it was received on 12 October I964 … There is no massive 'Higgs boson' in their paper" (Close, p. 150). Frank Close, *The Infinity Puzzle*, 2011.



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from one or more compound states, probably in the ^3P and ^1S configurations.[1,2]

The position of the hydrogen resonance on the energy scale is in very good agreement with theoretical predictions, which range from 9.6 to 9.8 eV.

Because of the difficulty of the present experiment the author had to seek advice on many aspects of the experiment. He is indebted to A. O. McCoubrey, R. F. C. Vessot, and F. Kaufman for advice on handling of atomic hydrogen; to B. R. McAvoy, J. L. Pack, and J. L. Moruzzi for advice on and loan of high-power microwave equipment; to A. V. Phelps and P. J. Chantry for frequent discussions; and to W. J. Uhlig, J. Kearney, and H. T. Garstka for technical assistance.

*This work was supported in part by the Advanced Research Projects Agency through the Office of Naval Research.

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[3]M. Gailitis and R. Damburg, Proc. Phys. Soc. (London) 82, 192 (1963), find the minimum of the cross section at 9.6 eV (singlet) and 9.8 eV (no exchange).

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[9]R. J. Fleming and G. S. Higginson, Proc. Phys. Soc. (London) 81, 974 (1963); see also J. A. Simpson and U. Fano, Phys. Rev. Letters 11, 158 (1963).

[10]G. J. Schulz, Phys. Rev. 136, A650 (1964).

[11]In addition to the usual problems encountered in calibrating energy scales, the charging of the glass and the existence of a residual plasma in the region in which the electron beam traverses the gas stream may play a role in establishing the potential in that region.

[12]The elastic cross section in both molecular and atomic hydrogen decreases with electron energy; thus the transmitted current vs electron energy under our operating conditions is a steeply rising function. On such a curve it would be very difficult to observe a resonance. Fortunately, the elastic cross section of H_2O increases with energy in the 9- to 10-eV range and thus it is possible to alter the slope of the transmitted current vs electron energy by admixing various amounts of H_2O to H_2.

[13]In a mixture of H_2 and H_2O it is difficult to establish the proper energy scale. In a mixture of H_2 and Ne, the rare gas serves both as a buffer gas for enhanced dissociation and as a calibrating gas.

GLOBAL CONSERVATION LAWS AND MASSLESS PARTICLES*

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(Received 12 October 1964)

In all of the fairly numerous attempts to date to formulate a consistent field theory possessing a broken symmetry, Goldstone's remarkable theorem[1] has played an important role. This theorem, briefly stated, asserts that if there exists a conserved operator Q_i such that

$$[Q_i, A_j(x)] = \sum_k t_{ijk} A_k(x),$$

and if it is possible consistently to take $\sum_k t_{ijk} \times \langle 0|A_k|0\rangle \neq 0$, then $A_j(x)$ has a zero-mass particle in its spectrum. It has more recently been observed that the assumed Lorentz invariance essential to the proof[2] may allow one the hope of avoiding such massless particles through the introduction of vector gauge fields and the consequent breakdown of manifest covariance.[3] This, of course, represents a departure from the assumptions of the theorem, and a limitation on its applicability which in no way reflects on the general validity of the proof.

In this note we shall show, within the framework of a simple soluble field theory, that it is possible consistently to break a symmetry (in the sense that $\sum_k t_{ijk}\langle 0|A_k|0\rangle \neq 0$) without requiring that $A(x)$ excite a zero-mass particle. While this result might suggest a general procedure for the elimination of unwanted massless bosons, it will be seen that this has been accomplished by giving up the global conservation law usually

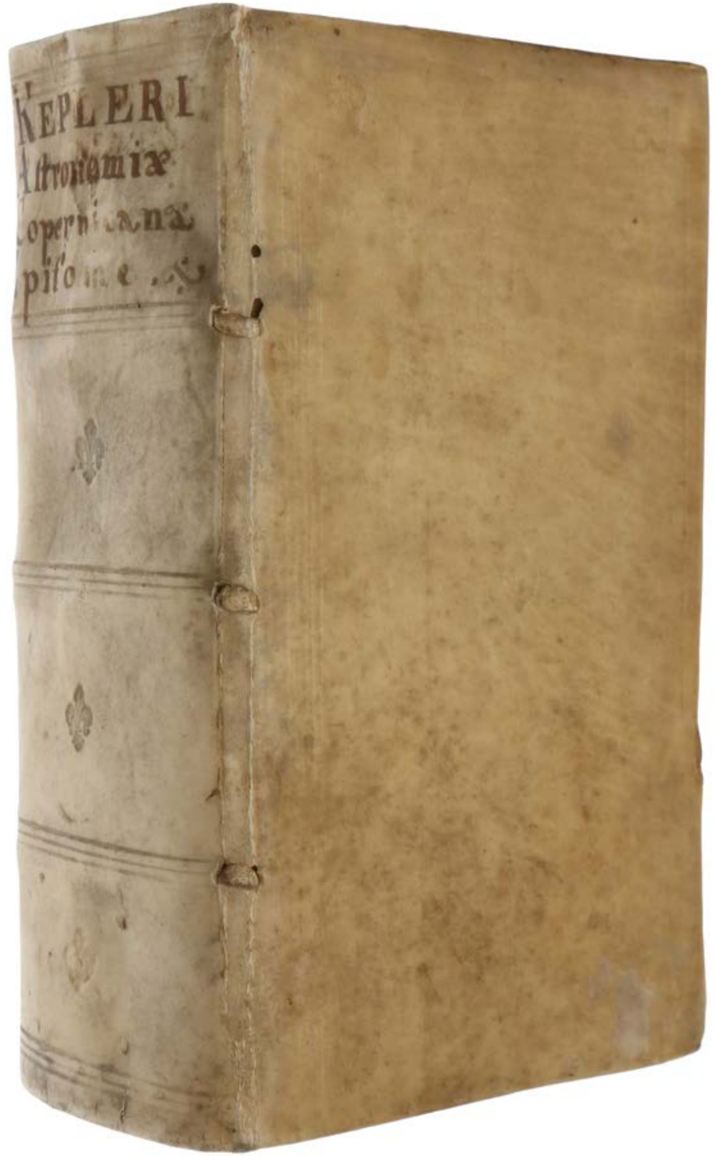
RANKS NEXT TO PTOLEMY'S ALMAGEST AND COPERNICUS' DE REVOLUTIONIBUS

KEPLER, Johannes. *Epitome astronomiae Copernicanae: usitatâ formâ quæstionum & responsionum conscripta, inque VII. libros digesta, quorum tres hi priores sunt de doctrina sphæricâ. Habes, amice lector, hac prima parte, præter physicam accuratam explicationem motus terræ diurni, ortusq[ue] ex eo circulorum sphæræ, totam doctrinam sphæricam nova & concinniori methodo, auctiorem, additis exemplis omnis generis computationum astronomicarum & geographicarum, quæ integrarum præceptionum vim sunt complexa.* Linz: Johann Planck, 1618 [Books I-III] & 1622 [Book IV]; Frankfurt: Georg Tampach, 1621 [Books V-VII].

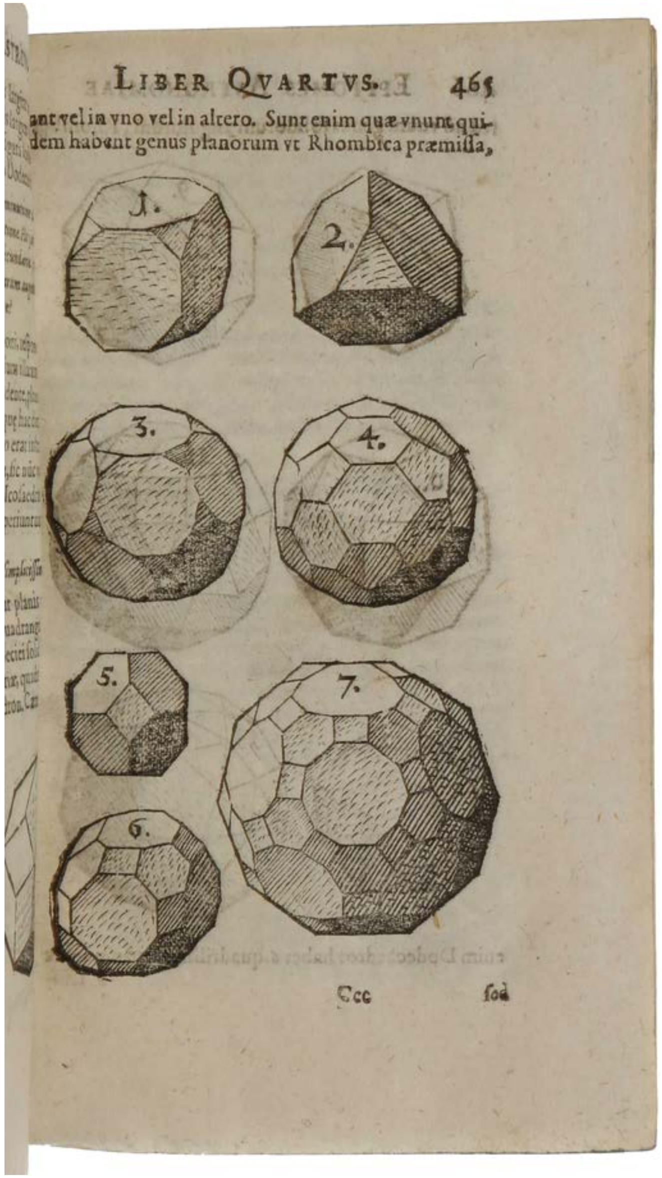
$125,000

8vo (161 x 94 mm), pp. [xxviii], 417 [recte 409], [3, blank]; [ii], 419-622, [2, errata and blank]; [xii], 641-932, [16, index], with numerous woodcut diagrams in text and one folding printed table (a few gatherings with some slight browning). Contemporary German vellum, blue edges. A large, fresh, unrestored, and attractive copy, with some lower edges uncut.

First edition, an immaculate copy, the finest we have seen, of the third of Kepler's great trilogy of astronomical treatises, following *Astronomia nova* (1609) and *Harmonice mundi* (1619), in which he introduced his three laws of planetary motion. The *Epitome* "ranks next to Ptolemy's *Almagest* and Copernicus' *De revolutionibus* … [It] is the first systematic complete presentation of astronomy



to introduce the ideas of modern celestial mechanics founded by Kepler … The title gives no inkling that Kepler had erected an entirely new structure on the foundation of the Copernican theory, that he had rescued the Copernican conception, at the time disputed and little believed, and helped it to break through by introducing his planet laws and by treating the phenomena of the motions physically" (Caspar, p. 297). "This work [the *Epitome*] would prove to be the most important theoretical resource for the Copernicans in the 17th century. Galileo and Descartes were probably influenced by it" (Britannica). Kepler "hypothesizes that force is needed to sustain motion and that hence some force must be acting on the planets. This force, he speculates, originates from the sun, can act over a vacuum, and may be magnetic. In contrast to many scientists of the time, Kepler believes much of space to be a vacuum" (Parkinson). "One important detail is Kepler's extension of his first two planetary laws to all the other planets [they originally applied only to Mars] as well as to the moon and the four satellites of Jupiter" (*Johannes Kepler Quadricentennial Celebration*, University of Texas at Austin (1971), p. 77). The *Epitome* was in seven books. "The first three books covered spherical astronomy, the fourth through sixth planetary and lunar theory, and the seventh precession and related material … The spherical astronomy of the early books was unconventional chiefly in its heliocentric, or Copernican, interpretation of the diurnal rotation of the heavens, and in its account of the likely physical causes of this motion. The later books, however, described Kepler's own theories: elliptical orbits, the area law, orbital planes passing through the center of the sun, and the various archetypal relations and physical forces underlying the structure and dynamics of the universe … This novel claim permeated the *Epitome* from beginning to end: astronomy was physics, and astronomical phenomena were best understood through mathematical study of their physical causes" (Stephenson, *Kepler's Physical Astronomy* (1987), p. 139). "The theory of the moon is easily the most original part of the *Epitome* … a subject which had occupied Kepler since the 1590s but about which he had published little prior



to the *Epitome*" (*ibid*., p. 140). Books I-III, IV and V-VII were originally issued separately and have their own title pages and imprints. In common with almost all copies, ours has the second issue of Book IV, dated 1622 rather than 1620. OCLC lists only four copies of the first issue of Book IV (none in US); only one has appeared at auction (the Richard Green copy, Christie's, 17 June 2008, lot 208, $92,500), and we know of only one other having appeared in commerce, which we handled several years ago, having acquired it from a private collector (who had himself acquired it from another collector some thirty years previously). The only other comparably fine copy on the market in recent years was that offered by W. P. Watson in Cat. 17 (2011), no. 55, for £75,000 (then about $120,000) – like our copy, Watson's had the second issue of Book IV.

"The composition of the *Epitome* was closely intertwined with the personal vicissitudes of its author's life. Although [Kepler] had been pressed for a more popular book on Copernican astronomy when his very technical *Astronomia nova* appeared, not until the spring of 1615 were the first three books ready for the printer. This part finally appeared in 1617 [but with imprint 1618], having been delayed a year because, even though he had previously signed a contract with an Augsburg publisher, Kepler wanted the work done by his new Linz printer. By that time his seventy-year-old mother had been charged with witchcraft, and the astronomer felt obliged to go to Württemberg to aid in her legal defence. Afterward, the writing of the *Harmonice mundi* interrupted progress on the *Epitome*, so that the second instalment, book IV, did not appear until 1620. The printing was barely completed when Kepler again journeyed to Württemberg, this time for the actual witchcraft trial. During pauses in the proceedings, he consulted with Maestlin at Tübingen about the lunar theory and arranged the printing of the last three books in Frankfurt. The publisher completed his work in the autumn of 1621, just as Kepler's mother won acquittal after enduring the threat of torture.


LIBER PRIMVS. 35

Si de fixis certius nihil constat, videtur illa regio infinita esse; nec Sol hic noster aliud erit, quam una ex fixis, nobis major & clarior visa, quia propior quam fixae: atque ita circa quamlibet fixam poterit esse talis mundus, qualis circa nos est; Vel, quod eodem redit, inter innumerabiles locos in illa infinita fixarum congerie, Mundus hic noster cum Sole suo erit unus, nulla re diversus à locis alijs circa fixas singulares: Vt in subjecta figura litera M.

Ita quidem Brunus & veterum aliqui. At non sequitur, si centra fixarum non sunt in eadem superficie Sphæ-ca; propterea regionem per quam sunt dispersæ fixæ, esse adiquaque sibi similem.

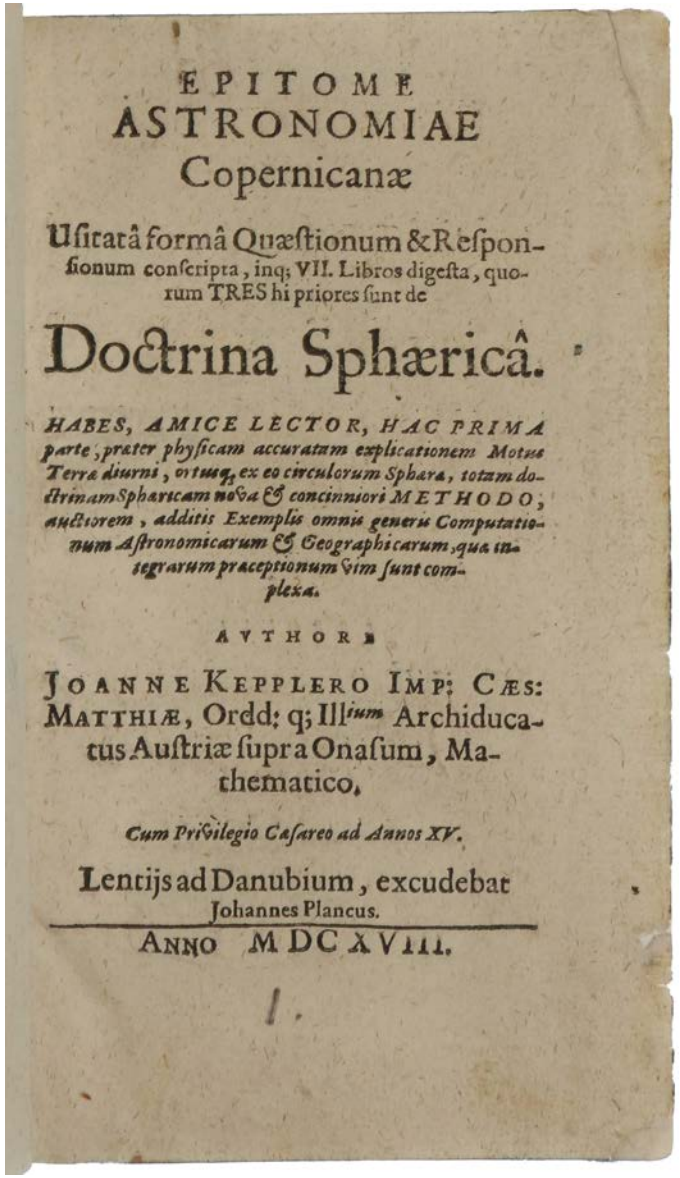
Habet enim illa omninò vacuum aliquem sinum, cavumque ingens, à fixarum agmine, confertim circumfuso,

C 2 ceu

"The first three books of this compendium deal mainly with spherical astronomy. Occasionally Kepler went beyond the conventional subject matter, considering, for example, the spatial distribution of stars and atmospheric refraction. Of special interest are the arguments for the motions of the earth; in describing the relativity of motion, he went considerably further than Copernicus and correctly formulated the principles later given more detailed treatment in Galileo's *Dialogo* (1632). Because of these arguments, and as a result of the anti-Copernican furore stirred up by Galileo's polemical writings, the *Epitome* was placed on the *Index Librorum Prohibitorum* in 1619 …

"Book IV opened with one of his favorite analogies, one that had already appeared in the *Mysterium cosmographicum* and that stressed the theological basis of his Copernicanism: The three regions of the universe were archetypal symbols of the Trinity – the center, a symbol of the Father; the outermost sphere, of the Son; and the intervening space, of the Holy Spirit. Immediately thereafter Kepler plunged into a consideration of final causes, seeking reasons for the apparent size of the sun, the length of the day, and the relative sizes and the densities of the planets. From first principles he attempted to deduce the distance of the sun by assuming that the earth's volume is to the sun's as the radius of the earth is to its distance from the sun. Nevertheless, his assumption was tempered by a perceptive examination of the observations. In their turn the nested polyhedrons, the harmonies, the magnetic forces, the elliptical orbits, and the law of areas also found their place within Kepler's astonishing organization.

"The harmonic law, which Kepler had discovered in 1619 and announced virtually without comment in the *Harmonice mundi*, received an extensive theoretical justification in the *Epitome*, book IV, part 2, section 2. His explanation of the $P \propto a^{3/2}$ law [where *P* is the period of rotation of the planet in its orbit and *a* is its mean distance from the sun], was based on the relation $P \propto (L \times M)/(S \times V)$,

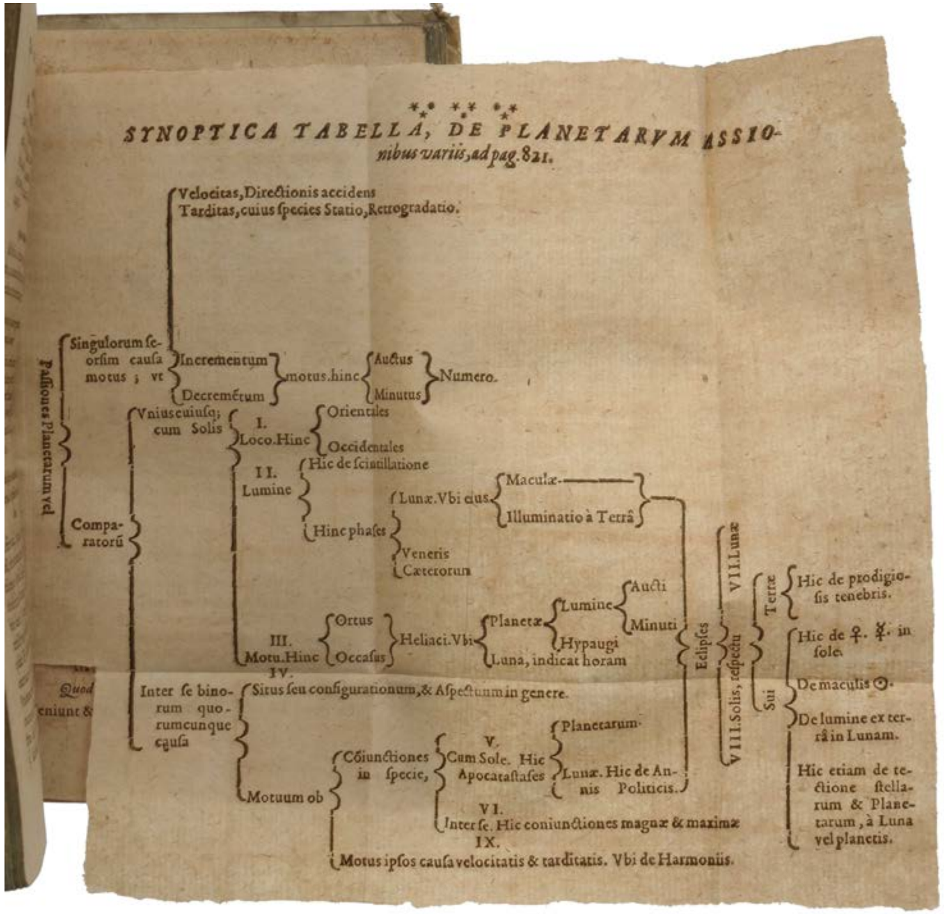


EPITOME
ASTRONOMIAE
Copernicanæ
Usitatâ formâ Quæstionum & Responsionum conscripta, inq; VII. Libros digesta, quorum TRES hi priores sunt de
Doctrina Sphæricâ.
HABES, AMICE LECTOR, HAC PRIMA parte, præter physicam accuratam explicationem Motus Terræ diurni, ortusq; ex eo circulorum Sphæræ, totam doctrinam Sphæricam nova & concinniori METHODO, auctiorem, additis Exemplis omnis generis Computationum Astronomicarum & Geographicarum, quæ integrarum præceptionum vim sunt complexa.
AVTHORE
JOANNE KEPPLERO IMP: CÆS: MATTHIÆ, Ordd: q; Ill^{ium} Archiducatus Austriæ supra Onasum, Mathematico.
Cum Privilegio Cæsareo ad Annos XV.
Lentijs ad Danubium, excudebat Johannes Plancus.
ANNO MDCXVIII.

where the longer the path length *L*, the longer the period; the greater the strength *S* of the magnetic emanation, the shorter the period (this magnetic 'species,' emitted from the sun, provided the push to the planet); the more matter *M* in the planet, the more inertia and the longer the period; the greater the volume *V* of the planet, the more magnetic emanation could be absorbed and the shorter the period. According to Kepler's distance rule, the driving force *S* was inversely proportional to the distance *a*, and hence *L/S* was proportional to a^2; thus the density *M/V* had to be proportional to $1/a^{1/2}$ in order to achieve the 3/2 power law. Consequently, he assumed that the density (as well as both *M* and *V*) of each planet depended monotonically on its distance from the sun, a requirement quite appropriate to his ideas of harmony. To a limited extent he could defend his choice of *V* from telescopic observations of planetary diameters, but generally he was obliged to fall back on vague archetypal principles.

"The lunar theory, which closed book IV of the *Epitome*, had long been a preoccupation of its author. In Tycho's original division of labor, Kepler had been assigned the orbit of Mars and [Christian] Longomontanus (1562-1647) that of the moon; but not long after Tycho's death Kepler applied his own ideas of physical causes to the lunar motion. To Longomontanus' angry remonstrance Kepler replied that it was not the same with astronomers as with smiths, where one made swords and another wagons. He believed that the moon would undergo magnetic propulsion from the sun as well as from the earth, but the complicated interrelations gave much difficulty. In 1616 Maestlin wrote to him:

'Concerning the motion of the moon, you write that you have traced all the inequalities to physical causes; I do not quite understand this. I think rather that one should leave physical causes out of account, and should explain astronomical matters only according to astronomical method with the aid of astronomical, not



physical, causes and hypotheses. That is, the calculation demands astronomical bases in the field of geometry and arithmetic …'

In other words, the circles, epicycles, and equants that Kepler had ultimately abandoned in his *Astronomia nova*.

"Kepler persisted in seeking the physical causes for the moon's motion and by 1620 had achieved the basis for his lunar tables. The fundamental form of his lunar orbit was elliptical, but the positions were further modified by the evection and by Tycho's so-called variation. Kepler's lunar theory, as given in book IV of the *Epitome*, failed to offer much foundation for further advances; nevertheless, his very early insight into the physical relation of the sun to this problem had enabled him to discover the annual equation in the lunar motion, which he handled by modifying the equation of time.

"Books V-VII of the *Epitome* dealt with practical geometrical problems arising from the elliptical orbits, the law of areas, and his lunar theory; and together with book IV they served as the theoretical explanation to the *Tabulae Rudolphinae*. Book V introduced what is now called Kepler's equation,

$E = M - e \sin E$,

where e is the orbital eccentricity, M is the mean angular motion about the sun, and E is an auxiliary angle related to M through the law of areas; Kepler named M and E the mean and the eccentric anomalies, respectively. Given E, Kepler's equation is readily solved for M; the more useful inverse problem has no closed solution in terms of elementary trigonometric functions, and he could only recommend an approximating procedure …

"Book VI of the *Epitome* treated problems of the apparent motions of the sun, the individual planets, and the moon. The short book VII discussed precession and the length of the year. To account for the changing obliquity, Kepler placed the pole of the ecliptic on a small circle, which in turn introduced a minor variation in the rate of precession (one last remnant of trepidation); because he was not satisfied with the ancient observations, he tabulated alternative rates in the *Tabulae Rudolphinae*. Such problems, he proposed, could be left to posterity "if it has pleased God to allot to the human race enough time on this earth for learning these left-over things"" (Owen Gingerich in DSB).

Johannes Kepler (1571-1630) came from a very modest family in the small German town of Weil der Stadt and was one of the beneficiaries of the ducal scholarship; it made possible his attendance at the Lutheran *Stift*, or seminary, at the University of Tübingen where he began his studies in 1589. At Tübingen, the professor of mathematics was Michael Maestlin (1550–1631), one of the most talented astronomers in Germany, and a Copernican (though a cautious one). Maestlin lent Kepler his own heavily annotated copy of *De revolutionibus,* and so while still a student, Kepler made it his mission to demonstrate rigorously Copernicus' theory.

In 1594 Kepler moved to Graz in Austria to take up a position as teacher at the Lutheran school there, and as provincial mathematician. Just over a year after arriving in Graz, Kepler discovered what he thought was the key to the universe: 'The earth's orbit is the measure of all things; circumscribe around it a dodecahedron, and the circle containing this will be Mars; circumscribe around Mars a tetrahedron, and the circle containing this will be Jupiter; circumscribe around Jupiter a cube, and the circle containing this will be Saturn. Now inscribe within the earth an icosahedron, and the circle contained in it will be Venus;

inscribe within Venus an octahedron, and the circle contained in it will be Mercury. You now have the reason for the number of planets.' This remarkable idea was published in *Mysterium cosmographicum* (1596), "the first unabashedly Copernican treatise since *De revolutionibus*" (DSB).

In place of the tradition that individual incorporeal souls push the planets and instead of Copernicus's passive, resting Sun, Kepler hypothesised that a single force from the Sun accounts for the increasingly long periods of motion as the planetary distances increase. A few years later he acquired William Gilbert's *De Magnete* (1600), and he generalized Gilbert's theory that the Earth is a magnet to the view that the universe is a system of magnetic bodies in which the rotating Sun sweeps the planets around by a magnetic force. This force, varying inversely with distance, was the major physical principle that guided Kepler's struggle to construct a better orbital theory for Mars.

The great Danish astronomer Tycho Brahe (1546–1601) had set himself the task of amassing a completely new set of planetary observations. In 1600 Tycho invited Kepler to join his court at Castle Benátky near Prague. When Tycho died suddenly in 1601, Kepler quickly succeeded him as imperial mathematician to Holy Roman Emperor Rudolf II. The relatively great intellectual freedom possible at Rudolf's court was now augmented by Kepler's unexpected inheritance of a critical resource: Tycho's observations. Without data of such precision to support his solar hypothesis, Kepler would have been unable to discover his 'first law', that Mars moves in an elliptical orbit. He published this discovery, together with his second or 'area law', that the time necessary for Mars to traverse any arc of its orbit is proportional to the area of the sector contained by the arc and the two radii from the sun, in *Astronomia nova*.

In 1611 Emperor Rudolf abdicated, and Kepler was forced to move to Linz where he was appointed district mathematician. The Linz authorities had anticipated that Kepler would use most of his time to work on and complete the astronomical tables begun by Tycho, but the work was tedious, and Kepler continued his search for the world harmonies that had inspired him since his youth. In 1619 his *Harmonice mundi*, which contained his third law, brought together more than two decades of investigations into the archetypal principles of the world: geometrical, musical, metaphysical, astrological, astronomical, and those principles pertaining to the soul. Eventually Newton would simply take over Kepler's laws while ignoring all reference to their original theological and philosophical framework.

Barchas 1147; Carli and Favaro 76 and 92; Caspar 55, 69, 66; Cinti 60, 72, 67; Houzeau & Lancaster 11831; Lalande p. 205; Parkinson 70; Zinner 4662, 4820, 4870. See PMM 112.

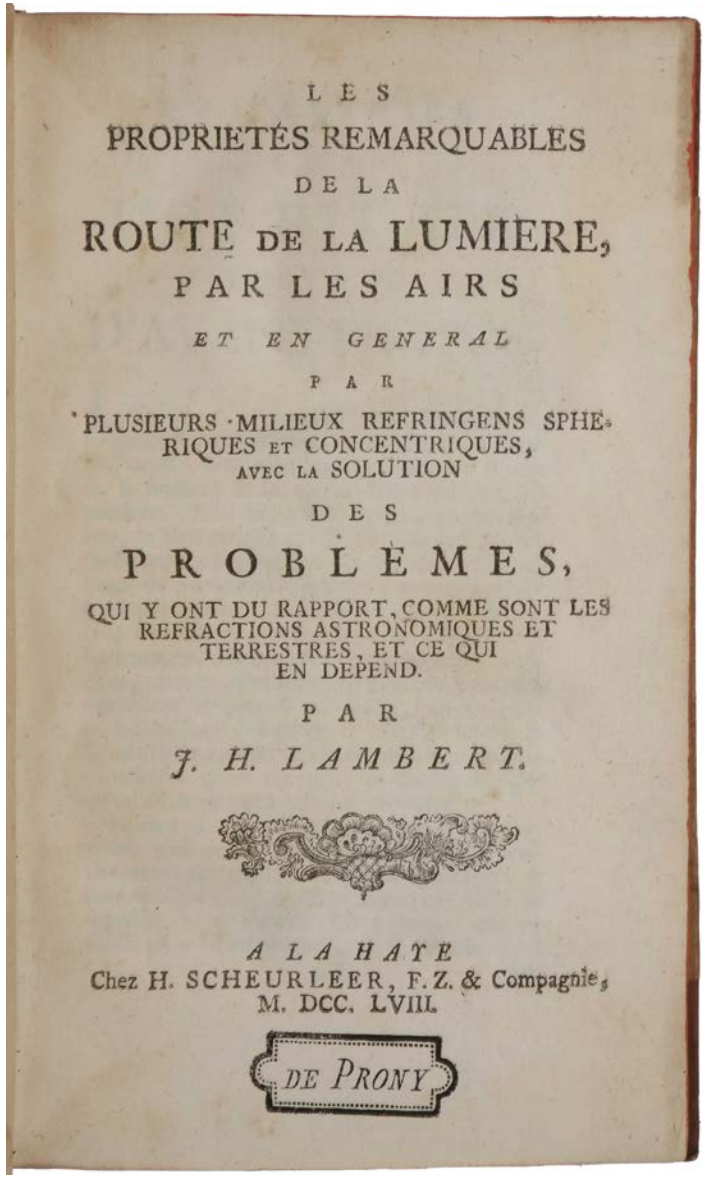
LAMBERT'S FIRST WORK ON LIGHT PUBLISHED TWO YEARS BEFORE THE PHOTOMETRIA

LAMBERT, Johann Heinrich. *Les propriétés remarquables de la route de la lumière par les airs et en général par plusieurs milieux réfringens sphériques et concentriques, avec la solution des problèmes qui y ont rapport...* The Hague: H. Scheurleer, 1758.

$25,000

8vo (196 x 117 mm), pp. 116 with two folding engraved plates. Contemporary calf, spine gilt with red lettering-piece, spine with some wear.

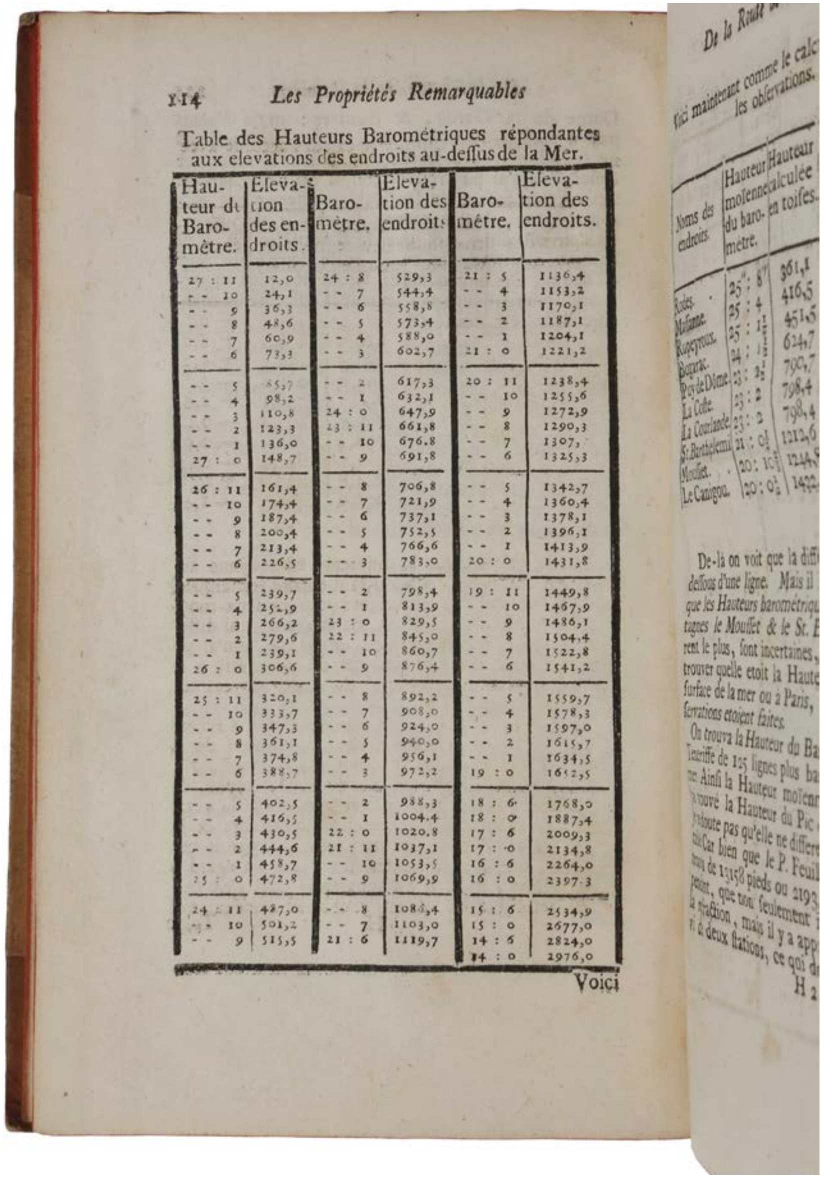
First edition, extremely rare, of Lambert's first published book, dealing with the path of light rays in air and other media. Lambert began working on aspects of refraction through the atmosphere in 1752, and from 1754 this work was carried out in parallel with his work on photometry. Lambert began the manuscript for the *Propriétés remarquables* in January 1758, and by March 1758 he had finished it and submitted it for publication in The Hague. The book is divided into three parts: 'Les propriétés générales de la route, qui la lumière prend, en passant par des milieux réfringens, sphériques et concentriques'; 'Des réfractions astronomiques, de la manière de les déterminer par approximation aussi exactement que l'on voudra, et de leur rapport à divers autres problèmes'; 'Des réfractions circulaires, de leur usage pour la détermination des réfractions terrestres: et de divers autres problèmes dépendant des réfractions tant astronomiques que terrestres'.


LES
PROPRIETÉS REMARQUABLES
DE LA
ROUTE DE LA LUMIÈRE,
PAR LES AIRS
ET EN GENERAL
PAR
PLUSIEURS MILIEUX REFRINGENS SPHERIQUES ET CONCENTRIQUES,
AVEC LA SOLUTION
DES
PROBLÈMES,
QUI Y ONT DU RAPPORT, COMME SONT LES REFRACTIONS ASTRONOMIQUES ET TERRESTRES, ET CE QUI EN DEPEND.
PAR
J. H. LAMBERT.
A LA HAYE
Chez H. SCHEURLEER, F. Z. & Compagnie,
M. DCC. LVIII.
DE PRONY

It is remarkable that during the entire period 1756-58 Lambert was traveling through northern Europe. He had with him a small library but also bought and read several additional optics books on his journey. In the *Propriétés remarquables* Lambert mentions that he is working on another work in optics and promises to publish it soon – this would eventually be his *Photometria*. In his preface to that work, Lambert notes that he has made good on his promise. The *Propriétés remarquables* was an immediate success, and was translated into German by Tempelhoff and published twice in Berlin in 1772 and 1773. This work, and his *Photometria*, undoubtedly influenced Euler, Gauss, Hamilton, Jacobi, Arago, and perhaps Fresnel and Cauchy. ABPC/RBH list no copies since the Andrade sale in 1965. COPAC lists only the Royal Society copy.

Provenance: title page with ex-libris of the great mathematician and engineer Gaspard de Prony (1755 – 1839).

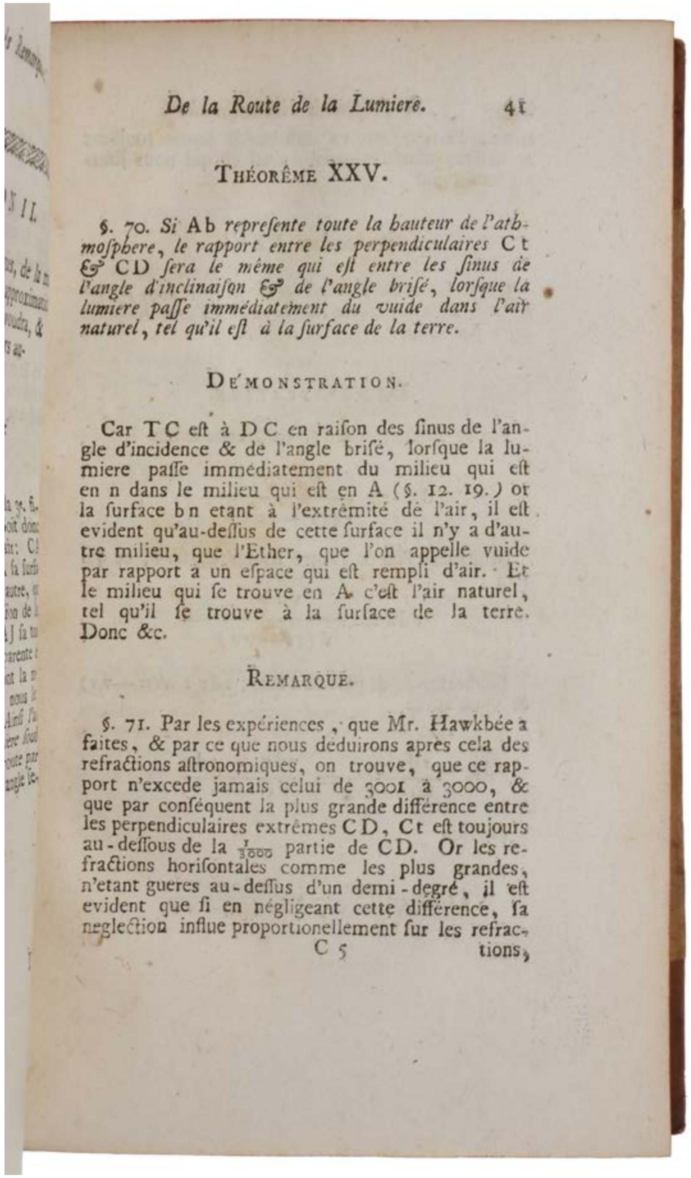
The history of the study of astronomical refraction to which the present work is devoted goes back to Tycho Brahe and Johannes Kepler. The first physical theories developed in this field are due to Thomas Simpson, who calculated the refraction in 1743 as a function of air density, and Edmund Halley, who calculated it as a function of pressure. In the foreword Lambert mentions Bouguer's *Essai d'Optique* (1729), Smith's *A Complete System of Optics* (1738), and Euler's 'Réflexion sur les différents degrés du soleil et dès autres corps célestes' (*Mémoires de l'Académie des Sciences de Berlin* 1752, pp. 280-302). However, Lambert's approach to the problem of atmospheric refraction differs entirely from Euler's. Euler attacked the physical problem in its entirety and also studied the hypotheses on the relation between temperature, pressure and density. Lambert, on the other hand, refrains from making such hypotheses and his merit is precisely to show how far we can go into this problem by using



considerations independent of any physical hypothesis, because, at the time when he wrote, scientists were far from a good understanding of thermodynamics.

Lambert undertook this work for practical applications – this was also the motivation for much of the work of many other contemporary scientists such as Euler: Lambert's theory of the refraction of light through the atmosphere served to correct astronomical observations and geodetic measurements. The organization of Lambert's book is determined by this requirement. Another characteristic feature of the work is the presentation of the theory in deductive form *more geometrico* in the Euclidean style: hypothesis, theorem, proof, corollary. Lambert limits himself to using only two 'experiments' as a starting point for his geometric reasoning. He refuses, moreover, to take into account physical relations between refraction and density. Lambert managed to avoid having to make use of such relations by assimilating the light ray to an arc of a circle whose radius he determines from observations. Although Lambert did not advance physical optics in this book, he did so two years later in the *Photometria*.

The behaviour of light rays at the boundary between two media of different refractive indices had been understood since Snel and Descartes, and is described by 'Snel's law'. In the atmosphere the refractive index of the air varies due to the varying temperature and pressure but this variation is continuous. Lambert's aim in the present work is to determine, using geometrical arguments, the path of light rays in a medium with continosly varying refractive index. He treats the case of a system of concentric spherical layers. The principal result is Theorem 7: 'for any pair of points along the ray, the ratio between the normals which go from the centre of the spheres to the tangent of the ray is constant whatever the angle of incidence'. This result is known nowadays under the name of 'Bouguer's law' – we do not know if Lambert took it from Bougeur's 1729 work or discovered it



De la Route de la Lumiere. 41

THÉORÊME XXV.

§. 70. *Si* Ab *reprefente toute la bauteur de l'atbmofphere, le rapport entre les perpendiculaires* Ct *&* CD *fera le même qui eft entre les finus de l'angle d'inclinaifon & de l'angle brifé, lorfque la lumiere paffe immédiatement du vuide dans l'air naturel, tel qu'il eft à la furface de la terre.*

DÉMONSTRATION.

Car TC eft à DC en raifon des finus de l'angle d'incidence & de l'angle brifé, lorfque la lumiere paffe immediatement du milieu qui eft en n dans le milieu qui eft en A (§. 12. 19.) or la furface bn etant à l'extrêmité de l'air, il eft evident qu'au-deffus de cette furface il n'y a d'autre milieu, que l'Ether, que l'on appelle vuide par rapport à un efpace qui eft rempli d'air. Et le milieu qui fe trouve en A c'eft l'air naturel, tel qu'il fe trouve à la furface de la terre. Donc &c.

REMARQUE.

§. 71. Par les expériences, que Mr. Hawkbée a faites, & par ce que nous deduirons apres cela des refractions aftronomiques, on trouve, que ce rapport n'excede jamais celui de 3001 à 3000, & que par conféquent la plus grande différence entre les perpendiculaires extrêmes CD, Ct eft toujours au-deffous de la $\frac{1}{3000}$ partie de CD. Or les refractions horifontales comme les plus grandes, n'etant gueres au-deffus d'un demi-degré, il eft evident que fi en négligeant cette différence, fa neglection influe proportionellement fur les refrac-

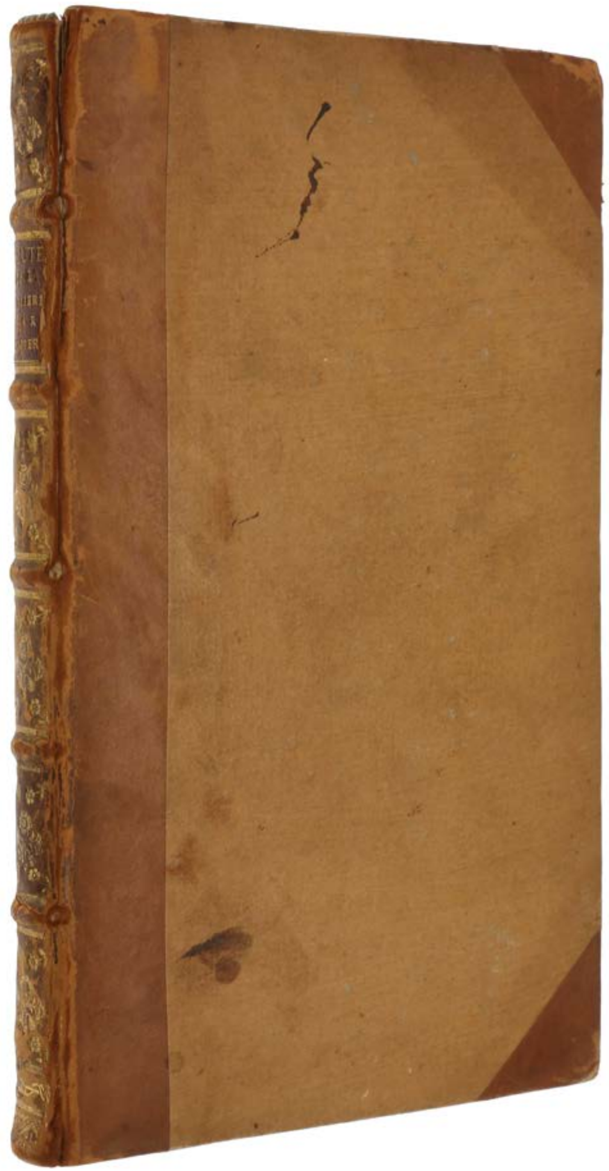
C 5 tions,

independently. Lambert deduces from it Theorem 16, in which he establishes that the locus of the centres of curvature of the trajectory of the ray lie on a straight line orthogonal to the line which passes through the centre of the spheres and the point where the ray enters the nonuniform medium (where the angle of incidence is defined). This theorem is, in the context of the optics of Hamilton-Jacobi, analogous to the conservation of angular momentum. It is used repeatedly in the sequel. In particular, Lambert shows that it can be applied to the atmosphere if one disregards the variation of the separation between the two media at the price of a minor error that decreases with the angle of incidence.

"But it is the applications that constitute the object of the second and third parts of the work. They are presented in the form of problems and to solve them Lambert once again resorts to the geometry of the circle. The starting point of his reasoning is the assimilation of the curve of the light rays to a circular arc, which is a hypothesis permitted in the particular case of atmospheric refraction. The discussion is especially detailed, and provides us with a vivid illustration of the scientific activities of the eighteenth century.

"The book testifies to the spirit of its time, using geometric methods to the very end, with the aim of reducing or eliminating the hypotheses. It would be false to say that the *Propriétés remarquables* lacks originality, but all things condidered, it is the pursuit of *classic* ideas through to their very last consequnces that characterizes the book" (Speiser & Williams, p. 247).

Speiser & Williams (eds.), *Discovering the Principles of Mechanics 1600-1800*, 2008.



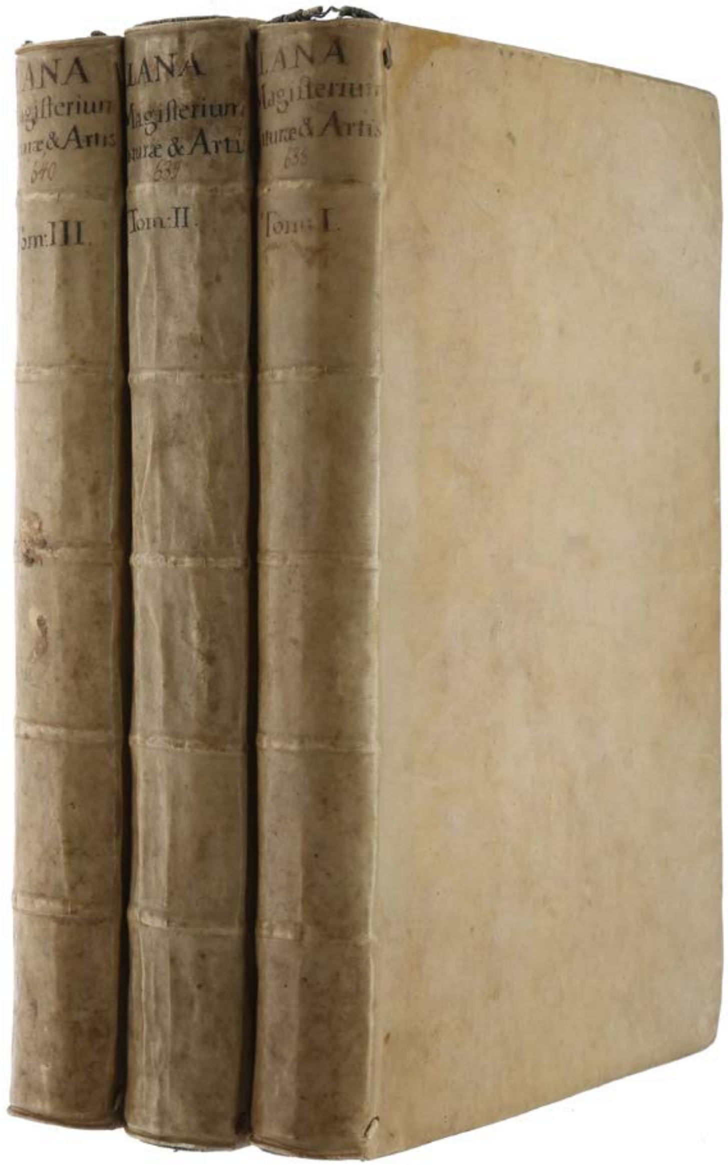
THE FINEST COPY WE HAVE SEEN

LANA TERZI, Francesco. *Magisterium naturæ et artis: opus physico-mathematicum P. Francisci Tertii de Lanis Societatis Iesu Brixiensis; in quo occultiora naturalis philosophiæ principia manifestantur, et multiplici tum experimentorum, tum demonstrationum serie comprobantur; ac demum tam antiqua pene omnia artis inuenta, quam multa noua ab ipso authore excogitata in lucem proferuntur.* Brescia; Parma: G. M. Riccardi; H. Rosati, 1684-1686; 1692.

$29,500

Three vols., folio (380 x 253 mm), pp. [xvi], 526 with 24 folding engraved plates; [xxxiv], 512, [18] with 20 folding engraved plates; [viii], 24, 571 with 13 folding engraved plates. Contemporary vellum, spines lettered in manuscript, red speckled edges.

First edition, complete with the very rare third volume, and the finest set we have seen, of Lana's *Magisterium Naturae,* a massive encyclopaedia of natural philosophy describing a myriad of topics, experiments and machines: "it would require an explanatory volume to give an idea of this work" (*Libri Catalogue*). Some of the subjects covered include hydraulics, elasticity, problems of motion and percussion, alchemical and chemical experiments, distillation, the vacuum, sound and acoustics, electricity and magnetism, meteorology, and perpetual motion. "In a word, he assembled an encyclopedia, [which includes] the most extensive and valuable account of electricity published in the seventeenth century" (Heilbron, p. 190). Thorndike (VII, p. 621 *et seq*) gives an account of "the more occult principles of natural philosophy, experimentation and demonstration" which the work contains. Originally intended to comprise nine volumes, Lana lived to complete only three, with the third volume being published posthumously.



Magisterium naturae et artis received long and flattering reviews in Germany (*Acta Eruditorum*, 1685, 31-7; 1688, 35-9; 1693, 45-50).

Franceso Lana Terzi (1631-87) entered the novitiate of the Society of Jesus in Rome on 11 November, 1647, and studied philosophy and theology at the Roman College. "While in Rome [Gaspar] Schott had helped instruct Lana, who completed his theology at the Collegio Romano in the early fifties, when [Athenasius] Kircher started to arrange the museum and Paolo Casati held the chair of mathematics there. Lana did not fail to profit from so favorable a conjunction of luminaries. He studied independently with Kircher, and, with fellow student Daniel Bartoli, assisted in the experiments of Casati. He mastered natural philosophy, but without great satisfaction, for he found its branches to be differently, even contradictorily, treated. At the conclusion of his studies, if his later testimony be credited, he decided to try to establish a complete and consistent approach to the subject, firmly based on experiment.

"The fulfillment of this design, made doubly difficult by the demands of the ordinary itinerant professorship, required almost forty years. Lana began, as was usual, by teaching humanities, probably at the Jesuit College in Terni. From there he moved to his home town, Brescia, and to philosophy, which he taught for three years and improved with experiments on the barometer; and thence to Ferrara, to [Niccolò] Cabeo's old chair of mathematics at the University. Some years later he was again in Brescia determining the declination, and then in Bologna assisting (as had Cabeo) in [Giovanni Battista] Riccioli's measurements of gravitational acceleration; and again in Ferrara, writing long letters, mainly on sound, to Bartoli. He retired to Brescia, where he founded a short-lived academy of mathematicians and natural philosophers called *Philo-exotici,* and devoted himself to completing his great work. The first volume *of Magisterium naturae et artis* left the press in 1684; the third, which was not intended as the last, followed posthumously eight years later.

"The *Magisterium* was announced in 1670 in a *Prodromo,* today remembered for its description of a balloon-like aircraft … The *Prodromo* contains proposals ingenious and impracticable, like the airship; others only impracticable, like a method of transmitting messages where neither vocal nor visible signals will do; and others both practicable and valuable, like improved techniques for writing for the blind and hints for the manufacture of lenses. Similar devices and inventions enliven the *Magisterium,* where a typical section begins with experiments, follows with principles and causes, and ends with an account of diverting, useful and instructive contrivances. Some sections, including electricity, lack the applications, but all are illustrated by experiment; for the experiments, and not their explanations, constitute the uniform approach to natural philosophy that Lana strove to attain. The design and completion of these experiments was a gigantic task. The effort involved in the *Prodromo* alone so fatigued and sickened its author that he set his great project aside. The *Physics* of [Honoré] Fabri, also intended as a uniform treatment, rekindled his ardor and ambition. Other duties, lack of assistance, and that peculiar clerical disorder, the reconciliation of the 'immodest expense' of the undertaking with a vow of religious poverty, conspired to delay his progress, and in the end prevented him from bringing to completion his *Great Guide to Nature and the Arts.*

"Lana's treatment of electricity is no discredit to his method. He announced new electrics, which, following the example of the *Accademia del Cim*ento, he compared in strength to those already established. He tested and amended the results of all previous investigators; he described delicate new experiments; and he presented fairly the theories that divided electricians. In a word, he assembled an encyclopedia, the most extensive and valuable account of electricity published in the seventeenth century …

"Lana's discussion of theory proceeds like Cabeo's. First comes the now standard ‘proof’ that electricity cannot be a sympathetic quality. Next, a string of syllogisms with the Aristotelian premises, ‘all true action of bodies consists in local motion,’ ‘no body can move itself to local motion,’ and ‘the mover must be contiguous or immediately applied to the moved,’ yields the electrical effluvium which, however, cannot be the whole story, were it as sticky as [William] Gilbert pretended. No gluey emanation, according to Lana, could cart chaff back to the electric against the opposing force of fresh effluvia. Some other agency, to wit the atmosphere, must cooperate. Like Cabeo, Lana uses the supposed absence of ‘repulsion’ – his word – to infer the intervention of the air. Lana goes a step beyond Schott by associating the action of effluvia on the air with their adhesive property. He considers electrics to be ‘igneo-sulphureous’ bodies whose emanations expand the near air by heat; at any weakening or cooling of the stream of effluvia the denser air beyond must rush in …

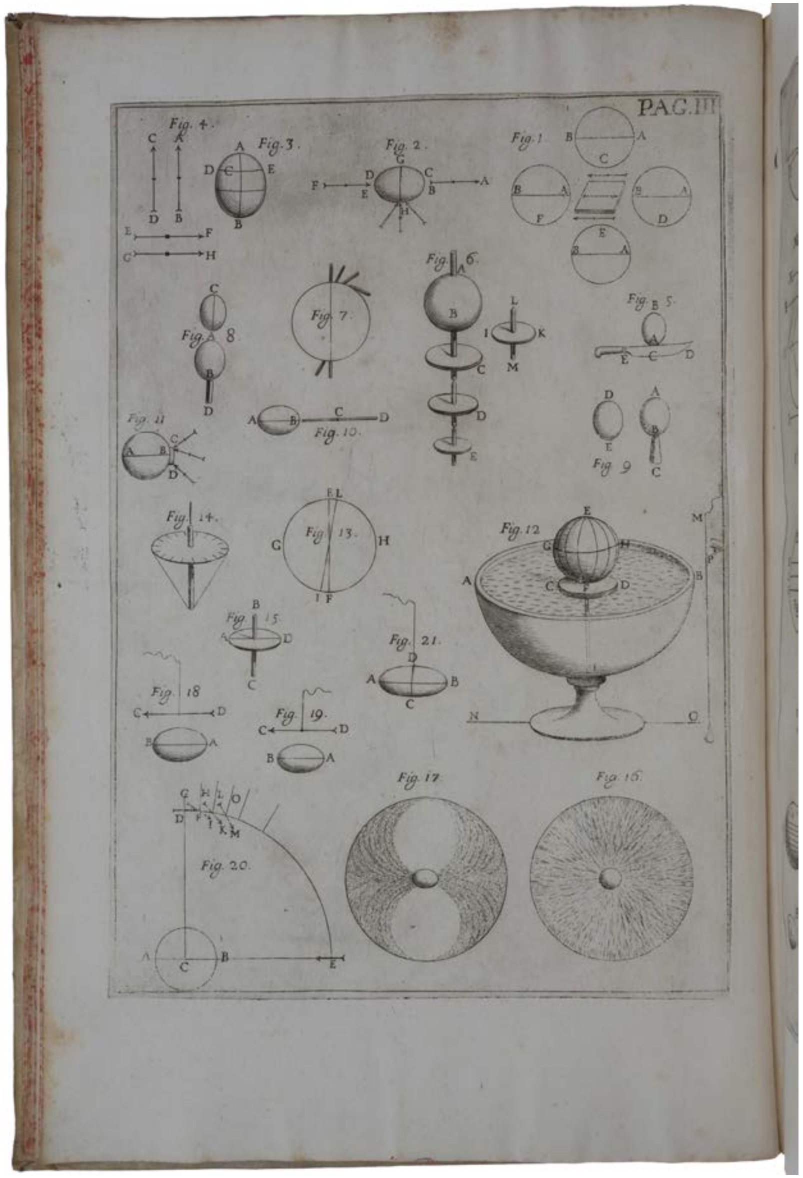
“Lana’s double-duty effluvia, which expand air and fix chaff, gave a complete and plausible account of electrical phenomena in keeping with received physics. The theory had a long life: it was primarily in Lana’s persuasive form that Schott’s compromise dominated German theory in the first decades of the eighteenth century” (Heilbron, pp. 189-92).

“The first volume of [*Magisterium*] describes Lana’s theory of dynamics and opposes the Copernican system (tract. iii, p. 409). The second volume, including chemistry, speaks of the transformation of rubies, sapphires, etc., into diamonds by means of steel filings (perhaps by heat-treatment removing the colour), the production of mercury from air (Bk. ii, p. 75), and concentrating alcohol by passing the vapour through pig’s bladder, when the phlegm is retained (Bk. i, c. 2, p. 32; this is a process mentioned by Libavius, etc., and depends on selective absorption). All sorts of tricks and wonders are described, such as sticking a needle into an arm or leg without pain (Bk. ii, p. 35). The production of water from air is

amplified from [*Prodromo*] and Lana is often quoted for this (it depended on the condensation of moisture from air on a cold vessel).

"The solidification of a mixture of concentrated solutions of calcium chloride and potassium carbonate (from precipitation of calcium carbonate), described by Lana in 1686, was known as the 'chemical miracle'; he ascribed it to Dr. Hieronymus Alegri of Verona. Lana thought some hexangular crystals found in a meadow, said to be generated from dew, were nitre (saltpeter), which he extracted from the soil, since nitre is 'the natural coagulum of water'" (Partington II, p. 334).

Caillet 6093; Heilbron, *Electricity in the 17th and 18th centuries*, 1979; Riccardi II 13 ('*importantissima opera*'); Scott Collection 143; Sommervogel IV 1442; Wheeler Gift 197.



THE DEDICATION COPY - INSCRIBED AND BOUND IN RED MOROCCO

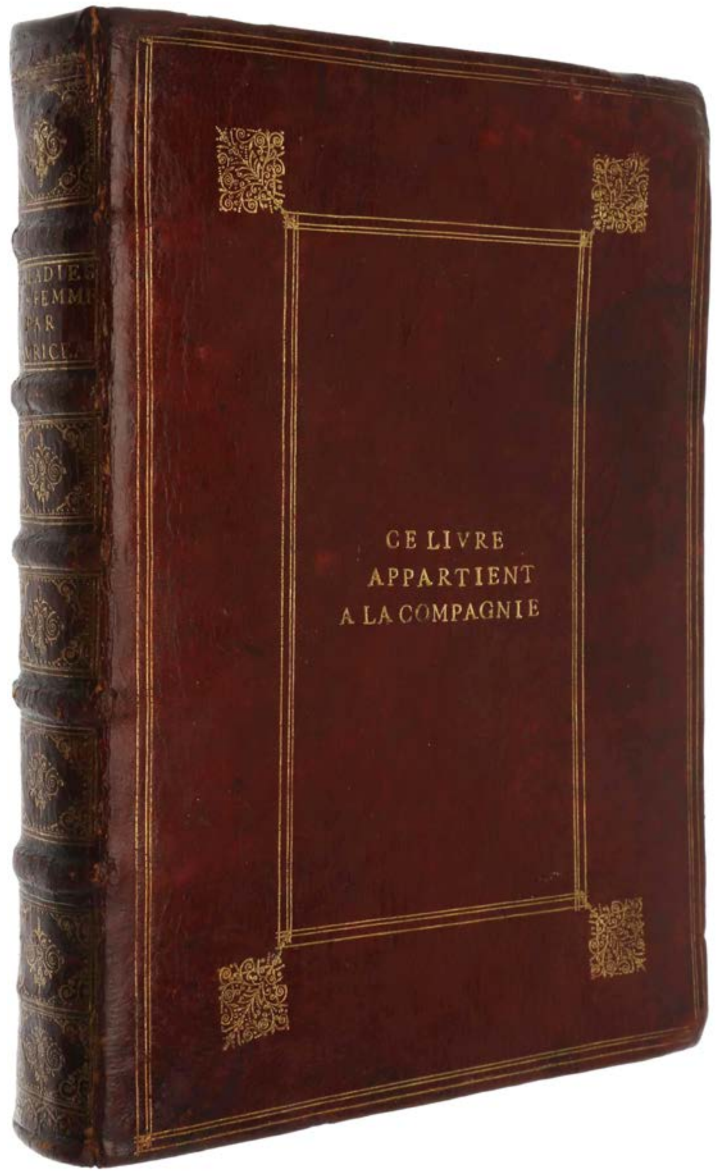
Grolier, *One Hundred Books Famous in Medicine 33; En français dans le texte* 107

MAURICEAU, François. *Des maladies des femmes grosses et accouchées. Avec la bonne et veritable méthode de les bien aider en leurs accouchemens naturels, & les moyens de remedier à tous ceux qui sont contre-nature, & aux indspositions des enfans nouveau-nés.* Paris: Chez Jean Henault, Jean d'Houry, Robert de Ninville, Jean Baptiste Coignard, 1668.

$75,000

4to (245 x 185 mm). [24, including engraved frontispiece by Guillaume Vallet after Antoine Paillet and letter-press title] 536 pp., including 11 full or nearly full-page, 15 half-page and 3 quarter page engravings in text. In a contemporary presentation binding of red morocco gilt, spine in 7 compartments richly tooled, covers triple-gilt-ruled with fleurons at corners, tooled in the center of the upper and lower covers: "Ce Livre Appartient à la Compagnie / Des Maistres Chirurgiens Iurez de Paris." Extremities and corners expertly repaired, preserved in a cloth box. Ruled in red throughout. Mauriceau's autograph cipher at the end of the printed dedication followed by three inscriptions signed by Mauriceau's cipher at the end of the printed dedication, dated 1675, 1681 and 1694. Correction in manuscript on p. 196. Some minor toning in extreme outer margin, but generally a broad-margined magnificent copy, in a splendid binding with an important historic association.

The dedication copy of the first edition of this groundbreaking medical work which "established obstetrics as a science" (G&M). This is a superb copy in a presentation binding of contemporary red morocco stamped with the name of the dedicatees—

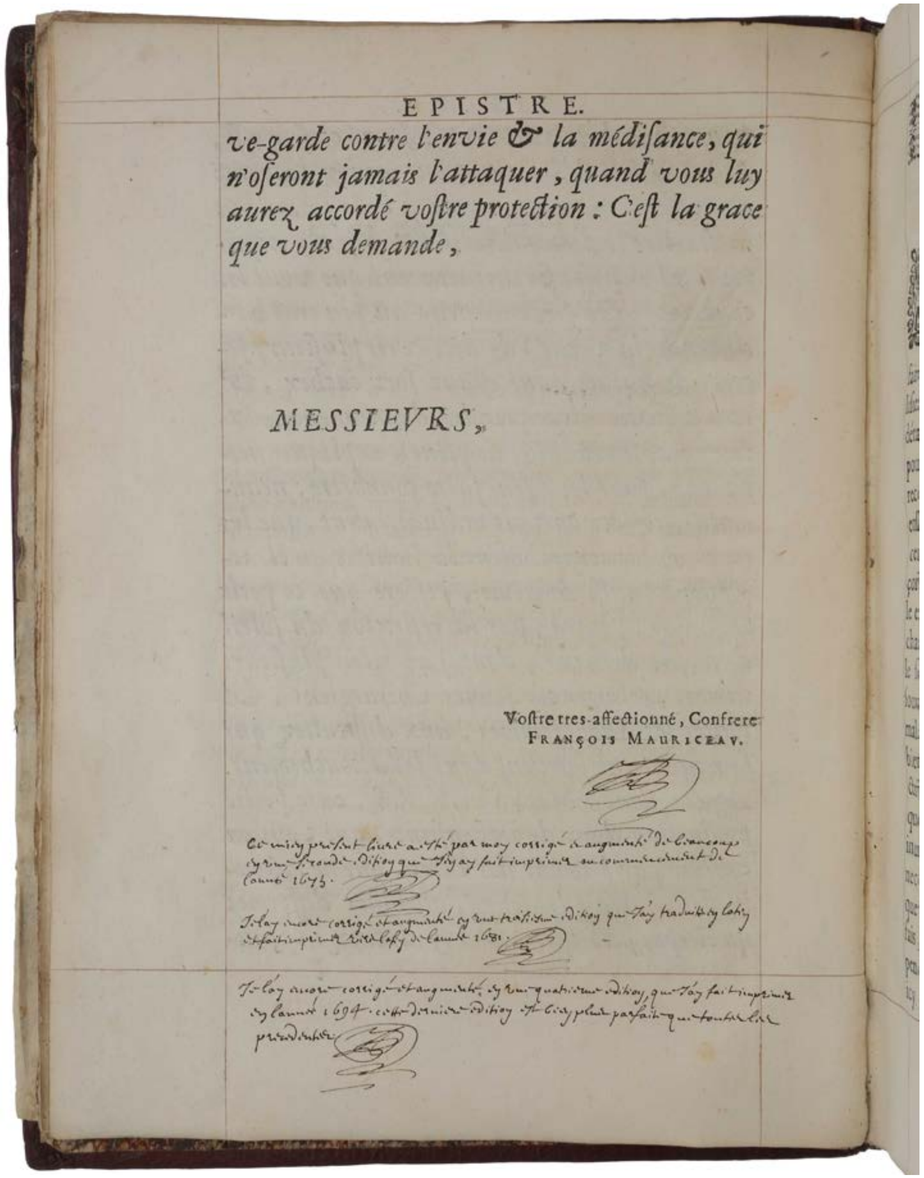


Les Maistres Chirurgiens Jurez de Paris—and with three signed inscriptions by the author at the end of the printed dedication, announcing the publication of his work's later 17th century revised editions. "This book was without question the most practical, explicit and accurate of the then known treatises on midwifery" (Cutter & Viets, *A Short History of Midwifery*, p. 51). Mauriceau was "the first to write on tubal pregnancy, epidemic puerperal fever, and the complications that arise in labor from misplacement of the umbilical cord" (Le Fanu, *Notable Medical Books from the Lilly Library*, p. 85). Mauriceau popularised the idea of delivery in bed rather than on a birth stool, and while recommending the reading of other learned authors, cautioned that "the most part of them, having never practised the art they undertake to teach, resemble…those geographers who give us the description of many countries which they never saw". "While much in Mauriceau's treatise echoed the teachings of his predecessors, the work also included several important new features, such as Mauriceau's detailed analysis of the mechanism of labor, his introduction of the practice of delivering women in bed rather than in the obstetric chair, the earliest account of the prevention of congenital syphilis by antisyphilitic treatment during pregnancy, and the rebuttal of Paré's erroneous account of pubic separation during birth" (Norman). For more than seventy years and through numerous translations and editions, *Des maladies des femmes grosses* contributed to the spread of good obstetric practice throughout Europe.

Provenance: The present copy's presentation binding testifies directly to Mauriceau's practical training in obstetrics and importance in the Parisian medical community: its covers declare its owner to be a member of Les Maîtres Chirurgiens Jurés (also known as the Confraternity of Saint-Come), the venerated guild of Paris surgeons established in the 13th century. Mauriceau's printed dedication, similarly addressed to "Mes chers Confrères," has manuscript addenda in this copy: Three inscriptions written by the author and signed with his cipher, the

first noting the publication of the corrected and augmented second edition of Des maladies des femmes in 1675, the second the publication of the third French and the first Latin editions in 1681, and the third noting the publication of the revised fourth edition “bien plus parfaite que toutes les précédentes.” It seems probable that after Mauriceau originally presented this copy to the library of the Confraternity he continued to revisit the copy on their shelves and documented, in this dedication copy of the first edition, the fact that he had continued to make improvements to his text in later editions.

“François Mauriceau had an extensive practice in midwifery in Paris, both private and in the Hotel Dieu, which was at that time the leading establishment for lying in women in Europe. In 1668, when only 31, he published his great work *Traité des Maladies des Femmes Grosses et Accouchies*, ‘which, according to Andre Levret drew from the cradle’ the art of midwifery. Two years later Mauriceau received a visit from Hugh Chamberlen, a member of the British family that possessed the secret of the obstetric forceps, who then translated his text, making it available to the English-speaking world. The influence of this work on many aspects of midwifery was immense, and Mauriceau is still remembered eponymously for his description of delivery of the after coming head in breech presentation. Mauriceau’s book also contains a section entitled ‘Of children newborn and their ordinary Distempers, together with necessary directions to chuse a Nurse’. Among the 18 chapters are ones on ‘Of cutting the Tongue when Tongue-ty’d’ and ‘How to cure the Venereal Lues in infants.’ Perhaps, though, in retrospect, his greatest impact was in the influence his advice had on the position that women should adopt during delivery. From earliest times women throughout the world had usually assumed an upright posture during parturition. In Europe, the birthing chair was particularly popular. As Atwood has written, ‘The first major obstetrical change in the position of the parturient occurred when François Mauriceau substituted the bed for the birth stool. The time honoured ‘position’ assumed in an obstetric


EPISTRE.

ve-garde contre l'envie & la médisance, qui n'oseront jamais l'attaquer, quand vous luy aurez accordé vostre protection : C'est la grace que vous demande,

MESSIEVRS,

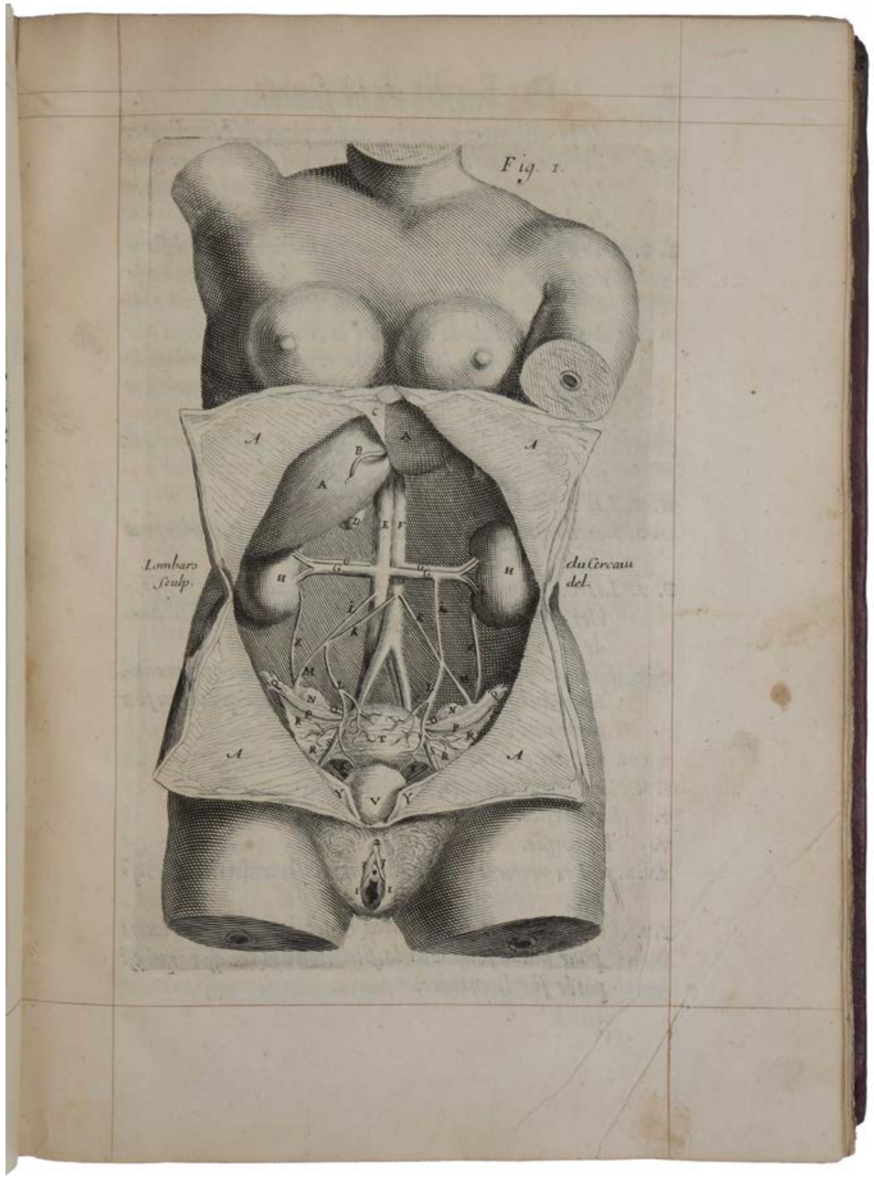
Vostre tres-affectionné, Confrere
FRANÇOIS MAURICEAV.

chair was replaced with the recumbent position to facilitate examinations and obstetric operations for the obstetrician.'

"Let us study what Mauricaeu actually wrote on this subject"

'The bed must be so made, that the woman being ready to be delivered, should lie on her back upon it, having her body in a convenient figure, that is, her head and breast a little raised, so that she be neither lying nor sitting; for in this manner she breathes best, and will have more strength to help her pains, than if she were otherwise, or sunk down in her bed. Being in this posture, she must spread her thighs abroad, folding her legs a little towards her buttocks … and have her feet stayed against some firm thing; besides this, let her hold some persons with her hands, that she may better stay herself during her pains … bearing them down when they take her, which she may do by holding her breath, and forcing herself, as much as she can, just as when she goeth to stool …'

"The semirecumbent delivery position described by Mauriceau became known as the 'French' position and its use steadily spread throughout Europe and North America in the centuries that followed. Gradually in many countries it evolved into the fully recumbent or lithotomy position. More recently, with the diffusion of Western obstetrics, the dorsal position has also been introduced into many developing countries. Though some authors have credited Mauriceau with this change in delivery position, others regard the dorsal recumbent posture to be the most mischievous intervention in modern obstetrics, causing parturition to be more drawn out, more painful for the mother, and less safe for the fetus. To be fair to Mauriceau it should be recorded that he also recommended ambulation during labour, writing:



'… she may walk about her chamber … The patient may likewise by intervals rest herself on her bed, to regain her strength; but not too long, especially little, or short thick women, for they have always worse labours if they be much on their beds in their travail, and yet much worse of their first children, than when they are prevailed with to walk about the chamber, supporting them under their arms, if necessary; for by this means, the weight of the child, the woman being on her legs, causeth the inward orifice of the womb to dilate sooner than in bed; and her pains to be stronger and frequenter, that her labour be nothing near so long'" (Dunn).

Dunn suggests that Mauriceau took his recommendation of the dorsal recumbent position from Aristotle, who recommended it around 350 BC, although Hippocrates, Soranus of Ephesus and other classical writers all recommended an upright posture for parturition.

"Mauriceau, who was an ordinary surgeon and not a doctor of medicine, was a skilful practitioner and an acute observer, publishing his observations in an admirably clear form. Mauriceau was the first to study the conformation of the female pelvis, showing that in a woman with a large pelvis birth could take place without separation of the bones. He studied the movements of the fetus in different positions, the circulation in the pregnant uterus, and the formation of milk. He advised the bimanual extraction of the head, and was the first to describe the complication of strangulation of the newborn by the umbilical cord. He strongly condemned cephalic version, and introduced a number of technical improvements. His treatment of haemorrhage was excellent, and he gave careful rules for the treatment of *placenta previa*. He condemned Caesarean section, which he regarded as fatal. Contrary to the opinion of his predecessors, he recognized the puerperal flow as a secretion analogous to the suppuration of a wound" (Castiglione, *A History of Medicine* (1941), pp. 555-6).

It is worth noting Mauriceau's relationship with the Confraternity to whose library the present volume was presented. The prestigious society had originally served to distinguish its members, usually academics, from "barber-surgeons" who had no university training. Yet in 1655 the two guilds had merged—in large part because the practical skills of itinerant surgeons often surpassed those of their academic competitors! In this context, Mauriceau's hands-on apprenticeship at the Hôtel-Dieu is significant, as is the publication of his work in French instead of Latin—a fact noted by the Bibliothèque Nationale's inclusion of the present volume in its exhibition catalogue *En Français dans le texte* (1990). Of interest also is Mauriceau's advertisement of his medical practice at the foot of the engraved frontispiece, which includes his portrait. He states, admittedly in small print, that his office is on rue St. Severin at the corner of rue Zacharie, etc., etc.

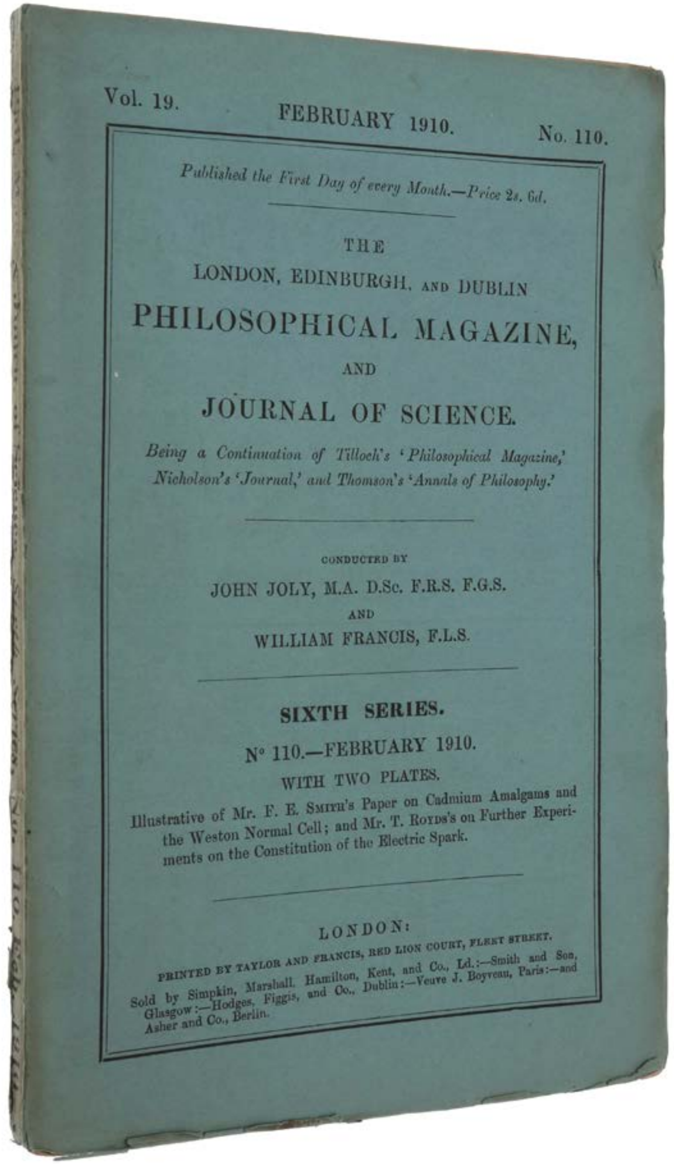
Garrison-Morton.com 6147. *En français dans le texte* 107. Norman 1461, Grolier, *One Hundred Books Famous in Medicine*, no. 33; Heirs of Hippocrates 604 (2nd. Edition); NLM/Krivatsy 7588; Wellcome IV, p. 85. Dunn, 'François Mauricea (1637-1709) and maternal posture for parturition,' Archives of Disease in Childhood 66 (1991), pp. 78-79.

THE OIL-DROP EXPERIMENT

MILLIKAN, Robert Andrews. *A New Modification of the Cloud Method of Determining the Elementary Electrical Charge and the Most Probable Value of that Charge.* London: Taylor & Francis, 1910.

$2,800

Contained in: The Philosophical Magazine for February 1910, vol 19, no. 110, pp. 209-228. The entire issue offered here, uncut and unopened in the original blue printed wrappers (spine strip with some very good restoration, hardly noticible). 8vo (225 x 147 mm). Rare in such fine condition.

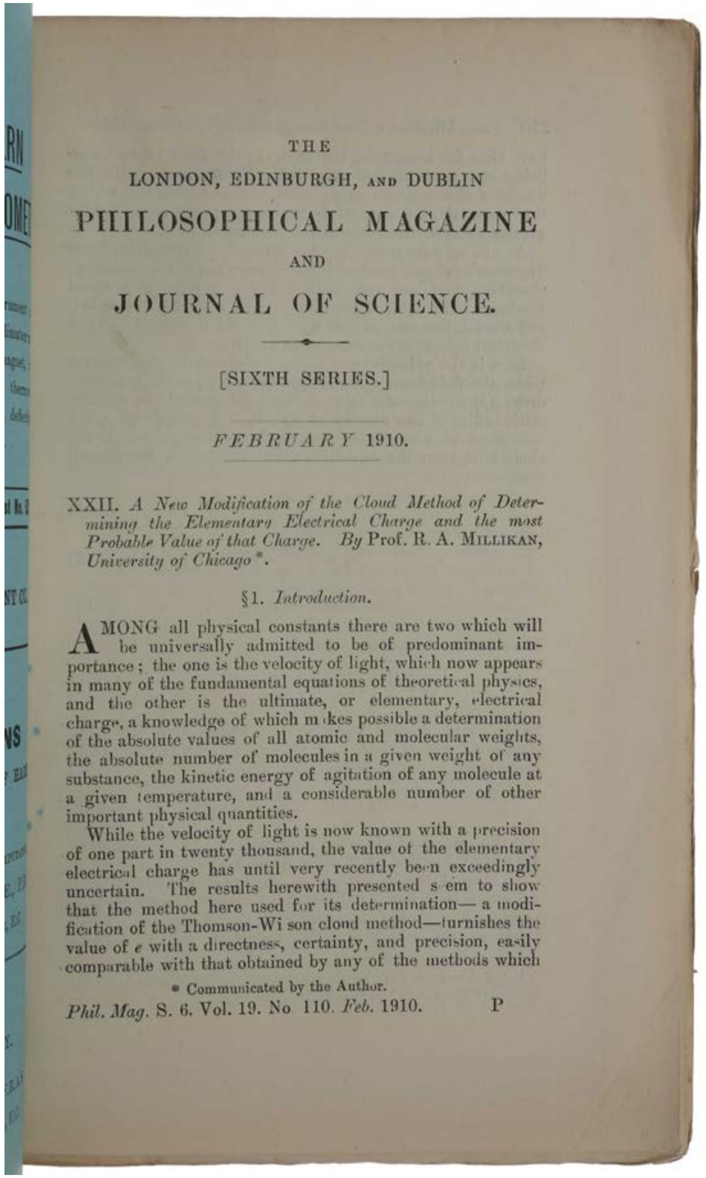


A fine copy of Millikan's famous experiment, later known as the 'oil-drop experiment', in which he first provided the definitive proof that all electrical charges are exact multiples of a definite, fundamental value—the charge of the electron. Millikan's experiment is nowadays known as the 'oil-drop experiment' due to a later improvement by Millikan and his student Harvey Fletcher in 1910 – using oil in the cloud chamber – but it was in this paper (although water and alcohol were the liquids used) that Millikan first made precise measurements of the charge on single isolated droplets instead of as earlier just statistical averages on the surface of clouds of droplets.

Although important, the fundamental breakthrough in Millikan's work was not his measurement of the actual value of the electron's charge (in fact he was as close to the correct value in this paper dated October 1909 as he was in the later oil experiment of 1910), but the fact that Millikan was able to produce, isolate, and observe single droplets with electrical charges, and show that repeated measurements of the charges always revealed exact integral multiples of one fundamental unity value. Previous experiments by Thomson and Wilson had in fact revealed the same value of the electron's charge as Millikan's experiment did but their determinations were based on statistical averages on the surface of large clouds of numerous water droplets and repeated measurements on the clouds gave fractional values of the electron's charge. This fact implied to some antiatomistic Continental physicists that it was not the constant of a unique particle but a statistical average of diverse electrical energies. However, in this 1909 experiment Millikan showed that his single droplets could not hold a fractional charge of the electron's but always had a charge that was an exact integral multiple of the electron's (e.g., *2e, 3e, 4e, …*). In 1910 Millikan and Fletcher improved and simplified the whole experiment by using oil, mercury, and glycerin as liquids instead of water; they could now observe the droplets for several hours instead of just under one minute and also neglect having to compensate for the evaporation of the water and alcohol droplets. And thus the experiment became known as the 'oil-drop experiment', but the crucial breakthrough had already taken place in this 1909 experiment.

In this paper Millikan emphasized that the very nature of his data refuted conclusively the minority of scientists who still held that electrons (and perhaps atoms too) were not necessarily fundamental, discrete particles. And he provided a value for the electronic charge which, when inserted in Niels Bohr's theoretical formula for the hydrogen spectrum, accurately gave the Rydberg constant—the first and most convincing proof of Bohr's quantum theory of the atom.

'Among all physical constants there are two which will be universally admitted to be of predominant importance; the one is the velocity of light, which now appears in many of the fundamental equations of theoretical physics, and the other is the ultimate, or elementary, electrical charge, a knowledge of which makes possible a determination of the absolute values of all atomic and molecular weights, the



THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[SIXTH SERIES.]

FEBRUARY 1910.

XXII. *A New Modification of the Cloud Method of Determining the Elementary Electrical Charge and the most Probable Value of that Charge.* By Prof. R. A. MILLIKAN, *University of Chicago**.

§1. *Introduction.*

AMONG all physical constants there are two which will be universally admitted to be of predominant importance; the one is the velocity of light, which now appears in many of the fundamental equations of theoretical physics, and the other is the ultimate, or elementary, electrical charge, a knowledge of which makes possible a determination of the absolute values of all atomic and molecular weights, the absolute number of molecules in a given weight of any substance, the kinetic energy of agitation of any molecule at a given temperature, and a considerable number of other important physical quantities.

While the velocity of light is now known with a precision of one part in twenty thousand, the value of the elementary electrical charge has until very recently been exceedingly uncertain. The results herewith presented seem to show that the method here used for its determination—a modification of the Thomson-Wilson cloud method—furnishes the value of *e* with a directness, certainty, and precision, easily comparable with that obtained by any of the methods which

* Communicated by the Author.

Phil. Mag. S. 6. Vol. 19. No 110. *Feb.* 1910. P *absolute number of molecules in a given weight of any substance, the kinetic energy of agitation of any molecule at a given temperature, and a considerable number of other important physical quantities.'* (First paragraph of the offered paper).

In 1923 Millikan became the first American-born Nobel laureate for this work together with his1916 determination of Planck's constant on the basis of Einstein's theory of the photoelectric effect.

IN EXCEPTIONALLY RARE ORIGINAL PUBLISHER'S BINDING

NIETZSCHE, Friedrich. *Die Geburt der Tragödie aus dem Geiste der Musik.* Leipzig: E.W. Fritzsch, 1872.

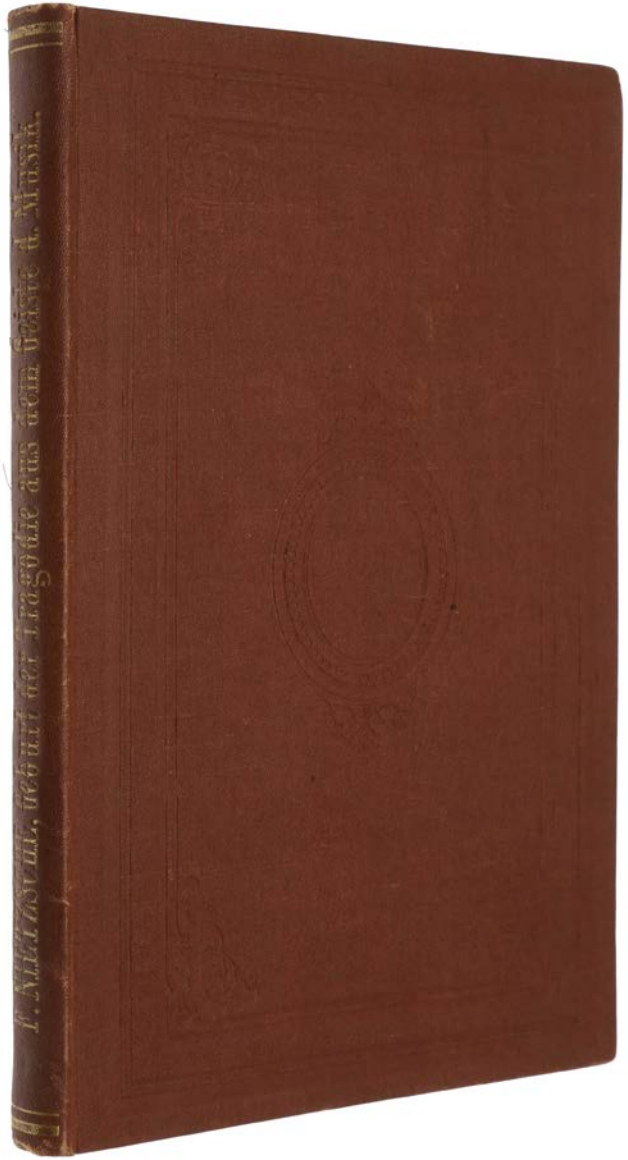
$14,500

8vo (216 x 138 mm) pp. [i-iii] iv [1] 2-143 [144]. Original publisher's dark-rust binding with an ornate blind-stamped design on the front and rear covers and the spine lettered and filleted in gilt. There is some light browning to the edges of the page margins and light foxing throughout. Rear hinge with a 10 cm split. Entirely unrestored copy in its original state. An extremely well preserved copy of this unusual and all-but-unobtainable original publisher's cloth binding.

First edition in exceptionally rare original publisher's cloth binding. This copy previously handled by Bill Schaberg: "When I wrote The Nietzsche Canon: A Publication History and Bibliography (The University of Chicago Press, 1995), I had never even heard of these cloth copies of Nietzsche's first book, put out by his publisher, Fritzsch. So, it was quite a shock when someone offered this copy to me. It turns out that Fritzsch's contemporary advertisements for the book mention a cloth binding, so this is not just a figment of some bookseller's imagination."

This, Nietzsche's first book, is a compelling argument for the necessity for art in life. It is fueled by his enthusiasms for Greek tragedy, for the philosophy of Schopenhauer and for the music of Wagner, to whom this work was dedicated.

Nietzsche argues that the tragedy of Ancient Greece was the highest form of art

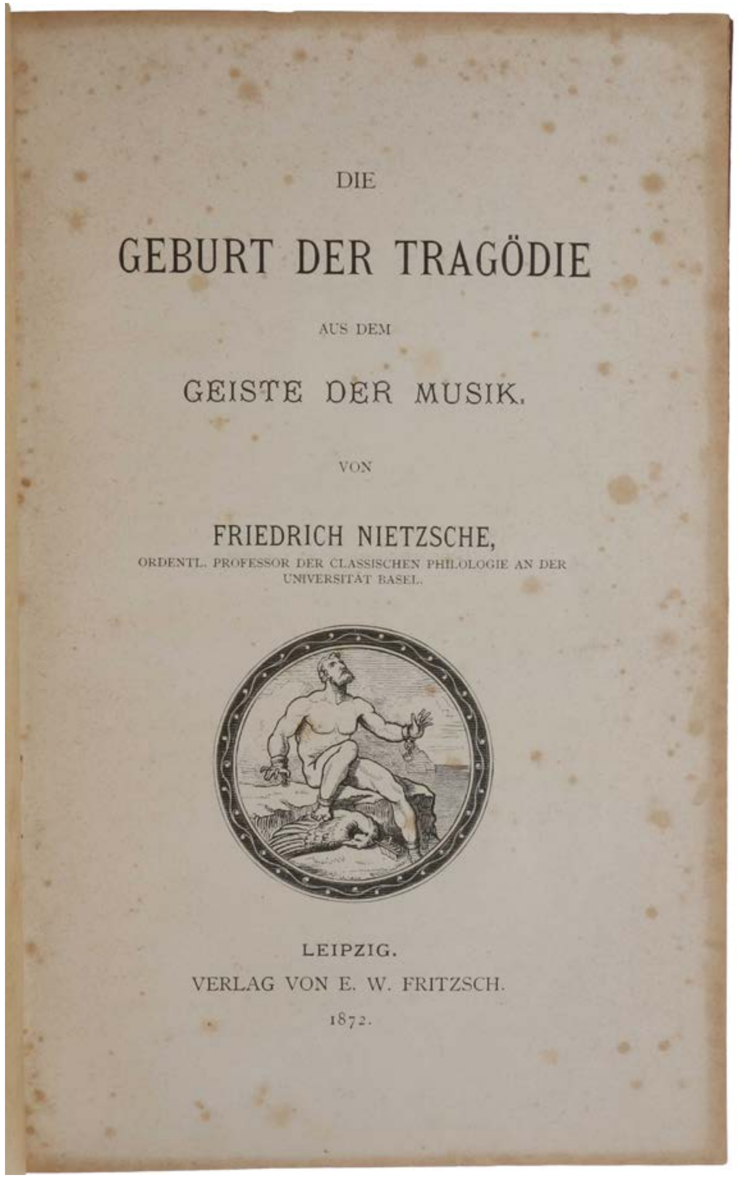


due to its mixture of both Apollonian and Dionysian elements into one seamless whole, allowing the spectator to experience the full spectrum of the human condition. The Dionysian element was to be found in the music of the chorus, while the Apollonian element was found in the dialogue which gave a concrete symbolism that balanced the Dionysiac revelry. Basically, the Apollonian spirit was able to give form to the abstract Dionysian.

In contrast to the typical Enlightenment view of ancient Greek culture as noble, simple, elegant and grandiose, Nietzsche believed the Greeks were grappling with pessimism. The universe in which we live is the product of great interacting forces; but we neither observe nor know these as such. What we put together as our conceptions of the world, Nietzsche thought, never actually addresses the underlying realities. It is human destiny to be controlled by the darkest universal realities and, at the same time, to live life in a human-dreamt world of illusions.

The issue, then, or so Nietzsche thought, is how to experience and understand the Dionysian side of life without destroying the obvious values of the Apollonian side. It is not healthy for an individual, or for a whole society, to become entirely absorbed in the rule of one or the other. The soundest (healthiest) foothold is in both. Nietzsche's theory of Athenian tragic drama suggests exactly how, before Euripides and Socrates, the Dionysian and Apollonian elements of life were artistically woven together. The Greek spectator became healthy through direct experience of the Dionysian within the protective spirit-of-tragedy on the Apollonian stage.

The Birth of Tragedy was the best selling book that Nietzsche ever published; still, it did not sell quickly. The Wagners had feared that there might not be an audience for the work and their apprehensions proved to be well-founded. A prediction that Nietzsche had once made to Rohde proved true: "The philologists won't read



it on account of the music, the musicians won't read it on account of the philology and the philosophers won't read it on account of the music and the philology." False hopes for brisk sales plagued the first half-year. In mid-April, Nietzsche was writing home that "a new edition of my book will be needed soon,"34 but the necessity of printing a second edition did not materialize quickly. By 20 July, Fritzsch complained that there had been "no results" even though he had "sent out a fair number of copies." (Schaberg, The Nietzsche Canon, p. 27)

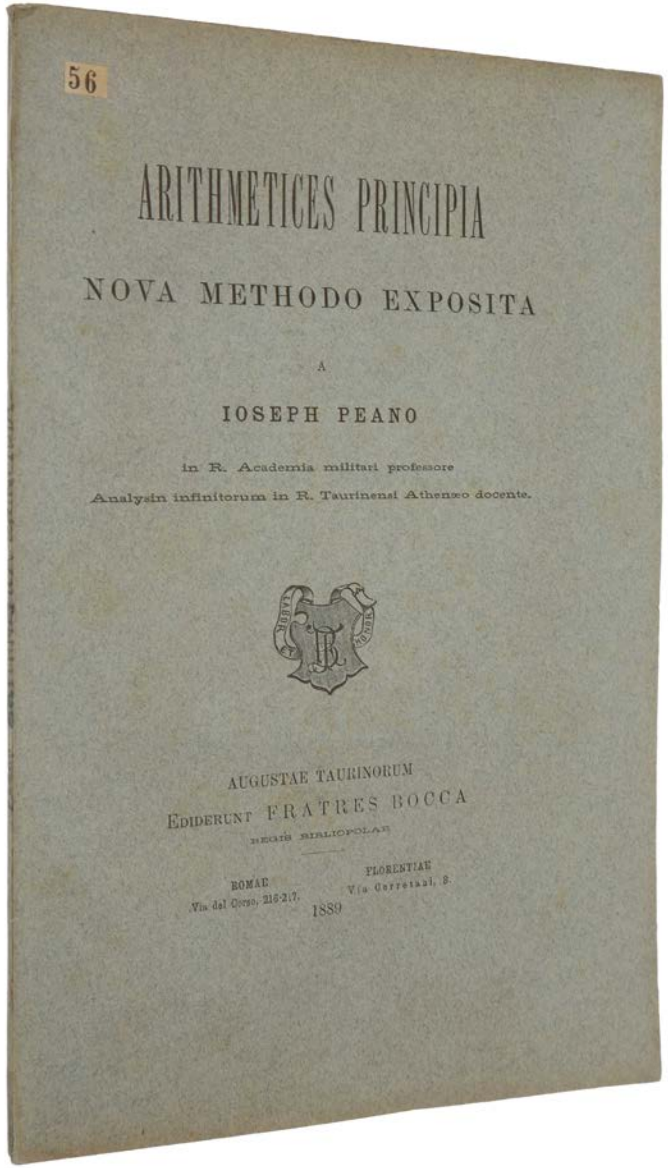
THE PEANO AXIOMS

PEANO, Guiseppe. *Arithmetices Principia Nova Methodo Exposita.* Turin: Bocca Brothers, 1889.

$16,500

8vo (240 x 159 mm), pp. [xvi], 20. Original printed wrappers, mostly unopened. Exlibris bookplate to inside of front wrapper. Manuscript lettering to spine strip. A fine copy.

First edition, and a fine copy in the original printed wrappers, of Peano's most important work, which contains the first statement of the famous 'Peano axioms' for the natural numbers and which remains of seminal importance to mathematics and mathematical logic. "Peano's most important contribution to the development of the theory and practice of the axiomatic method was his system of axioms for the arithmetic of the natural numbers… On the basis of his axiomatization, Peano constructed the entire theory of natural numbers. In particular, he showed how the elementary theorems of arithmetic can be obtained from his axioms" (Styazhkin, *History of Mathematical Logic from Leibniz to Peano*, 1969, pp. 278-9). "… with the publication of *Arithmetices principia, nova methodo exposita,* Peano not only improved his logical symbolism but also used his new method to achieve important new results in mathematics; this short booklet contains Peano's first statement of his famous postulates for the natural numbers, perhaps the best known of all his creations. His research was done independently of the work of Dedekind, who the previous year had published an analysis of the natural numbers, which was essentially that of Peano but without the clarity of Peano. (This work was the only work Peano wrote in Latin.). *Arithmetices principia* made important innovations in logical notation, such as Î for set membership and a new



notation for universal quantification. Indeed, much of Peano's notation found its way, either directly or in a somewhat modified form, into mid-twentieth-century logic" (DSB). No copies listed on ABPC/RBH.

"Written in Latin, this small book was Peano's first attempt at an axiomatization of mathematics in a symbolic language … after having introduced logical notations and formulas, Peano undertakes to rewrite arithmetic in symbolic notation. But he aspires to more than just the provision of a correct logical foundation for arithmetic: the book deals also with fractions, real numbers, and even the notion of limit and definitions in point-set theory… The initial arithmetic notions are "number," "one," "successor" and "is equal to," and nine axioms are stated concerning these notions. Today we would consider that Axioms 2, 3, 4 and 5, which deal with identity, belong to the underlying logic. That leaves the five axioms that have become universally known as "the Peano axioms"… The ease with which we read Peano's booklet today shows how much of his notation has found its way, either directly or in a somewhat modified form, into contemporary logic" (van Heijenoort, pp. 83-4). Peano's axioms were subsequently modified and republished by their creator in the five successive versions of his *Formulaire* and finally perfected in Whitehead and Russell's *Principia Mathematica*.

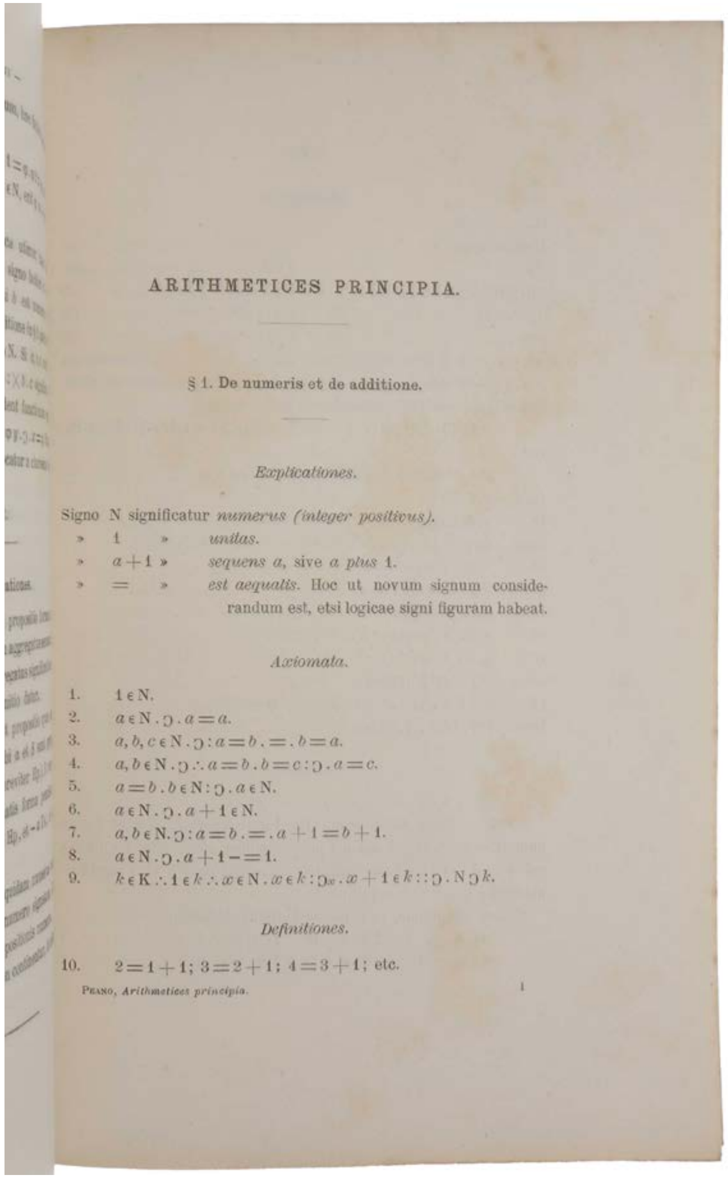
"Peano's *Arithmetices principia* not only deals with the natural numbers. Having presented all of the basic arithmetical operations, Peano goes on to discuss several topics in order to 'better show the power of this [new] method'. First he offers a selection of number-theoretical results (without proof, art. 7) and then he introduces the rational and the real numbers. The rationals are rendered as ratios of two natural numbers (art. 8), the reals as formal 'limits' of sets of rationals, essentially following Dedekind's definition by means of cuts (art. 9) … Finally, art. 10 discusses basic results in the topology of the real numbers, belonging to the theory of 'what Cantor calls *Punktmenge* (*ensemble de points*)', on the basis of the concepts of interior, exterior and limit point. Some of these results were new" (*Landmark Writings in Western Mathematics, 1640-1940*, pp. 622-3).

Peano exerted a profound influence on Bertrand Russell and his work on the foundations of mathematics. "*Principia Mathematica* had its origins in Russell's discovery of the work of Peano at the International Congress of Philosophy held in Paris in the summer of 1900, which Peano and his supporters attended in force. To that time Russell had been working for several years attempting to develop a satisfactory philosophy of mathematics. Despite some philosophical successes … a satisfactory outcome had always eluded him. At the conference, however, he very quickly realized that the Peano school had a set of techniques of which he could make use, and on his return from the conference he immediately set about applying them. As a result, he quickly rewrote *The Principles of Mathematics*, which he had started in 1899, finishing the new version by the end of the year. It was published, after some delay and substantial revisions of Part I, in 1903, billed as the first of two volumes. It was intended as a philosophical introduction to, and defence of, the logicist program that all mathematical concepts could be defined in terms of logic and that all mathematical theorems could be derived from purely logical axioms. It was to be followed by a second volume, done in Peano's notation, in which the logicist program would actually be carried out by providing the requisite definitions and proofs. At about the same time that Russell was finishing *The Principles of Mathematics*, he began the collaboration with his former teacher, Whitehead, that produced, many years later, *Principia Mathematica*" (*The Palgrave Centenary Companion to Principia Mathematica*, p. xvi).

That this pamphlet was written Latin reveals a concern of Peano's: international accessibility. It was so important to him that he later devoted much of his time to the cause of the auxiliary international language, Interlingua. "In his mathematical writing, addressed to mathematicians at large, Peano changed over early on from his own language of Italian to French, which is more widely known; but even French is not fully international, and he looked back with regret to the time, not so very distant, when Latin had been the universal language of scholars" (Kneebone, *Mathematical Logic and the Foundations of Mathematics*, 1963, p. 149). Kennedy (*Life and Works of Giuseppe* Peano, p. 41), however, suggests that both the title and the language of composition were acts "of sheer romanticism, perhaps the unique romantic act of his scientific career". The Greek *Arithmetices* was perhaps meant to evoke Euclid, while *Principia* may have been a tribute to Newton. And writing in French, with which Peano was certainly familiar, would have made the book even more accessible to an international audience.

Giuseppe Peano (1858-1932) "became a lecturer of infinitesimal calculus at the University of Turin in 1884 and a professor in 1890. He also held the post of professor at the *Academia Militare* in Turin from 1886 to 1901. Peano made several important discoveries, including a continuous mapping of a line onto every point of a square, that were highly counterintuitive and convinced him that mathematics should be developed formally if mistakes were to be avoided. His *Formulaire de mathématiques* (Italian *Formulario mathematico*, "Mathematical Formulary"), published from 1894 to 1908 with collaborators, was intended to develop mathematics in its entirety from its fundamental postulates, using Peano's logical notation and his simplified international language... Peano is also known as the creator of *Latino sine Flexione*, an artificial language later called Interlingua. Based on a synthesis of Latin, French, German, and English vocabularies, with a greatly simplified grammar, Interlingua was intended for use as an international auxiliary language. Peano compiled a *Vocabulario de Interlingua* (1915) and was for a time president of the Academia pro Interlingua" (Britannica).

DSB X: 442; Jean van Heijenoort: *From Frege to Gödel. A Source Book in Mathematical Logic, 1879-1931*.



ARITHMETICES PRINCIPIA.

§ 1. De numeris et de additione.

Explicationes.

Signo N significatur *numerus (integer positivus).*
» 1 » *unitas.*
» a + 1 » *sequens a*, sive *a plus* 1.
» = » *est aequalis.* Hoc ut novum signum considerandum est, etsi logicae signi figuram habeat.

Axiomata.

1. 1 ε N.
2. a ε N . Ɔ . a = a.
3. a, b, c ε N . Ɔ : a = b . = . b = a.
4. a, b ε N . Ɔ ∴ a = b . b = c : Ɔ . a = c.
5. a = b . b ε N : Ɔ . a ε N.
6. a ε N . Ɔ . a + 1 ε N.
7. a, b ε N . Ɔ : a = b . = . a + 1 = b + 1.
8. a ε N . Ɔ . a + 1 −= 1.
9. k ε K ∴ 1 ε k ∴ x ε N . x ε k : Ɔ_x . x + 1 ε k :: Ɔ . N Ɔ k.

Definitiones.

10. 2 = 1 + 1; 3 = 2 + 1; 4 = 3 + 1; etc.

Peano, *Arithmetices principia.* 1

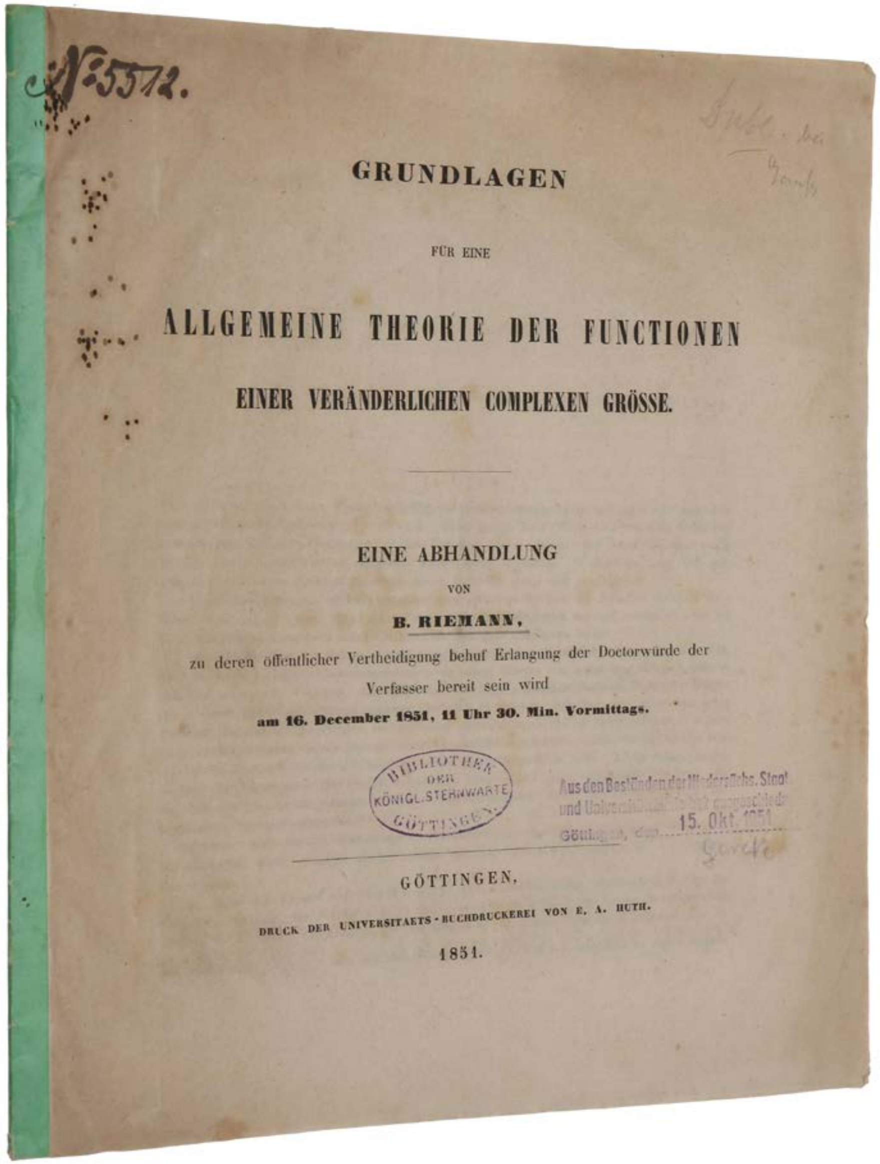
ONE OF THE MOST IMPORTANT ACHIEVEMENTS OF 19TH CENTURY MATHEMATICS

RIEMANN, George Friedrich Bernhard. *Grundlagen für eine allgemeine Theorie der Functionen einer veränderlichen complexen Grösse. Eine Abhandlung, zu deren öffentlicher Vertheidigung behuf Erlangung der Doctorwürde der Verfasser bereit sein wird am 16. December 1851.* Göttingen: E. A. Huth, 1851.

$28,500

4to (255 x 211 mm), pp [ii] 32. Stamps on title of the Göttingen Royal Observatory (of which Gauss was director from 1807 to 1855), and of Göttingen State and University Library (deaccessioned by librarian). The leaves contemporarily bound with green paper strip spine. Pencil-underlining to author's name, and another pencil annotation to upper right corner of front wrapper. Old library numbering in ink to upper left corner.

Very rare first edition of Riemann's *Dissertation*, "one of the most important achievements of 19th century mathematics" (Laugwitz), "which marked a new era in the development of the theory of analytic functions" (Kolmogorov & Yushkevich, p. 199), introducing geometric and topological methods, notably the idea of a 'Riemann surface'. "Riemann's doctoral thesis is, in short, a masterpiece" (Derbyshire, p. 121). It is also of great rarity, for "although [it] was a printed booklet, it was not usually published or publicised in the normal way; the candidate had to pay for the print-run, and sales and marketing were executed on an infinitesimal scale. So the first printing of Riemann's thesis consisted only of



the obligatory copies he had to hand in at Göttingen University, and a few copies for his personal use" *Landmarks in Western Mathematics*, no. 34). The present copy is evidently one of those handed to the University.

Riemann begins his thesis by offering a new foundation for the theory of analytic functions, based not on analytic expressions but on the assumption that the complex function $w = u + iv$ of the complex variable $z = x + iy$ is 'differentiable'. Riemann noted that this condition is equivalent to requiring that u and v satisfy the 'Cauchy-Riemann equations' (as they are now called), and that, when the derivative is non-zero, it is also equivalent to requiring that the function determines a conformal mapping from the z-plane to the w-plane. At this point he refers to Gauss's work on conformal mapping, published in 1825 in Schumacher's *Astronomische Abhandlungen*, which he had studied in Berlin (this is the only reference in the thesis to the work of others).

In order to deal with multi-valued functions such as algebraic functions and their integrals, Riemann introduced the surfaces now named after him: the Riemann surface associated with a function is composed of as many sheets as there are branches of the function, connected in a particular way so that continuity is preserved and a single-valued function on the surface is obtained. Such a surface can be represented on a plane by a series of 'cross-cuts', which divide the surface into simply-connected regions. "Riemann's thesis studied the theory of complex variables and, in particular, what we now call Riemann surfaces. It therefore introduced topological methods into complex function theory… Riemann's thesis is a strikingly original piece of work which examined geometric properties of analytic functions, conformal mappings and the connectivity of surfaces" (Mactutor).

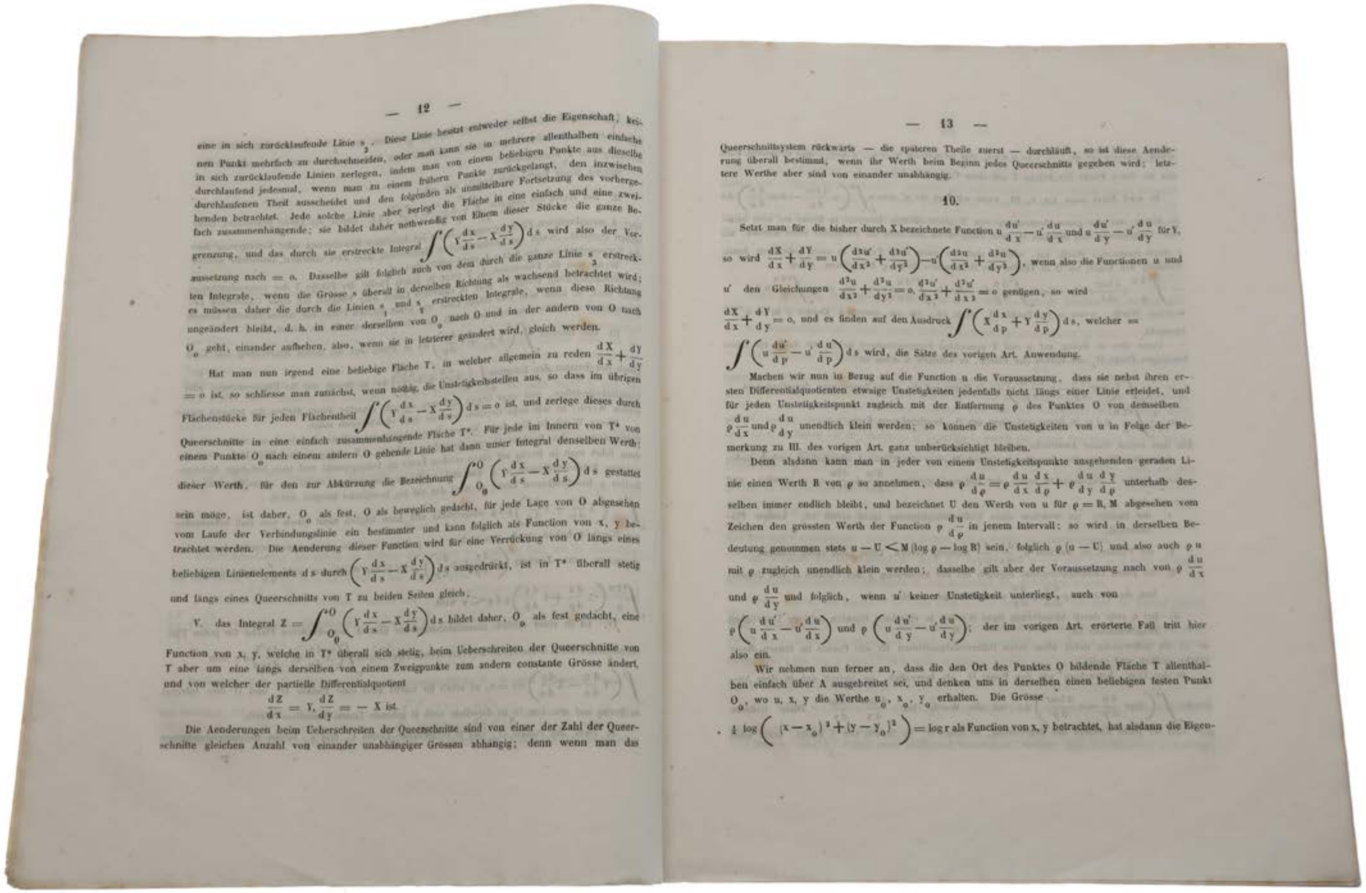
The rest of the thesis is devoted to the study of functions on Riemann surfaces. From the Cauchy-Riemann equations it follows that if $w = u + iv$ is an analytic function, then u and v are harmonic functions, i.e. solutions of Laplace's equation. This establishes a link between the theory of analytic functions and potential theory, a subject with which Riemann was familiar, having attended Gauss and Weber's Göttingen seminar on mathematical physics (Gauss himself had made a decisive contribution to potential theory in 1849). Riemann's approach in the remainder of the thesis was deeply influenced by potential theory.

To construct harmonic functions such as u and v, Riemann began with the case of a simply-connected region and made use of what he called 'Dirichlet's principle (he had learned it from Dirichlet's lectures in Berlin): this asserts that the harmonic functions are exactly those which minimize the value of a certain integral. He then extended this to the non-simply connected case using cross-cuts and other variants. This approach was later to prove controversial, as Weierstrass gave examples of situations in which the minimizing function does not exist, but it was rehabilitated by Hilbert early in the next century.

The crowning glory of the thesis, and the most difficult part of the theory of conformal mappings, is his celebrated mapping theorem. "As an application of his approach he gave a 'worked-out example', showing that two simply-connected plane surfaces can always be made to correspond in such a way that each point of one corresponds continuously with its image in the other, and so that corresponding parts are 'similar in the small', or conformal … what is nowadays called the 'Riemann mapping theorem'." (*Landmarks*, p. 454).

According to Richard Dedekind (*Bernhard Riemann's Lebenslauf*, p. 7), Riemann probably conceived the main ideas of the thesis in autumn 1847. It was submitted on 14 November, 1851 and the Dean of the Faculty asked Gauss for his opinion. Always sparing with his praise, Gauss nevertheless wrote: "The paper submitted by Mr Riemann bears conclusive evidence of the profound and penetrating studies of the author in the area to which the topic dealt with belongs" (quoted from R. Remmert, "From Riemann surfaces to complex spaces", *Bull. Soc. Math. France* (1998), p. 207). Following the thesis examination on 16 December, 1851, Riemann was awarded his *Doctor Philosophiae* and Gauss recommended that he be formally appointed to a position at Göttingen.

I. Grattan-Guiness, *Landmarks in Western Mathematics*, Chapter 34; Poggendorff II, 641; DSB XI 449-450; J. Derbyshire, *Prime Obsession*, 2003; A. N. Kolmogorov & A. P. Yushkevich (eds.), *Mathematics in the 19th century*, Vol. II, 1996; D. Laugwitz, *Bernhard Riemann, 1826-1866*, 1998.



FIRST STATEMENT OF THE LAW OF THE CONSTANCY OF INTERFACIAL ANGLES

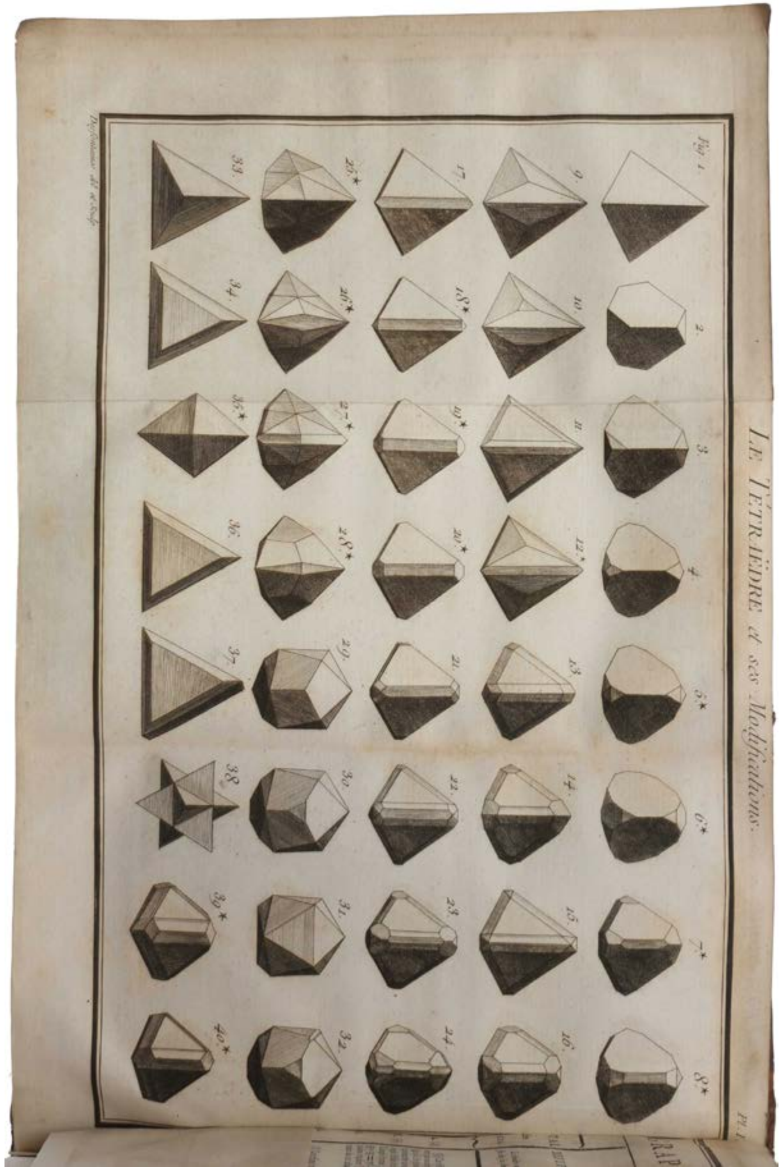
ROMÉ DE L'ISLE, Jean-Baptiste Louis. *Cristallographie, ou Description des formes propres à tous les corps du règne minéral, Dans l'état de Combinaison saline, pierreuse ou métallique.* Leipzig: F.W. Vogel, 1909.

$8,500

Four volumes, 8vo (205 x 125 mm), pp. xxxviii, [2], 623, [1]; [4], 659, [1]; [4], 611, [1]; xvi, 80, with 12 folding engraved plates and 32 large folding tables. Contemporary quarter-calf and marbled boards with vellum tips, red and black lettering-pieces on spines (rubbed, joints cracked).

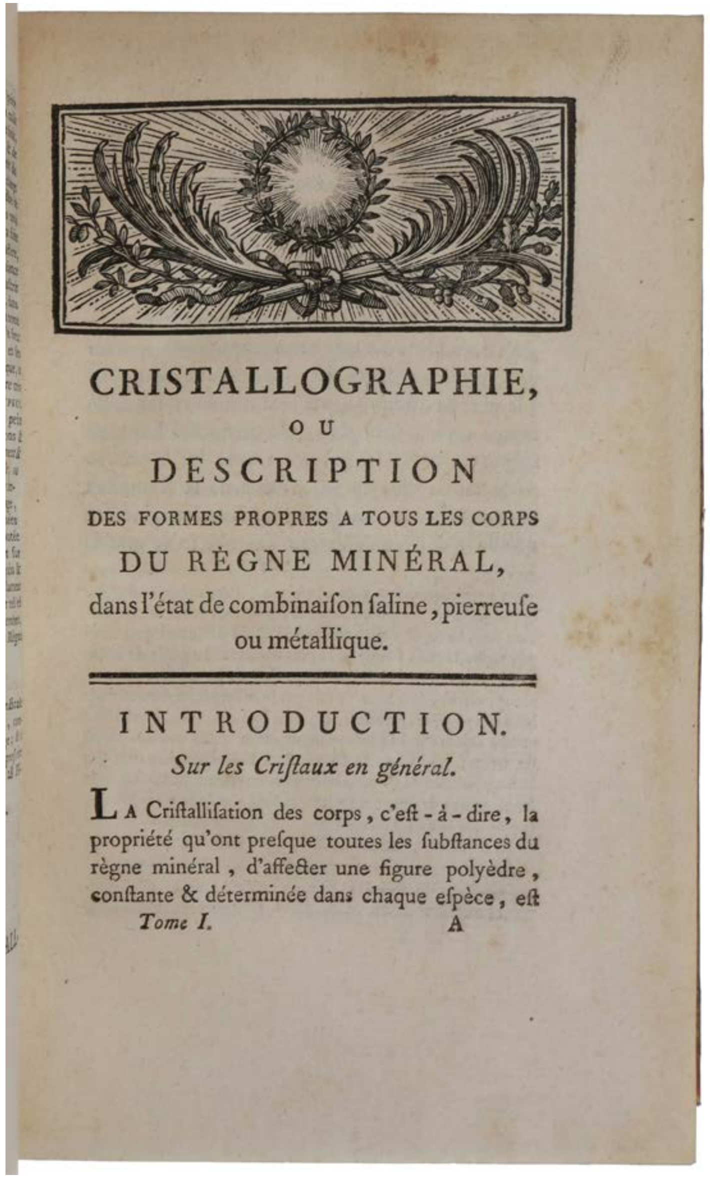
First edition under this title, expanding Romé's earlier work *Essai de cristallographie* (1772) into four volumes that include an atlas describing more than 450 crystal forms. It is in this work, rather than in the *Essai*, that Romé first states the crucial fact of the constancy of the interfacial angles in a crystal, which had earlier been described only in special cases. "The importance of Romé de l'Isle's work was stressed by Haüy (1795) who wrote: 'To the exact descriptions he gave of the crystalline forms, he added the measure of their angles, and, which was essential, showed that these angles were constant for each variety. In one word, his crystallography was the fruit of an immense work, almost entirely new and most precious for its usefulness'" (Authier, pp. 313-4).

"J.-B. L. Romé de l'Isle (1736-90) had started collecting minerals during his travels as a naval officer. Back in Paris after the Indian wars, he was introduced into mineralogy by the apothecary, chemist and mineralogist Balthazar Georges



Sage (1740-1824), whio became his friend. It was very fashionable at the time in Paris to have a mineral collection. The owner of an important private collection, P. Davila, wanted to sell his. At Sage's suggestion, he asked Romé de l'Isle to draw up the inventory. Romé made a very thorough job of it, the inventory running up to three thick volumes. This was his first work on mineralogy, published in 1767 [*Catalogue systematique et raisonne des curiosites de la nature et de l'art, qui composent le cabinet de M. Davila*]. It gave him the opportunity to study crystalline forms in detail and led to his *Essai de cristallographie, ou Description des figures géométriques propres à différens corps du règne minéral, connus vulgairement sous le nom de cristaux* (1772). In the preface, he noted that 'of the curious phenomena of the mineral kingdom those which struck him most were the regular and constant forms taken by some bodies designated by the name of crystals.' It was encouraged by the works of Linnaeus, he added, that he undertook the study of the angular forms of crystals and of their transformations. Their polyhedral shape was known by the Ancients for quartz, diamond and a few others, and Romé widely extended this observation. Minerals are sorted by him into four classes, salts, stony, pyratic and metallic. For each mineral, the most frequent forms observed are described, with a reference to Linnaeus's classification in *Systema naturae*. In general, with a few exception (calcite, garnet, gypsum, quartz), there are no values of facial or interfacial angles and those given are old ones. Steno's ideas relative to the growth of quartz layer by layer are quoted at length, and Romé de l'Islefelt they could be applied to all crystals. The book was a success, acclaimed by Linnaeus himself, and brought international fame to Romé de l'Isle.

"The second crystallographic treatise, *Cristallographie, ou Description des formes propres à tous les corps du règne minéral*, dedicated to the Prussian Royal Academy of Sciences, contains a description of a much larger number of crystal forms (more than 500) than the first one (110) and Linnaeus's (about 40). It is in this work that Romé de l'Isle states the constancy of interfacial angles: 'Nothing


CRISTALLOGRAPHIE,
OU
DESCRIPTION
DES FORMES PROPRES A TOUS LES CORPS
DU RÈGNE MINÉRAL,
dans l'état de combinaiſon ſaline, pierreuſe ou métallique.

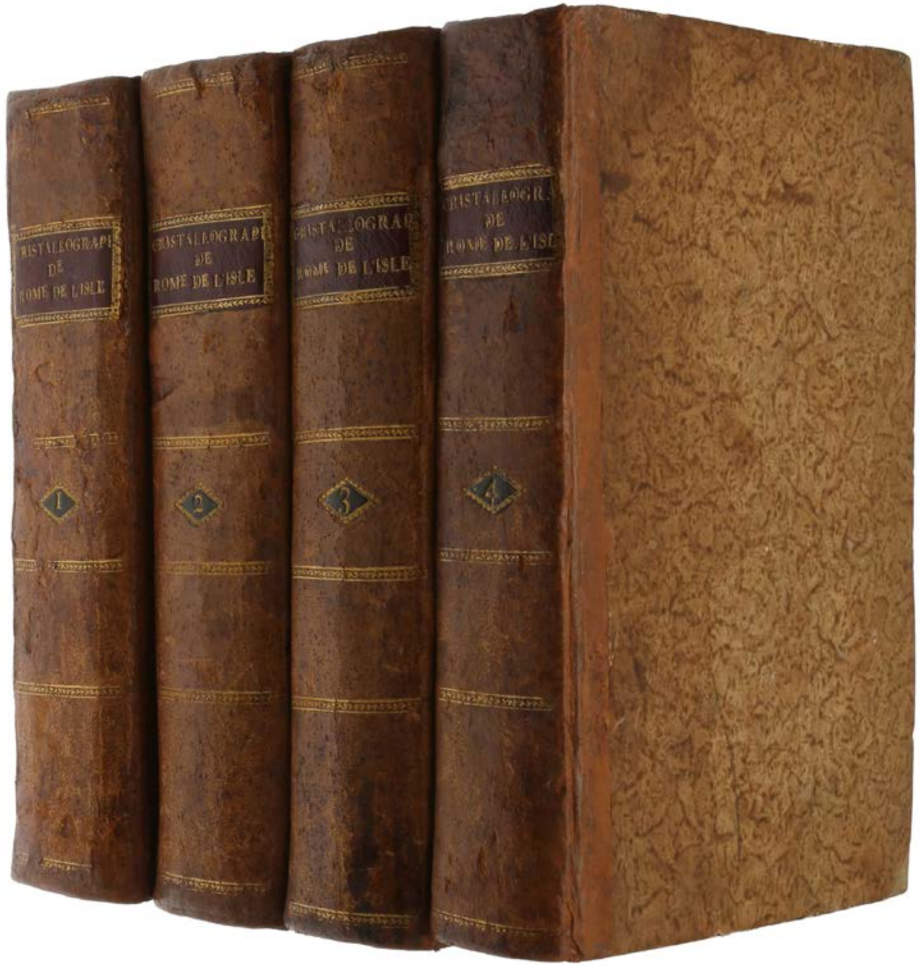
INTRODUCTION.
Sur les Criſtaux en général.

LA Criſtalliſation des corps, c'eſt-à-dire, la propriété qu'ont preſque toutes les ſubſtances du règne minéral, d'affecter une figure polyèdre, conſtante & déterminée dans chaque eſpèce, eſt

Tome I. A

is easier than to show, with the help of the goniometer, which we owe to M. Carangeot, the constancy of the [interfacial] angles and of the crystalline form of every species.' More precisely, 'the faces of a crystal may vary in their shape and in their extension, but their respective inclination is constant and invariable in each species.' Romé de l'Isle's aim was to put some order in the confusion created by the large variety of forms exhibited by most crystals. He notes that 'at the imitation of the famous Bergmann, some physicists among us busy themselves at present demonstrating by geometrical figures and calculations the mechanism by which are constructed some crystals that are easy to divide with a cutting tool.' He had Haüy specifically in mind whom he calls a *cristalloclaste*, who 'mutilates the few crystals that can be divided mechanically, looking for an alleged nucleus which, even if it existed, could not be explained by geometry alone.' Romé de l'Isle also criticized Haüy's interpretation of the garnet forms. For him, on the contrary, 'one should start by investigating all the various forms of a given species.' This he did by carefully measuring the interfacial angles with the Carangeot contact goniometer and identifying the individual forms associated in a given specimen of a crystal. He defined six primitive forms, and showed that each of the individual forms can be derived from a primitive form by suitable truncations. Romé de l'Isle was, however, himself criticized for the arbitrary choice of the primitive forms, but also by mineralogists such as Bergmann and Kirwan, who described him as a mere 'catalogue maker'!" (*ibid*., pp. 314-6).

Cole 1124. Poggendorff, vol. II, col. 682-683. Schuh, *Mineralogy & Cristallography*, 4152. Authier, *Early Days of X-ray Crystallography*, 2013.



ONE OF THE MOST LAVISHLY ILLUSTRATED ASTRONOMICAL WORKS

SCHEINER, Christoph. *Rosa ursina sive Sol ex admirando facularum & macularum suarum phoenomeno varius: necnon circa centrum suum et axem fixum ab occasu in ortum annua, circaq[ue] alium axem mobilem ab ortu in occasum conuersione quasi menstrua, super polos proprios, libris quatuor mobilis ostensus* ... Bracciano: Andreas Phaeus, 1626-30.

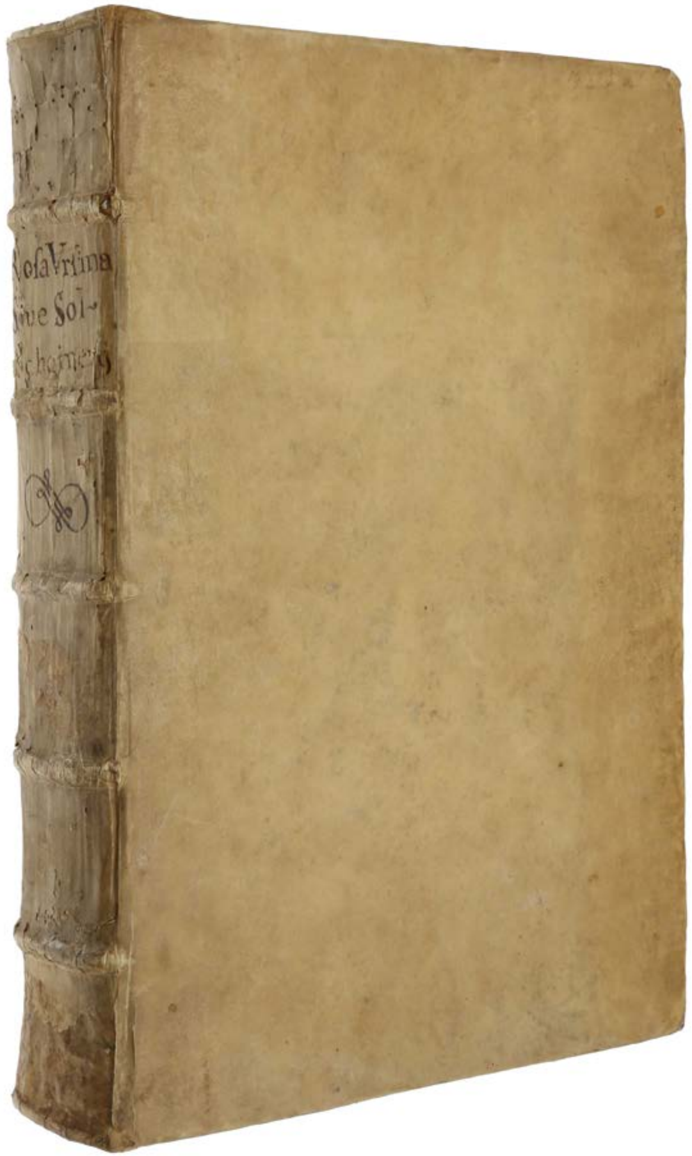
$95,000

Folio (352 x 248 mm), pp. [xl, including frontispiece], 1-66, [2, blank], [67]-125, [126]; ff. 126-149, [12, including blank R6]; pp. [2, unpaginated opening leaf of Liber tertius], 149-784, [2, blank], [36, index and errata], with engraved frontispiece, engraved plate on title, engraved portrait of Orsini, and 172 engraved plates folded in. Contemporary vellum with manuscript title on spine. Moderate browning and spotting to some leaves - much less than is usually seen in this work.

First edition of the most lavishly illustrated astronomical work published in the first half of the seventeenth century, with many full-page illustrations of Scheiner's observations of the sun and of the optical instruments he had designed for the purpose. "For his masterpiece, Scheiner produced the first monograph on a heavenly body, the Sun. Even today it is still an impressive volume, with scores of engravings of sunspots and the various instruments needed for solar observations" (*Jesuit Science in the Age of Galileo*). "Scheiner's drawings in the *Rosa Ursina* are of almost modern quality, and there was little improvement in solar imaging until 1905" (Britannica). In this work "Scheiner agreed with Galileo that sunspots are on the Sun's surface or in its atmosphere, that they are often

generated and perish there, and that the Sun is therefore not perfect. Scheiner further advocated a fluid heavens (against the Aristotelian solid spheres), and he pioneered new ways of representing the motions of spots across the Sun's face" (Galileo Project). Scheiner was one of the first to observe sunspots by telescope, in March 1611, and in 1612 he published his findings anonymously. This led to a famous controversy with Galileo, who claimed to have observed sunspots earlier, involving the exchange of several letters. Galileo then turned to other matters, notably the preparation of the *Dialogo*, but Scheiner continued his observations of sunspots, culminating in the publication of the present work more than a decade later. Scheiner devised a number of new instruments in order to make his observations. Kepler had conceived the 'astronomical' telescope, consisting of two converging lenses, but he never constructed one. Scheiner was the first to do so, and he added a third convex lens which transformed the inverted image into an erect one and greatly increased the field of view and brightness of the image. Scheiner also invented the first equatorially mounted telescope. All of these instruments are described and illustrated in *Rosa Ursina*, in which "Scheiner confirmed his method and criticized Galileo for failing to mention the inclination of the axis of rotation of the sunspots to the plane of the ecliptic" (*DSB*). But when the *Dialogo* was published in 1632, Scheiner was dismayed to find that Galileo dismissed Scheiner's work and claimed there that he [Galileo] had known of the curved motion of sunspots and its explanation in terms of the inclination of the Sun's axis since 1614 (although the evidence casts serious doubt on Galileo's claims). "It has been said that his [i.e., Scheiner's] enmity toward Galileo was instrumental in starting the process against the Florentine in 1633" (Galileo Project). Although this book appears on the market from time to time, fine, complete copies in untouched contemporary bindings are rare in commerce.

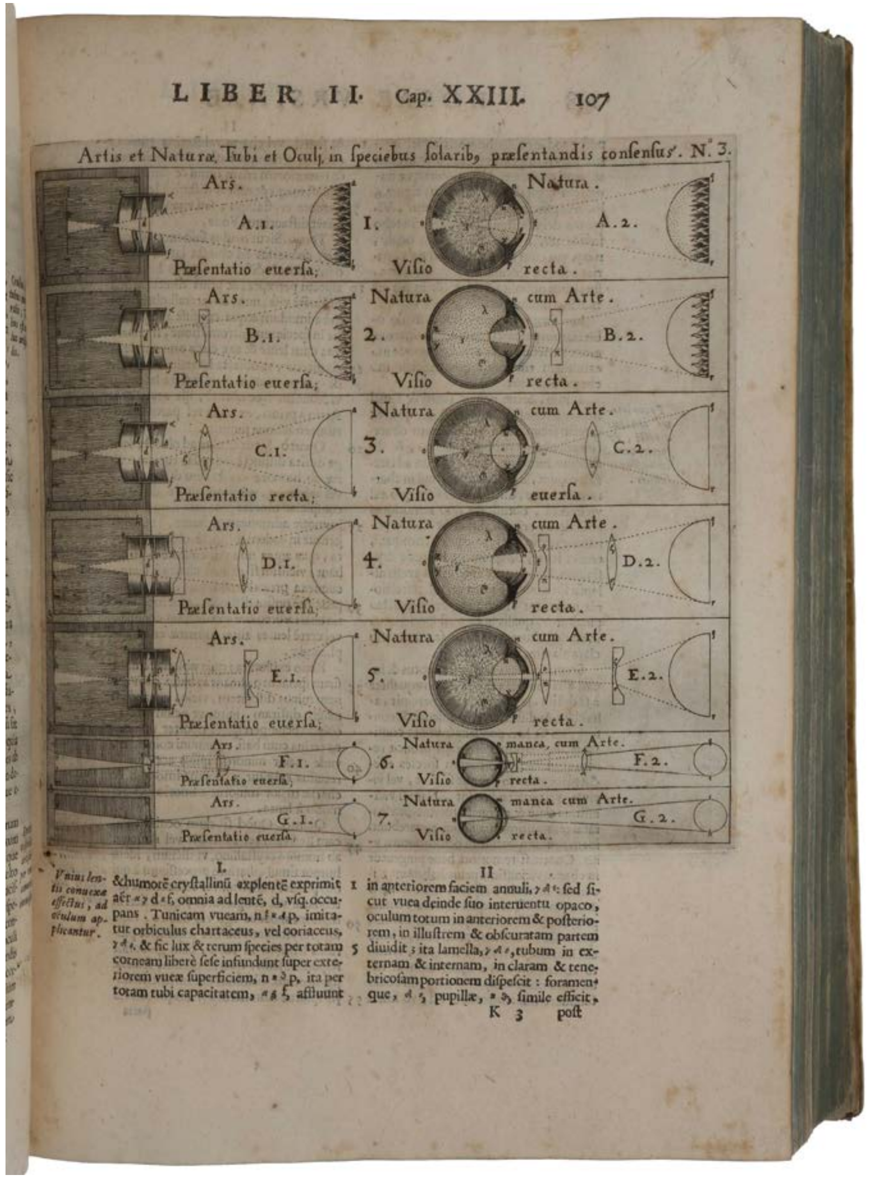
Scheiner (1573-1650) was appointed professor of Hebrew and mathematics at the Jesuit College at Ingolstadt in 1610. The following year Scheiner, together



with his student Johann Baptist Cysat (1587-1657), constructed a telescope with which to observe the satellites of Jupiter, partly to investigate the claims made by Galileo in *Sidereus nuncius* (1610). At sunrise one day in March, they decided to observe the sun and noticed dark spots on its surface, although initially they were unsure whether this might be due to flaws in the lenses or to clouds. Scheiner was preoccupied with observations of Jupiter, and also of Venus, but Cysat persuaded him to return to the solar observations using coloured glass to enable them to observe in full daylight, a technique that was used by sailors when taking the altitude of the Sun. This was on 21 October, as Scheiner tells us in *Rosa Ursina* (Ad Lectorum, p. [2]). Others soon became aware of his observations, including the well-connected Augsburg humanist Marc Welser (1558-1614). Scheiner wrote three letters to Welser, dated 12 November and 19 and 26 December, which Welser published at his private press under the title *Tres epistolae de maculis solaribus* (1612). They appeared pseudonymously, as Scheiner's Jesuit superiors urged caution, and were signed *Apelles latens post tabulum*, 'Apelles hiding behind the painting' (this refers to a story told by Pliny, well known in the Renaissance, about the famed Greek painter Apelles hiding behind one of his pictures to hear the comments of spectators). Welser sent copies abroad, notably to Galileo (1564-1642). Galileo identified Scheiner as a Jesuit and took him to task in three letters addressed to Welser, to which Scheiner replied in a further series of letters published as *De maculis solaribus … accuratior disquisitio* (1612). In this work Scheiner discussed the individual motions of the spots, their period of revolution, and the appearance of brighter patches or *faculae* on the surface of the sun. Galileo's letters were published in Rome in 1613 as *Istoria e dimostrazioni intorno alle macchie solari*. His criticism of Scheiner's priority claims was misconceived, for the sunspots were observed independently not only by Galileo in Florence and Scheiner in Ingolstadt, but also by Thomas Harriot in Oxford (who was the first to observe them by telescope), Johann Fabricius in Wittenberg (who was the first to publish a work on sunspots), and Domenico Passignani in Rome.

Having declared victory with the publication of *Istoria e dimostrazioni*, Galileo turned to other matters, notably the controversy on the comets (in which Scheiner may have played a role behind the scenes) and the preparation of the *Dialogo*. Scheiner was admonished personally by Claudio Aquaviva (1543-1615), the Superior General of the Jesuits, to follow the doctrines of traditional philosophy, and in his publications he now concentrated on the strictly mathematical and non-controversial subject of optics. Nevertheless, "it was in this period that Scheiner laid the foundations of his greatest work, *Rosa Ursina*. He had constructed a 'helioscope' for observing the Sun: the image of the Sun through the telescope was projected onto a sheet of paper placed about one metre from the eyepiece. This was a technique developed by Benedetto Castelli (1578-1643) and used by Galileo, but in his continuing study of sunspots and in demonstrating them to others, Scheiner made successive improvements. Following the sun with one's telescope in order to keep the sun's image centred on the paper was very difficult. The first problem was that the form of telescope he used projected an inverted image. In following the motion of the Sun, therefore, one has to turn the telescope in the direction contrary to the motion of the solar image … Scheiner had studied Kepler's *Dioptrice* (1611), and he knew that there was more than one combination of lenses to achieve the telescopic effect. Replacing the concave ocular with a convex one would produce an inverted direct image but an erect *projected* image, making manipulation of the telescope much easier … Since this combination of lenses presents an inverted image if one looks through it, one would expect that for terrestrial purposes it would be useless, and neutral, at best, for astronomical purposes. But when Scheiner looked through the combination, he found something unexpected:

'If you fit two like [convex] lenses in a tube … and apply your eye to it in the proper way, you will see any terrestrial object whatever in an inverted position but with an incredible magnitude, clarity and width. But also you will compel any



stars you wish you submit to your sight; for since they are all round, the inversion of the position of the total view is not confusing to the visual configuration' [fol. 130r].

"The astronomical telescope, as an instrument with a convex ocular is called, has a much larger field of view and brighter image than the Galilean form of the instrument. The replacement of the Galilean telescope by the astronomical telescope can, in fact, be dated from the publication of *Rosa Ursina* in 1630 …

"Besides using a telescope with a convex ocular for projection, Scheiner also provided the entire apparatus with a convenient mounting [p. 77]. The main axis of the mounting is made parallel to the axis of rotation of the Earth, so that an object in the sky can be followed merely by turning the telescope around this axis. This means that on the pre-drawn circle on which the image of the Sun is projected, the Sun's path (the ecliptic) is always represented by a horizontal line. Scheiner systematically taught his students and associates to draw the perpendicular to this horizontal line, in order not to make errors in the complicated motions of the spots [pp. 158-9].

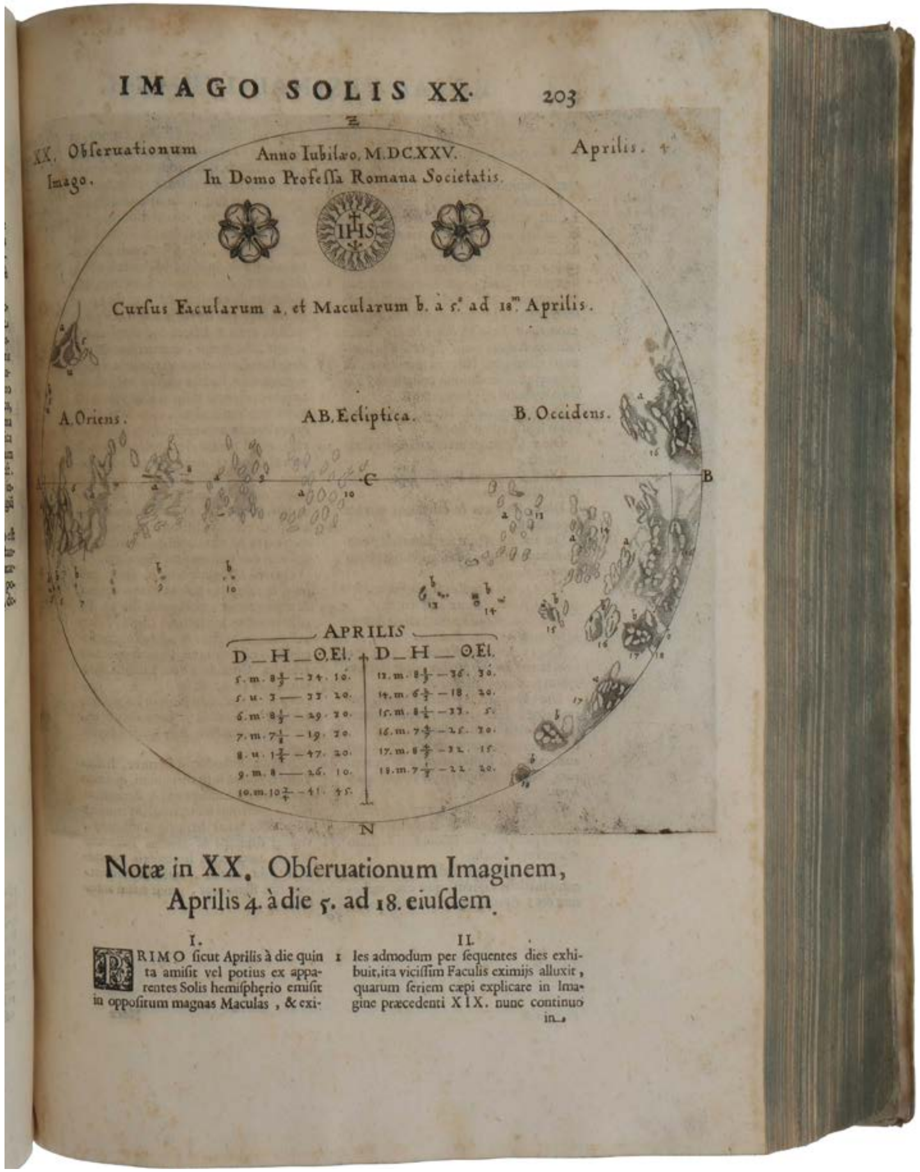
"But other duties increasingly occupied Scheiner, and it was not until he had settled in Rome in 1624 that he could return to sunspots. Obtaining the observations that he and others had made in the German region was complicated by the campaign of the Thirty Years' War, and many of those which he did manage to procure from various observers were useless because no perpendicular had been marked. His student Georg Schönberger (1596-1645) did, however, send observations with the perpendicular line, and Scheiner was able to use them to demonstrate the curved motions of the spots …

"In Rome Scheiner made a large number of excellent observations of sunspots,

using this time an equatorial mounting for his projection apparatus [p. 349], designed by his colleague Christoph Grienberger (1561-1636) and, in 1626, began the publication process. The central argument of the *Rosa Ursina* was the demonstration that Galileo had erred on the path of the spots and had concluded that the Sun's axis of rotation was perpendicular to the ecliptic in his letters on sunspots on 1612-1613. Scheiner determined that this axis is, in fact, inclined to that perpendicular by 7° 15′. Scheiner was especially eager to keep that information from Galileo before unveiling it in *Rosa Ursina* … The printing of *Rosa Ursina* began in 1626 and was finished in 1630. It was a magisterial work that was to remain the definitive study of sunspots for over a century …

"Galileo and his associates were certainly aware of Scheiner's presence in Rome in these years, and they commented occasionally on both his forthcoming work on the sunspots and on his relationship with the powerful Archduke Leopold and with Cardinal Francesco Barberini, nephew to Pope Urban VIII … In early 1626 Francesco Stelluti related that Scheiner was printing his sunspot observations, and that he had asked if it was true that Galileo was engaged in publishing a treatise called 'On the tides.' Scheiner appeared tolerably well informed, for this was in fact the subject of the eventual Fourth Day of the *Dialogue*, the original title of the work, and a question that Galileo had been investigating for its evidence of a Copernican world system about a year earlier. The Jesuit astronomer evidently added that he was eager to see such a work, and that he concurred with Galileo's opinion about the world system.

"It is certain that the exchanges in 1625-1626 between Scheiner and Galileo's friends in Rome were guarded and less than candid, as if both sides correctly sensed that the much anticipated works of the two rivals would involve open conflict. Over the next few years Galileo's friends urged him repeatedly to finish his *Dialogue*, and in early 1629 Castelli, writing from Rome, told him 'soon we

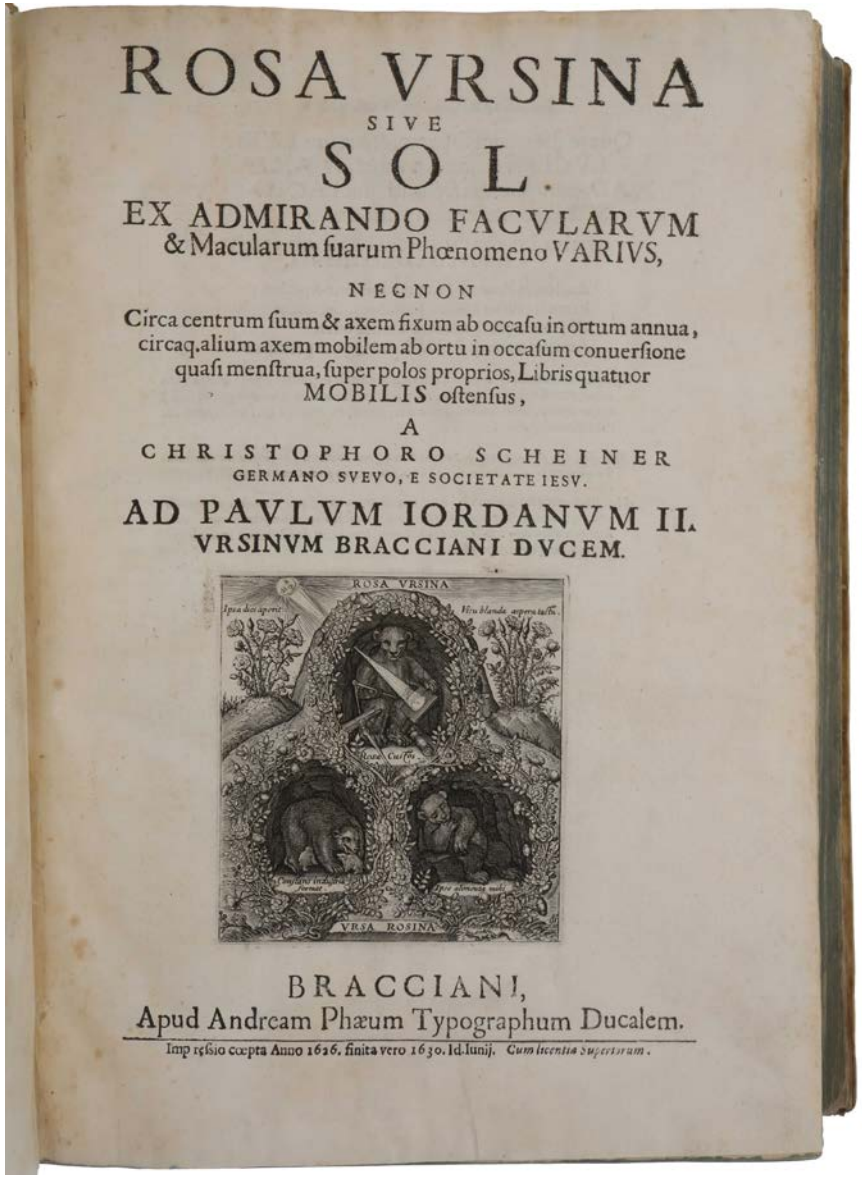


will have a big new book on sunspots from the masked Apelles. We shall see.' A month later Castelli promised to send a copy to Florence as soon as it became available, and as if to inspire Galileo to devote himself particularly to the issue of solar phenomena. He also reported on the timely return of a vast sunspot that had passed from view fifteen days earlier. Galileo, for his part, insisted upon his low expectations of his rival's work, telling another friend that spring that he was certain that wherever the *Rosa Ursina* diverged from what had earlier been established in the *History and Demonstrations*, Scheiner would simply be offering 'nonsense and lies'.

"The enormous work emerged a year later, in the spring of 1630; Juan de Alvarado S.J. of the Collegio Romano noted on 28 May 1630 that the *Rosa Ursina* had been licensed by Father Niccolo Riccardi, master of the Holy Palace. Galileo was by then in Rome seeking permission for his recently completed *Dialogue* … The imprimatur was granted in mid-September 1630.

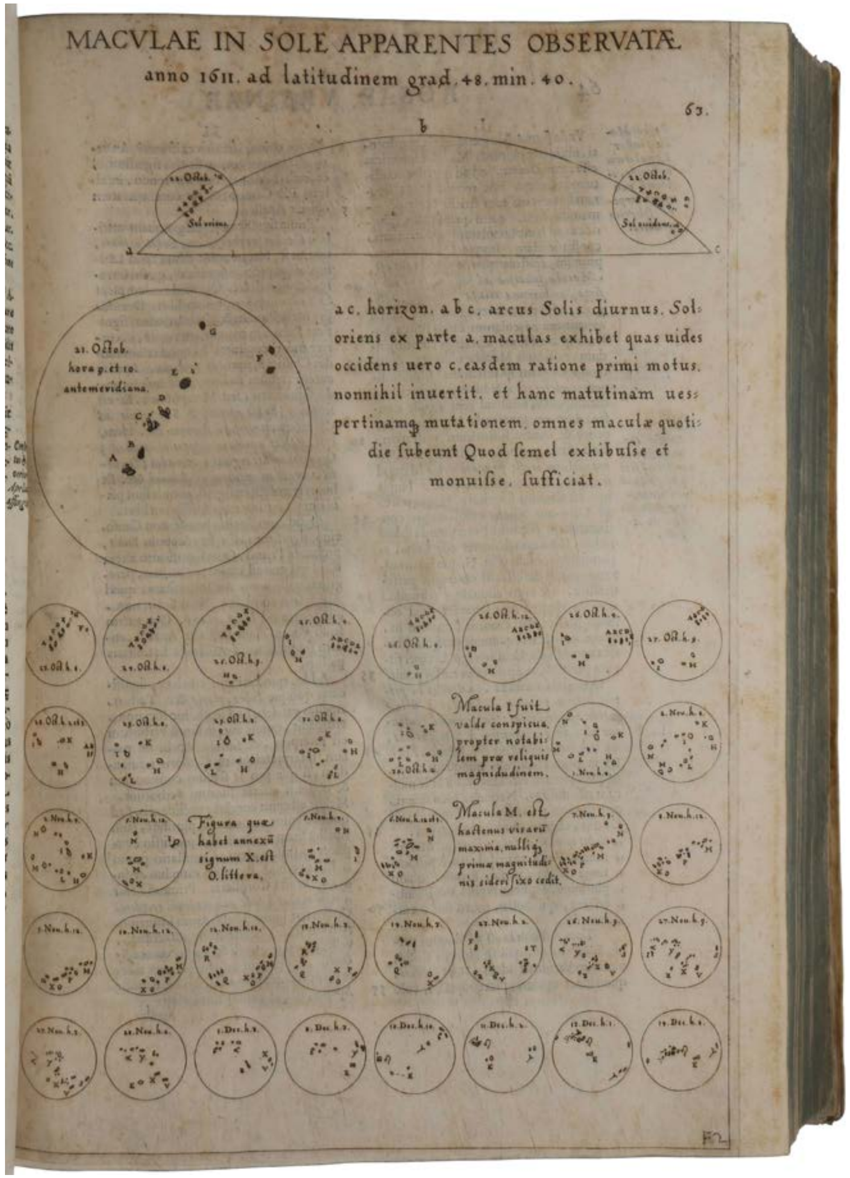
"Though Galileo heard in mid-April 1631 that Scheiner referred to his letters on sunspots with great frequency and hostility in the *Rosa Ursina*, he claimed not to have seen the treatise until the fall or winter of that year, when he expressed his displeasure to Paolo Giordano [II] Orsini (1591-1656), duke of Bracciano, who now regretted, both for fiscal and for personal reasons, having agreed to finance the expensive publication …

"Scheiner had very accurately determined the solar axis of rotation. Accounting for this phenomenon by means of a geocentric construction was a straightforward astronomical exercise of the kind technical astronomers had done at least since Ptolemy. To the standard solar description of the Sun's diurnal and annual motions, Scheiner added a construction to make the Sun rotate in about a month



on an axis that pointed to a place in the fixed stars 7° 15′ removed from the pole of the ecliptic. To keep this axis always pointing to the same spot (i.e., to keep it parallel to itself), Scheiner added a conical construction [shown on p. 565]. All of Scheiner's aims had been achieved: he had shown Galileo to be wrong about the motion of sunspots, had demonstrated the correct movement, and had supplied a mathematical model to account for that motion" (*On Sunspots*, pp. 311-323).

Scheiner's pleasure at the publication of his greatest work was to be short lived. If it seemed to some that Galileo was the target of the *Rosa Ursina*, Scheiner felt that he was likewise the victim of the *Dialogo* when it emerged in the spring of 1632. In the First Day, a discussion of sunspots formed part of Galileo's arguments against the perfection of the heavens. Salviati asked, 'But you, Simplicio, what have you thought of to reply to the objections based on these annoying spots which have come to mess up the heavens and even more so the Peripatetic philosophy?' Simplicio answered with Scheiner's original argument, that sunspots were dark bodies orbiting the Sun, and continued sarcastically, 'this seems to me to be the most convenient escape found so far to account for such a phenomenon and at the same time retain the indestructibility and ingenerability of the heavens; and, if this were not sufficient, there will be no lack of loftier intellects who will find better explanations.' But worse was to come. In the Third Day, Galileo recounted his discovery of sunspots, his initial supposition that the Sun turned on an axis of rotation perpendicular to the ecliptic, and his eventual, but still timely, conclusion to the contrary. Salviati recalled, in the only passages in the *Dialogo* that purport to contain direct quotations from his friend Galileo, that having observed a large and solitary sunspot, they noted that its passage was not exactly in a straight line, and that Galileo had then put forward the explanation that the axis around which the Sun revolves is not perpendicular to the plane of the ecliptic, but somewhat inclined to it.



There are several reasons to doubt this account. Salviati died in 1614, so the observations he describes would have to have been made before that time, and there is no evidence in Galileo's papers to support his claim. Moreover, upon receiving his copy of the *Dialogo*, Castelli wrote to Galileo: 'When I got to that false attestation of the sunspots, I was beside myself with happiness in seeing how much light these dark marks shed on the matter.' But if Galileo had made this discovery in 1613 or earlier, when Castelli was working very closely with him and had developed their method of projecting sunspots, he would surely have known about it and would not have expressed himself in this way on receiving Galileo's work. Although it is not certain, it certainly seems probable that Galileo's knowledge of the annual paths of sunspots derives from the *Rosa Ursina*, and that his focus on this issue on Day Three of the *Dialogo* reflects changes made to his text after the imprimatur had been granted (see *On Sunspots*, pp. 325-7).

Rosa Ursina contains four books. In Book I, Scheiner discusses the question of priority in regard to the discovery sunspots. Book II not only describes telescopes, different kinds of projection and the helioscope, but also compares the optics of the telescope to the physiological optics of the eye. In Book III, Scheiner presents a comprehensive collection of the data from his observation of the sunspots. Book IV consists of two parts: the first part deals once again with solar phenomena like sunspots and faculae, the Sun's rotation period of 27 days and the inclination of its axis of rotation; in the second part, Scheiner mentions numerous passages and quotations from the Bible, the writings of the Church Fathers and philosophers to prove that his geocentric view is in accordance with the teachings of the Catholic Church.

The last few pages of the main text comprise the first printing of Prince Federico Cesi's important letter of 1618 to Cardinal Robert Bellarmine, 'De caeli unitate, tenuitate, fusaque & pervia stellarum motibus natura' (pp. [775]-782) with Bellarmine's reply (pp. 783-784). In his letter Cesi (1585-1630), head of the Roman *Accademia dei Lincei* and ally of Galileo, defended the concepts of a 'fluid' and 'elemental' cosmos; he may even have written this work as part of a plan to resuscitate the Copernican cause after the Condemnation of 1616. What is equally significant is that Cardinal Bellarmine (1542-1621), who was by no means sympathetic to Copernicanism, accepted Cesi's theses with equanimity and responded that these positions were most certainly true.

The quality of the illustrations in the *Rosa Ursina* is exceptional. The engraved plate on the title is a play on the caption 'Rosa Ursina / Ursa Rosina', featuring a rose-festooned bower-cave with three bears, one with a telescope which is projecting an image of the sun onto a board. "The frontispiece of this volume is an elaborate allegory on epistemology and the sources of truth. At the top, two beams of light stream out from the Godhead, and they are labelled Sacred Authority and Reason. Both derive their certainty from God. Below, two more beams emanate from the Sun, and they illuminate Profane Authority and Sense. Note that Sense is represented by a view through the telescope of the spots on the sun. Note also that the telescopic sunspots are fuzzy and imprecise. If we return to Reason at top right, we see that Reason too is represented by a view of the Sun, but this time the spots are sharp and clear. It is Reason, Scheiner seems to be saying, that allows us to make 'sense' of our senses; Sense alone is never enough to establish anything with certainty. This frontispiece beautifully captures the divide that separated Galilean science and Jesuit science" (Ashworth, lindahall.org/christoph-scheiner/). The main anti-Copernican element of Scheiner's frontispiece is its rendering of the Rose of the Orsini, *Rosa Ursina*, which formed part of the Orsini family's coat of arms. Scheiner had dedicated his work to the Orsini family. The spotted Sun, depicted by the rose of the Orsini, can be seen in the very centre of the frontispiece, moving on the zodiac, thereby refuting the idea of heliocentricity. The portrait of Orsini (looking rather ursine) is surrounded by a garland of roses interspersed with maculate suns. Another plate, which serves as a frontispiece to Book III, shows Jesuit astronomers at work with telescopes, before which is a depiction of a darkened room in which an image of the Sun is being projected from a telescope, with one astronomer taking measurements and another transferring them onto paper, certainly a representation of how the sunspot illustrations in the book itself were made. It is signed by the engraver Daniel Widman.

"Scheiner attended the Jesuit Latin school at Augsburg and the Jesuit College at Landsberg before he joined the Society of Jesus in 1595. In 1600 he was sent to Ingolstadt, where he studied philosophy and, especially, mathematics under Johann Lanz. From 1603 to 1605 he spent his "magisterium", or period of training as a teacher, at Dillingen, where he taught humanities in the Gymnasium and mathematics in the neighbouring academy. During this period he invented the pantograph, an instrument for copying plans on any scale; and his results were published several years later in the *Pantographice, seu ars delineandi* (1631). He returned to Ingolstadt to study theology, and after completing his second novitiate or 'third year' at Edersberg, he was appointed professor of Hebrew and mathematics at Ingolstadt in 1610 … From 1633 to 1639 Scheiner lived in Vienna and then in Neisse, where he was active in pastoral work until his death in 1650" (DSB).

The collations given for this work vary because of the peculiar mixture of pagination and foliation. But this copy is complete. After page 125 [-126] the book is foliated 126-149 (the latter being P6), followed by 12 leaves (gatherings Q-R^6, all but R6 (which is blank) foliated 149); pagination recommences with aa2 (aa1,

beginning *Liber tertius*, is unpaginated) which is paginated 149. Furthermore, pages 511-522 are mispaginated 459-470.

Backer-Sommervogel VII, 738 8; Carli & Favaro 116; Cinti 79; Grässe VI, 298; Parkinson p. 74; *Jesuit Science in the Age of Galileo* 6; Rowland 19. Galilei & Scheiner (Reeves & Van Helden, tr.), *On Sunspots*, 2010. On the Cesi-Bellarmine correspondence, see: Galluzzi, *The Lynx and the Telescope* (2017), Ch. 7.

ONE OF THE KEY DOCUMENTS IN THE HISTORY OF COMPUTER SCIENCE

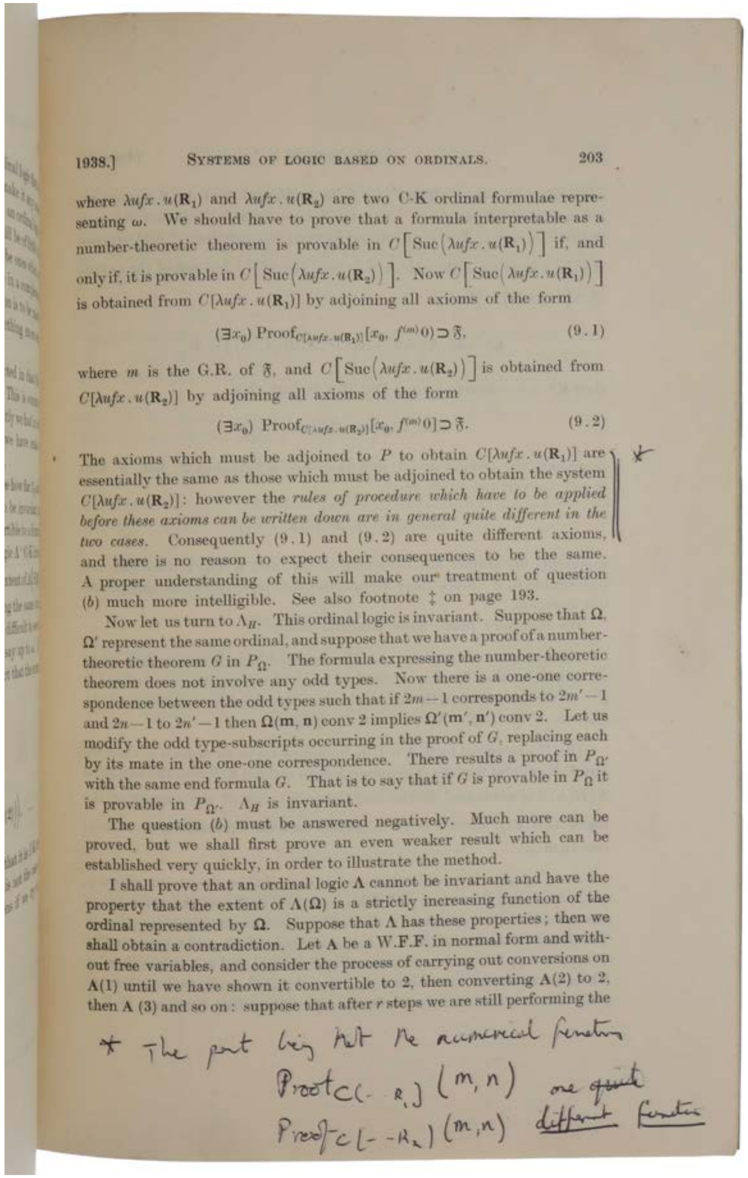
TURING, Alan Mathison. *Systems of Logic Based on Ordinals.* London: C.F. Hodgson & Son, 1939.

$28,500

Offprint from: Proceedings of the London Mathematical Society, Second Series, Vol. 45, pp. 161-228. 8vo (258 x 178 mm), original printed wrappers (plain rear wrapper replaced from another similar issue of the journal, spine worn with loss at head and foot, some light soiling, pencil inscription 'With corrections by ROG' on upper wrapper and some corrections and annotations in pencil by Gandy in text).

First edition, the incredibly rare offprint issue, and the copy of Robin Gandy, of Turing's PhD thesis, "one of the key documents in the history of mathematics and computer science" (Appel), and perhaps Turing's most formidable paper. "*Systems of logic based on ordinals* is a profound work of first rank importance. Among its achievements are the exploration of a means of circumventing Gödel's incompleteness theorems; the introduction of the concept of an 'oracle machine,' thereby opening the field of relative computability; and, in the wake of the demolition of the Hilbert programme (by Gödel, Turing and Church), an analysis of the place of intuition in mathematics and logic" (Copeland, p. 126). ABPC/RBH list only one other copy, also given to Gandy (Christie's, May 21, 2014, lot 45, £22,500).

"Turing's 1938 Princeton PhD thesis, *Systems of logic based on ordinals,* which includes his notion of an oracle machine, has had a lasting influence on computer



1938.] SYSTEMS OF LOGIC BASED ON ORDINALS. 203

where $\lambda ufx . u(\mathbf{R}_1)$ and $\lambda ufx . u(\mathbf{R}_2)$ are two C-K ordinal formulae representing ω. We should have to prove that a formula interpretable as a number-theoretic theorem is provable in $C\left[\mathrm{Suc}\left(\lambda ufx . u(\mathbf{R}_1)\right)\right]$ if, and only if, it is provable in $C\left[\mathrm{Suc}\left(\lambda ufx . u(\mathbf{R}_2)\right)\right]$. Now $C\left[\mathrm{Suc}\left(\lambda ufx . u(\mathbf{R}_1)\right)\right]$ is obtained from $C[\lambda ufx . u(\mathbf{R}_1)]$ by adjoining all axioms of the form

$$(\exists x_0)\ \mathrm{Proof}_{C[\lambda ufx . u(\mathbf{R}_1)]}[x_0, f^{(m)}0) \supset \mathfrak{F}. \qquad (9.1)$$

where m is the G.R. of $\mathfrak{F}$, and $C\left[\mathrm{Suc}\left(\lambda ufx . u(\mathbf{R}_2)\right)\right]$ is obtained from $C[\lambda ufx . u(\mathbf{R}_2)]$ by adjoining all axioms of the form

$$(\exists x_0)\ \mathrm{Proof}_{C[\lambda ufx . u(\mathbf{R}_2)]}[x_0, f^{(m)}0] \supset \mathfrak{F}. \qquad (9.2)$$

The axioms which must be adjoined to P to obtain $C[\lambda ufx . u(\mathbf{R}_1)]$ are essentially the same as those which must be adjoined to obtain the system $C[\lambda ufx . u(\mathbf{R}_2)]$: however the *rules of procedure which have to be applied before these axioms can be written down are in general quite different in the two cases.* Consequently (9.1) and (9.2) are quite different axioms, and there is no reason to expect their consequences to be the same. A proper understanding of this will make our treatment of question (*b*) much more intelligible. See also footnote ‡ on page 193.

Now let us turn to Λ_H. This ordinal logic is invariant. Suppose that Ω, Ω' represent the same ordinal, and suppose that we have a proof of a number-theoretic theorem G in P_Ω. The formula expressing the number-theoretic theorem does not involve any odd types. Now there is a one-one correspondence between the odd types such that if $2m-1$ corresponds to $2m'-1$ and $2n-1$ to $2n'-1$ then $\Omega(\mathbf{m}, \mathbf{n})$ conv 2 implies $\Omega'(\mathbf{m}', \mathbf{n}')$ conv 2. Let us modify the odd type-subscripts occurring in the proof of G, replacing each by its mate in the one-one correspondence. There results a proof in $P_{\Omega'}$ with the same end formula G. That is to say that if G is provable in P_Ω it is provable in $P_{\Omega'}$. Λ_H is invariant.

The question (*b*) must be answered negatively. Much more can be proved, but we shall first prove an even weaker result which can be established very quickly, in order to illustrate the method.

I shall prove that an ordinal logic Λ cannot be invariant and have the property that the extent of $\Lambda(\Omega)$ is a strictly increasing function of the ordinal represented by Ω. Suppose that Λ has these properties; then we shall obtain a contradiction. Let $\mathbf{A}$ be a W.F.F. in normal form and without free variables, and consider the process of carrying out conversions on $\mathbf{A}(1)$ until we have shown it convertible to 2, then converting $\mathbf{A}(2)$ to 2, then $\mathbf{A}$ (3) and so on: suppose that after r steps we are still performing the science and mathematics... A work of philosophy as well as mathematics, Turing's thesis envisions a practical goal – a logical system to formalize mathematical proofs so that they can be checked mechanically. If every step of a theorem could be verified mechanically, the burden on intuition would be limited to the axioms... Turing's vision of 'constructive systems of logic for practical use' has become reality: in the twenty-first century, automated 'formal methods' are now routine" (Appel).

Turing studied at King's College, Cambridge, becoming a Fellow in 1935. In that year he attended the logic lectures of the topologist M. H. A. Newman, from which he learned of the *Entscheidungsproblem*: Could there exist, at least in principle, a definite method or process by which it could be decided whether any given mathematical assertion was provable? His negative answer to this question was published in 1936 as *On computable numbers, with an application to the Entscheidungsproblem*,' shortly after Alonzo Church at Princeton had published his own solution. Turing's paper, containing the description of his 'universal machine,' is now recognized as the founding theoretical work of modern computer science. "It was only natural that the mathematician M. H. A. Newman should suggest that Turing come to Princeton to work with Church. Some of the greatest logicians in the world, thinking about the issues that in later decades became the foundation of computer science, were in Princeton's (old) Fine Hall in the 1930s: Gödel, Church, Stephen Kleene, Barkley Rosser, John von Neumann, and others. In fact, it is hard to imagine a more appropriate place for Turing to have pursued graduate study. After publishing his great result on computability, Turing spent two years (1936–38) at Princeton, writing his PhD thesis on 'ordinal logics' with Church as his adviser...

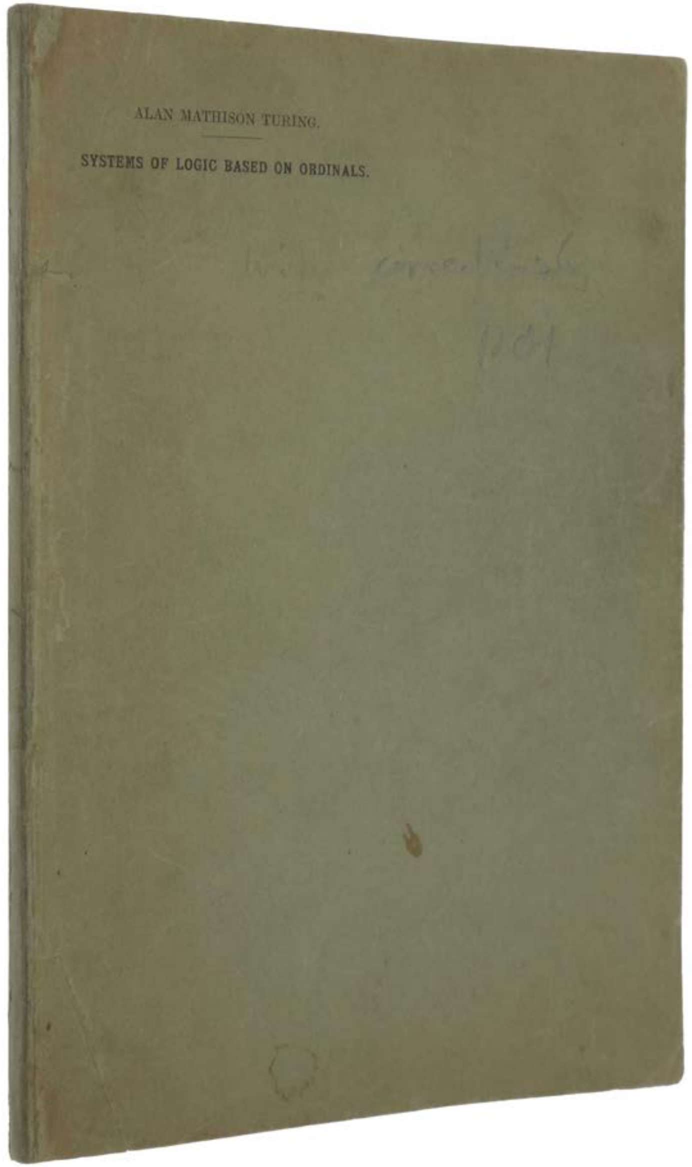
"[In his PhD thesis], Turing turns his attention from computation to logic. Gödel and Church would not have called themselves computer scientists: they were mathematical logicians; and even Turing, when he got his big 1936 result 'On computable numbers,' was answering a question in *logic* posed by Hilbert in 1928. Turing's thesis, *Systems of Logic Based on Ordinals*, takes Gödel's stunning incompleteness theorems as its point of departure. Gödel had shown that if a formal axiomatic system (of at least minimal expressive power) is consistent, then it cannot be complete. And not only is the system incomplete, but the formal statement of the consistency of the system is true and unprovable if the system is consistent. Thus if we already have informal or intuitive reasons for accepting the axioms of the system as true, then we ought to accept the statement of its consistency as a new axiom. And then we can apply the same considerations to the new system; that is, we can iterate the process of adding consistency statements as new axioms. In his thesis, Turing investigated that process systematically by iterating it into the constructive transfinite, taking unions of logical systems at limit ordinal notations. His main result was that one can thereby overcome incompleteness for an important class of arithmetical statements (though not for all)...

"Just as one of the strengths of Turing's great 1936 paper was its philosophical component—in which he explains the motivation for the Turing machine as a model of computation—here in the PhD thesis he is also motivated by philosophical concerns, as in section 9: 'We might hope to obtain some intellectually satisfying system of logical inference (for the proof of number theoretic theorems) with some ordinal logic. Gödel's theorem shows that such a system cannot be wholly mechanical, but with a complete ordinal logic we should be able to confine the non-mechanical steps entirely to verifications that particular formulae are ordinal formulae.'

"Turing greatly expands on these philosophical motivations in section 11 of the thesis. His program, then, is this: We wish to reason in some logic, so that our proofs can be mechanically checked (for example, by a Turing machine). Thus we don't need to trust our students and journal-referees to check our proofs. But no (sufficiently expressive) logic can be complete, as Gödel showed. If we are using a given logic, sometimes we may want to reason about statements unprovable in that logic. Turing's proposal is to use an ordinal logic sufficiently high in the hierarchy; checking proofs in that logic will be completely mechanical, but the one 'intuitive' step remains of verifying ordinal formulas...

"But the PhD thesis contains, almost as an aside, an enormously influential mathematical insight. Turing invented the notion of oracles, in which one kind of computer consults from time to time, in an explicitly axiomatized way, a more powerful kind. Oracle computations are now an important part of the tool kit of both mathematicians and computer scientists working in computability theory and computational complexity theory. This method may actually be the most significant result in Turing's PhD thesis" (Appel, Chapter 1: *The Birth of Computer Science at Princeton in the 1930s*).

The preparation of the thesis was somewhat protracted, partly because of the clash of styles between Church and Turing. Turing found Church's lectures "ponderous and excessively precise; by contrast, Turing's native style was rough-and-ready and prone to minor errors" (Feferman, p. 4). "[Turing] ended up with a draft containing the main results by Christmas of 1937. But then he wrote Philip Hall [who had been his undergraduate tutor at Cambridge] in March 1938 that the work on his thesis was 'proving rather intractable, and I am always rewriting parts of it.' Later he wrote that 'Church made a number of suggestions which resulted in the thesis being expanded to an appalling length.'" (ibid., p. 5). Church's influence may have also been partly responsible for the rather muted reception of the thesis. "One reason that the reception of Turing's [PhD thesis] may have been so limited is that (no doubt at Church's behest) it was formulated in terms



of the λ-calculus, which makes expressions for the ordinals and formal systems very hard to understand" (Appel, *loc.cit.*, p. 4). Following an oral examination in May, on which his performance was noted as 'Excellent,' Turing was granted his PhD in June 1938.

Provenance: From the library of Robin Oliver Gandy (1919-95). "[Gandy's] interest in [mathematical logic] commenced through his wartime acquaintance with Alan Turing as far back as 1944. His twin interests in the foundations of science and mathematics were fostered by Turing. These interests moulded a career which always seemed larger than his publication list, although that grew in diversity with the years to include some seminal papers. Initially, he read widely and published little, but around 1960 he started to produce the major results which made him an international figure in the theory of abstract recursion and in effective, descriptive set theory. There were also major conceptual innovations such as the theory of inductive definitions, and a plethora of ingenious intricate proofs in different corners of the subject. He wrote papers on many areas of logic and was much in demand as a reviewer of books on the foundations of mathematics and science. He remained active and productive and was a familiar figure at international conferences until his sad and unexpected death (from an aortic rupture) on November 20th, 1995.

"He was born on September 22nd, 1919, in Peppard, Oxfordshire, where his father, Thomas Gandy, was in general practice. His mother Ida Gandy earned a reputation for a sequence of books based on her early life in Wiltshire. Educated at Abbotsholme, a progressive public school, he went on to join that special elite at King's College, Cambridge, intellectual home of such famous names as E. M. Forster the novelist, J. Maynard Keynes the economist – and Alan Turing. He met Turing at a party in 1940 (Gandy's graduation year) but their early wartime careers were separate. Gandy was commissioned in the Royal Electrical and Mechanical Engineers and became an expert on military radio and radar, whilst Turing joined the cryptanalysts at Bletchley Park. They were brought together at Hanslope Park in 1944 to work on a speech decipherment system, christened 'Delilah' at Gandy's suggestion because it was intended to be a 'deceiver of men'.

"Their friendship continued after the war, back at King's College where Turing had resumed his fellowship. Gandy took Part III of the Mathematical Tripos with distinction, then began studying for a PhD under Turing's supervision; his successful thesis on the logical foundation of physics (*On axiomatic systems in mathematics and theories in physics*) was presented in 1953 and can now be seen as a bridge between his wartime expertise and later career. When Turing died in 1954 he left his mathematical books and papers to Gandy, who, in 1963, took over from Max Newman the task of editing the papers for publication" (Moschovakis & Yates, pp. 367-8).

Offprints of Turing's papers are extremely rare in institutional holdings, and even more so in commerce. We have located only two copies: one in the Alan Turing Archive at King's College Cambridge (AMT/B/15), one at St. Andrew's, and then one in the Max Newman collection at Bletchley Park.

Andrew W. Appel (ed.), *Alan Turing's Systems of Logic: The Princeton Thesis*, Princeton University Press, 2012; B. J. Copeland, *The Essential Turing*, Clarendon Press, 2004; Solomon Feferman, 'Turing's Thesis,' *Notices of the American Mathematical Society*, Vol. 53, 2006, pp. 1-8; Andrew Hodges, *Alan Turing: The Enigma*, 1983, pp. 142-3; Yiannis Moschovakis & Mike Yates, 'In Memoriam: Robin Oliver Gandy 1919-1995', *Bulletin of Symbolic Logic*, Vol. 2, 1996, pp. 367-370.

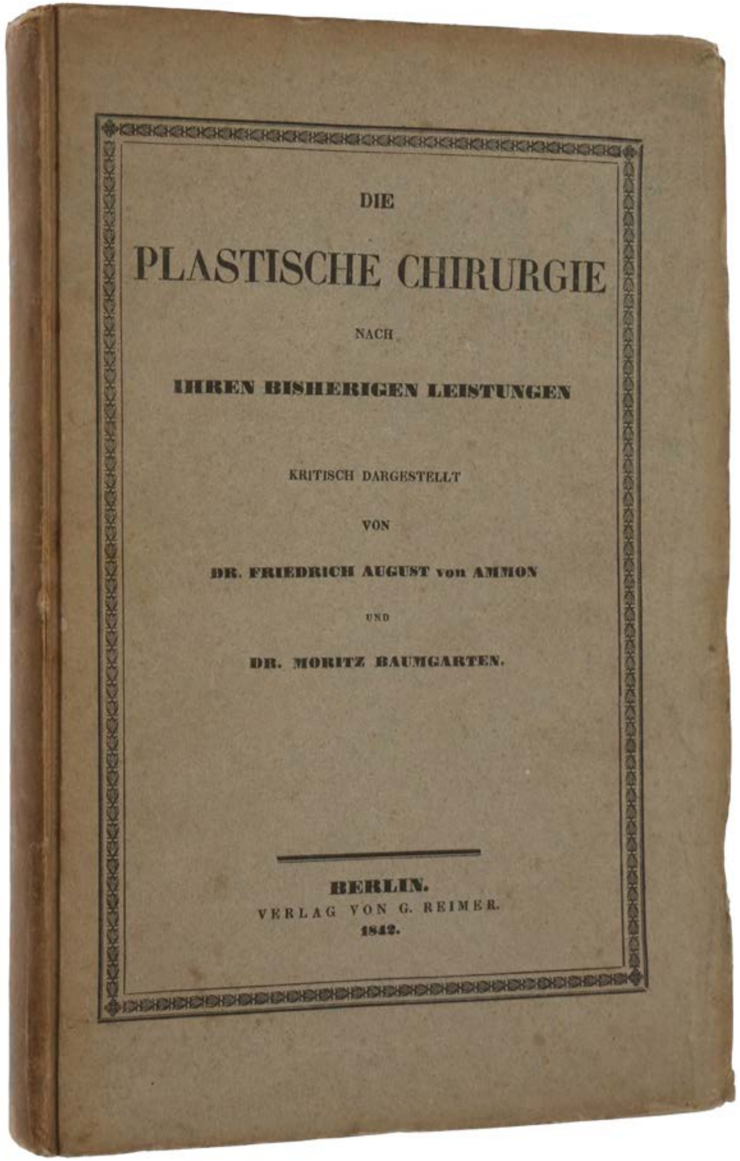
A CLASSIC IN PLASTIC SURGERY

VON AMMON, Friedrich August & BAUMGARTEN, Moritz. *Die Plastische Chirurgie Nach Ihren Bisherigen Leistungen Kritisch Dargestellt.* Berlin: Reimer, 1842.

$4,500

8vo (230 x 150 mm), pp. xxvi, 310, original printed boards, unopened.

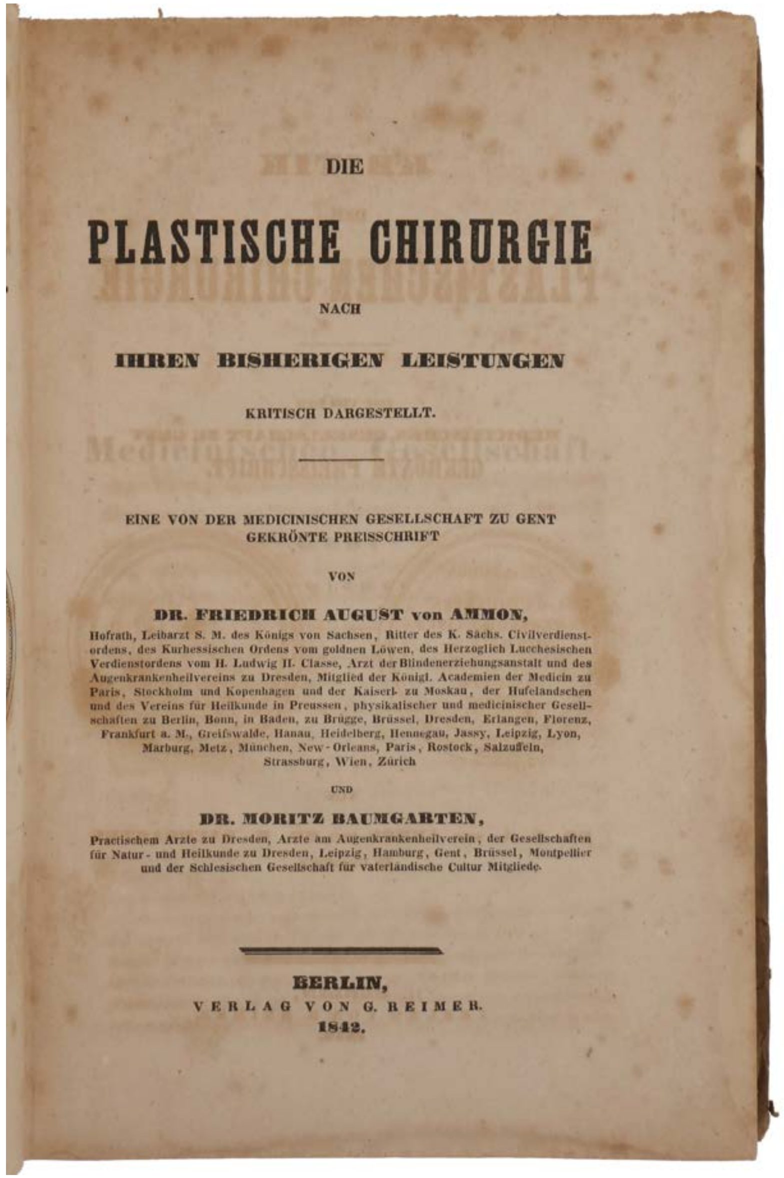
First edition, a wonderful copy in completely original state, of the first critical review of the new field of plastic surgery, and the second comprehensive work on the subject, preceded only by Eduard Zeis's *Handbuch der plastischen Chirurgie* of 1838. Von Ammon was in fact Zeis's teacher, and he persuaded Zeis to write his *Handbuch*, which Zeis then dedicated to von Ammon and to Dieffenbach. In his *Die Literatur und Geschichte der plastischen Chirurgie* (1863), Zeis wrote: 'Von Ammon had already rendered good service to this branch of surgery over a long period of time, by the number of plastic operations which he had carried out – and also by his various papers, particularly on the physiology of transplanted tissue, when he published with Baumgarten in 1842 his *Kritik der plastischen Chirurgie* [an alternative title], for which they were awarded a prize by the Medical Society of Ghent. Very little new material had appeared after my textbook [*Handbuch*], so that it was only necessary for these authors to add a few details and to give a critical discussion of the material which I had collected" (Zeis, p. 108). Ammon "exercised a tremendous influence on the plastic surgery of his time. His friendship with Dieffenbach induced him to make great contributions to plastic surgery, both through his critical reports and his publication of new methods, especially for the areas of the lips and lids" (Gabka & Vaubel, *Plastic Surgery Past and Present*, p.



134). Ammon is best known for his work in ophthalmology, notably for his great atlas of the pathology of the eye. He took a special interest in ophthalmic plastic surgery and gives a full account of blepharoplasty and canthoplasty in this book. Rare in this condition.

“Friedrich August von Ammon (1799-1861) was a German surgeon and ophthalmologist born in Göttingen. He was the son of theologian Christoph Friedrich von Ammon (1766–1850). He studied medicine at the Universities of Göttingen and Leipzig, and following an educational journey through Germany and Paris, he settled in Dresden in 1823 as a physician. Here his primary focus dealt with surgical and surgical-anatomical duties. In 1828 he attained the title of professor, becoming director of the surgical-medical academy in Dresden. In 1837 he was named royal physician to Friedrich August II, King of Saxony. Known for his work in ophthalmology, he was instrumental in making Dresden a center of ophthalmic learning during his lifetime. In 1830 founded *Zeitschrift für die Ophthalmologie*, an early journal devoted to ophthalmology. In his prize-winning book, *De Iritide* (1835), he made contributions involving investigations of iritis and sympathetic ophthalmia. His most ambitious written effort in the field of ophthalmology was *Klinische Darstellung der Krankheiten und Bildungsfehler des menschlichen Auges* (1838-47), a monograph acclaimed for its comprehensive treatment of eye disease, as well as for its superb hand-colored illustrations and its descriptions of congenital eye anomalies. One of Ammon’s earlier works was an impartial comparative study between French and German surgery titled *Vergleich zwischen französischer und deutscher Chirurgie* (1823)” (Wikipedia, accessed 24 April, 2018).

Albert, Norton & Hurtes 58. Becker catalogue 15. Garrison-Morton 5744. Wallace, *Progress of plastic surgery* 47. Zeis, *Index* 463.



DIE

PLASTISCHE CHIRURGIE

NACH

IHREN BISHERIGEN LEISTUNGEN

KRITISCH DARGESTELLT.

EINE VON DER MEDICINISCHEN GESELLSCHAFT ZU GENT GEKRÖNTE PREISSCHRIFT

VON

DR. FRIEDRICH AUGUST von AMMON,

Hofrath, Leibarzt S. M. des Königs von Sachsen, Ritter des K. Sächs. Civilverdienstordens, des Kurhessischen Ordens vom goldnen Löwen, des Herzoglich Lucchesischen Verdienstordens vom H. Ludwig II. Classe, Arzt der Blindenerziehungsanstalt und des Augenkrankenheilvereins zu Dresden, Mitglied der Königl. Academien der Medicin zu Paris, Stockholm und Kopenhagen und der Kaiserl. zu Moskau, der Hufelandschen und des Vereins für Heilkunde in Preussen, physikalischer und medicinischer Gesellschaften zu Berlin, Bonn, in Baden, zu Brügge, Brüssel, Dresden, Erlangen, Florenz, Frankfurt a. M., Greifswalde, Hanau, Heidelberg, Hennegau, Jassy, Leipzig, Lyon, Marburg, Metz, München, New-Orleans, Paris, Rostock, Salzuffeln, Strassburg, Wien, Zürich

UND

DR. MORITZ BAUMGARTEN,

Practischem Arzte zu Dresden, Arzte am Augenkrankenheilverein, der Gesellschaften für Natur- und Heilkunde zu Dresden, Leipzig, Hamburg, Gent, Brüssel, Montpellier und der Schlesischen Gesellschaft für vaterländische Cultur Mitgliede.

BERLIN,

VERLAG VON G. REIMER.

1842.

A VERY FINE SET OF THE DNA-PAPERS

WATSON, J. D. & CRICK, F. H. C. *Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid*; **WILKINS, M. H. F., STOKES, A. R. & WILSON, H. R.** *Molecular Structure of Deoxypentose Nucleic Acids*; **FRANKLIN, R. E. & GOSLING, R. G.** *Molecular Configuration in Sodium Thymonucleate*, pp. 737-41 in Nature, Vol. 171, No. 4356, April 25, 1953. [WITH:] **WATSON, J. D. & CRICK, F. H. C.** *Genetical Implications of the Structure of Deoxyribonucleic Acid*, pp. 964-7 in Nature, Vol. 171, No. 4361, May 30, 1953. [WITH:] **FRANKLIN, R. E. & GOSLING, R. G.** *Evidence for 2-Chain Helix in Crystalline Structure of Sodium Deoxyribonucleate*, pp. 156-7 in Nature, Vol. 172, No. 4369, July 25, 1953. [WITH:] **WILKINS, M. H. F., SEEDS, W. E. STOKES, A. R. & WILSON, H. R.** *Helical Structure of Crystalline Deoxypentose Nucleic Acid*, pp. 759-62 in Nature, Vol. 172, No. 4382, October 24, 1953; [WITH:] **PAULING, L. & COREY, R. B.** *Structure of the Nucleic Acids*, p. 346 in Nature, Vol. 171, No. 4347, February 21, 1953.

$16,500

Five complete journal issues, 4to, 4347: pp. cxiii-cxxii, 317-336, i-xii, 337-358, cxiii-cxxx; 4356: pp. cclxix-cclxxviii, 709-732, i-xii, 733-758, cclxxix-cclxxxvi; 4361: pp. ccclv-ccclxii, 943-964, i-xvi, 965-986, ccclxiii-ccclxx; 4369: pp. li-lx, 131-150, i-xii, 151-172, lxi-lxviii; 4382: pp. ccxciii-ccc, 737-758, i-xvi, 759-780, ccci-cccviii. Original printed wrappers. A virtually mint set. Rare in such fine condition.

First edition of Watson & Crick's paper which "records the discovery of the molecular structure of deoxyribonucleic acid (DNA), the main component of chromosomes and the material that transfers genetic characteristics in all life forms. Publication of this paper initiated the science of molecular biology. Forty years after Watson and Crick's discovery, so much of the basic understanding of medicine and disease has advanced to the molecular level that their paper may be considered the most significant single contribution to biology and medicine in the twentieth century" (*One Hundred Books Famous in Medicine*, p. 362). Watson & Crick's paper is here accompanied by their paper published one month later "in which they elaborated on their proposed DNA replication mechanism" (*ibid.*), together with the four papers which provided the experimental data on which their proposed structure was based, and further data confirming its correctness. In 1962, Watson, Crick, and Wilkins shared the Nobel Prize in Physiology or Medicine "for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material."

DNA was first isolated by the Swiss physician Friedrich Miescher in 1869, and over the succeeding years many researchers investigated its structure and function, with some arguing that it may be involved in genetic inheritance. By the early 1950s this had become one of the most important questions in biology. Maurice Wilkins of King's College London and his colleague Rosalind Franklin were both working on DNA, with Franklin producing X-ray diffraction images of its structure. Wilkins also introduced his friend Francis Crick to the subject, and Crick and his partner James Watson began their own investigation at the Cavendish Laboratory in Cambridge, focusing on building molecular models. After one failed attempt in which they postulated a triple-helix structure, they were banned by the Cavendish from spending any additional time on the subject. But a year later, after seeing new X-ray diffraction images taken by Franklin (notably the famous 'Photo 51', which is reproduced in the third offered paper), they resumed their work and soon announced that not only had they discovered the double-helix structure of DNA, but even more importantly, that "the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."

"When Watson and Crick's paper was submitted for publication in *Nature*, Sir Lawrence Bragg, the director of the Cavendish Laboratory at Cambridge, and Sir John Randall of King's College agreed that the paper should be published simultaneously with those of two other groups of researches who had also prepared important papers on DNA: Maurice Wilkins, A.R. Stokes, and H.R. Wilson, authors of "Molecular Structure of Deoxypentose Nucleic Acids," and Rosalind Franklin and Raymond Gosling, who submitted the paper "Molecular Configuration in Sodium Thymonucleate." The three papers were published in *Nature* under the general title "The Molecular Structure of Nucleic Acids." Shortly afterwards, Watson and Crick published their paper "Genetical Implication of the Structure of Deoxyribonucleic Acid," in which they elaborated on their proposed DNA replication mechanism" (*ibid.*). In this last paper Watson & Crick state their conclusion simply and elegantly: "we feel that our proposed structure for deoxyribonucleic acid may help solve one of the fundamental biological problems--the molecular basis of the template needed for genetic replication." The two papers in Vol. 172 provide confirmation of the double-helix structure based on further X-ray diffraction data.

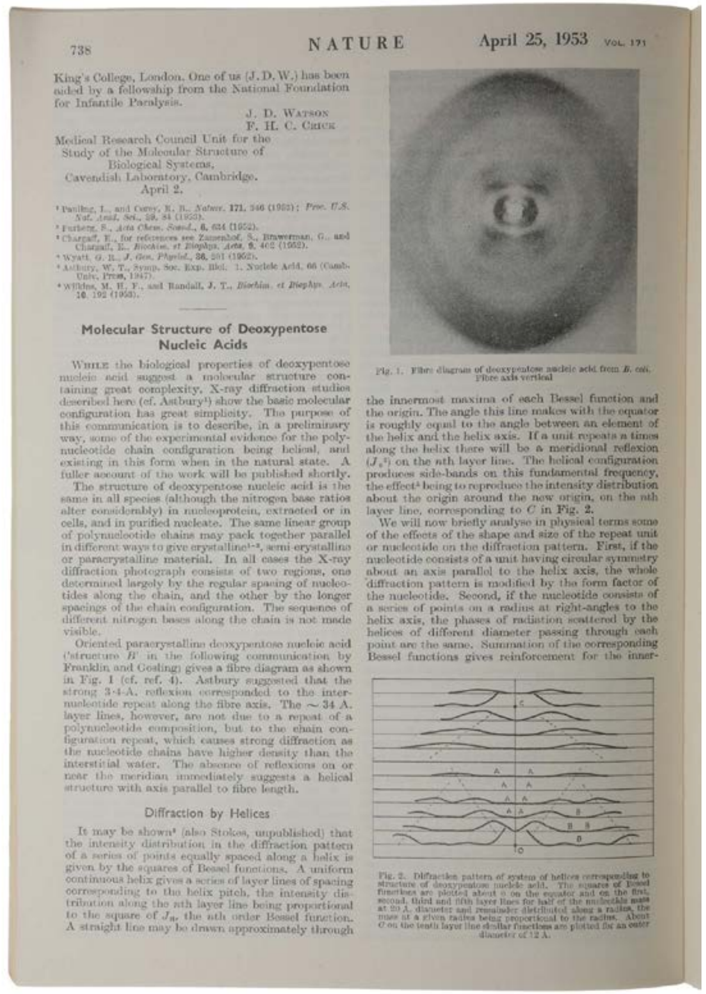
The papers of the Cambridge and King's College, London scientists are here accompanied by an earlier attempt at elucidating the structure of DNA by the great Caltech chemist Linus Pauling, who had already solved the secondary structure of proteins. Pauling's hypothetical DNA structure – a triple helix with the phosphates in the middle and the bases radiating outwards – was similar to one Watson and Crick had first advanced a year earlier and then rejected on both chemical and physical grounds. It failed to accommodate Chargaff's observation that the abundance of A in DNA approximately equals T, and C equals G; it also fails to explain the biology and replication of DNA. Watson described his feelings upon reading the Pauling manuscript in *The Double Helix* (p. 102): "At once I felt something was not right. I could not pinpoint the mistake, however, until I looked at the illustrations for several minutes. Then I realized that the phosphate groups in Linus' model were not ionized, but that each group contained a bound hydrogen atom and so had no net charge. Pauling's nucleic acid in a sense was not an acid at all. Moreover, the uncharged phosphate groups were not incidental features. The hydrogens were part of the hydrogen bonds that held together the three intertwined chains. Without the hydrogen atoms, the chains would immediately fly apart and the structure vanish."

The realization that Pauling was not, as they had feared, on the right track gave Watson and Crick the green light to pursue their own model of DNA. A few days after first seeing their structure, Pauling received an advance copy of the Watson/Crick manuscript. In a letter to Watson and Crick written on March 27, 1953, Pauling noted:

"I think that it is fine that there are now two proposed structures for nucleic acid, and I am looking forward to finding out what the decision will be as to which is incorrect."

However, he had still not seen Rosalind Franklin's data; Watson and Crick had. (Interestingly enough, Robert Corey had traveled to England in 1952 and viewed Franklin's photographs. It is unknown whether or not he purposely failed to provide Pauling with the details of the images.) In April 1953, on his way to a conference in Belgium, Pauling stopped in England to see the Watson and Crick model of DNA as well as Franklin's photographs. After examining both, Pauling was finally convinced that his structure was wrong and that Watson and Crick had found the correct DNA structure. For Pauling, this event was a single failure in a sea of successes. In fact, the very next year, he would win the Nobel Prize in Chemistry – the first of his two Nobel Prizes.

Grolier Club, *One Hundred Books Famous in Medicine*, 99; Dibner, *Heralds of Science*, 200. Garrison-Morton 256.3; Judson, *Eighth Day of Creation*, pp. 145-56.



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King's College, London. One of us (J. D. W.) has been aided by a fellowship from the National Foundation for Infantile Paralysis.

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April 2.

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Molecular Structure of Deoxypentose Nucleic Acids

WHILE the biological properties of deoxypentose nucleic acid suggest a molecular structure containing great complexity, X-ray diffraction studies described here (cf. Astbury[1]) show the basic molecular configuration has great simplicity. The purpose of this communication is to describe, in a preliminary way, some of the experimental evidence for the polynucleotide chain configuration being helical, and existing in this form when in the natural state. A fuller account of the work will be published shortly.

The structure of deoxypentose nucleic acid is the same in all species (although the nitrogen base ratios alter considerably) in nucleoprotein, extracted or in cells, and in purified nucleate. The same linear group of polynucleotide chains may pack together parallel in different ways to give crystalline[1-3], semi-crystalline or paracrystalline material. In all cases the X-ray diffraction photograph consists of two regions, one determined largely by the regular spacing of nucleotides along the chain, and the other by the longer spacings of the chain configuration. The sequence of different nitrogen bases along the chain is not made visible.

Oriented paracrystalline deoxypentose nucleic acid ('structure *B*' in the following communication by Franklin and Gosling) gives a fibre diagram as shown in Fig. 1 (cf. ref. 4). Astbury suggested that the strong 3·4-A. reflexion corresponded to the internucleotide repeat along the fibre axis. The ~ 34 A. layer lines, however, are not due to a repeat of a polynucleotide composition, but to the chain configuration repeat, which causes strong diffraction as the nucleotide chains have higher density than the interstitial water. The absence of reflexions on or near the meridian immediately suggests a helical structure with axis parallel to fibre length.

Diffraction by Helices

It may be shown[5] (also Stokes, unpublished) that the intensity distribution in the diffraction pattern of a series of points equally spaced along a helix is given by the squares of Bessel functions. A uniform continuous helix gives a series of layer lines of spacing corresponding to the helix pitch, the intensity distribution along the *n*th layer line being proportional to the square of J_n, the *n*th order Bessel function. A straight line may be drawn approximately through

Fig. 1. Fibre diagram of deoxypentose nucleic acid from *B. coli*. Fibre axis vertical

the innermost maxima of each Bessel function and the origin. The angle this line makes with the equator is roughly equal to the angle between an element of the helix and the helix axis. If a unit repeats *n* times along the helix there will be a meridional reflexion (J_0^2) on the *n*th layer line. The helical configuration produces side-bands on this fundamental frequency, the effect[5] being to reproduce the intensity distribution about the origin around the new origin, on the *n*th layer line, corresponding to *C* in Fig. 2.

We will now briefly analyse in physical terms some of the effects of the shape and size of the repeat unit or nucleotide on the diffraction pattern. First, if the nucleotide consists of a unit having circular symmetry about an axis parallel to the helix axis, the whole diffraction pattern is modified by the form factor of the nucleotide. Second, if the nucleotide consists of a series of points on a radius at right-angles to the helix axis, the phases of radiation scattered by the helices of different diameter passing through each point are the same. Summation of the corresponding Bessel functions gives reinforcement for the inner-

Fig. 2. Diffraction pattern of system of helices corresponding to structure of deoxypentose nucleic acid. The squares of Bessel functions are plotted about 0 on the equator and on the first, second, third and fifth layer lines for half of the nucleotide mass at 20 A. diameter and remainder distributed along a radius, the mass at a given radius being proportional to the radius. About *C* on the tenth layer line similar functions are plotted for an outer diameter of 12 A.