About *Opticks*

Isaac Newton *Opticks*

London 1704

The bare bones of Sir Isaac Newton's biography are easily sketched. Born a posthumous child in England on Christmas Day, 1642, he entered Trinity College at Cambridge in 1661, was made a professor there in 1669 (he would retain the appointment for nearly six decades) and a Fellow of the Royal Society in 1672. He was chosen to represent the university in Parliament in 1689, was named England's Warden of the Mint in 1696 and its Master in 1699, subsequently being elected president of the Royal Society and dying laden with honors in 1727. The French *philosophe* Voltaire attended the funeral, later writing that "in a country where mortals are canonized, his discoveries might very well pass for miracles."

Newton can be seen as a Renaissance colossus, a polymath straddling his age with one foot confidently planted in the Enlightenment and the other still mired in the Middle Ages. A firm believer in reason and the ability of human beings to understand how the universe worked ("the inward frame of bodies is not *yet* known to us," he writes in one place, with apparent confidence that eventually it would be), he also held some surprisingly reactionary ideas about God, and about how the truth of Holy Writ could be reconciled with Nature. Raised a Puritan, he compiled a list of his sins at the age of nineteen (among them wishing several people dead, and threatening to burn down his stepfather's house, with the old man in it); Newton later in life came to disbelieve in the divinity of Christ. He did, however, remain a closeted Socinian (or as we would now say, Unitarian) who could and did reprove his dear friend Edmund Halley – for whom the spectacular comet which appeared in 1680 is now named – on account of the latter's unbelief and consequent blasphemies.

A genius? Undoubtedly; but also a mixture of frailties, who could say in all honesty that one of his experiments had proved less than he wished to know from it, yet could also connive in the official disapproval of the work of a rival (the mathematician Gottfried Wilhelm von Leibnitz, who invented his own version of the calculus simultaneously with Newton's) by the Royal Society, while concealing disingenuously his own conflict of interest as both president and party to the dispute. Newton did not suffer competitors gladly, however politely he expressed his scorn.

His contempt for Robert Hooke, whose *Micrographia* has already been published by Octavo, may have been that of a brilliant man for one whom he thought less clever than himself (much as Sir John Harington, godson of Good Queen Bess, translator of Ariosto's *Orlando Furioso*, and inventor of the world's first flush toilet, merrily ridiculed a hundred years earlier the grandiose claims of his contemporary, Hugh Plat, for the latter's own inventions). "The gall of envie, the venom of slander, the foam of malice" often characterized the intellectual controversies of Queen Anne's day, according to one of its novelists, Daniel Defoe; still, even at a distance of three centuries, Newton's mistreatment of Leibnitz seems egregious.

A great deal has been written (some of it surely apocryphal) about Newton the woolgathering professor and sometime-mad genius, including much speculation over his famous nervous breakdown in September 1693. Whatever the cause – biographer Frank Manuel's psychiatric paradigm persuaded him that it hinged on Newton's sexual ambivalence, citing as evidence Newton's letter to John Locke admitting his mistake in supposing Locke to have "endeavored to embroil me with woemen" [sic] – Newton's florid paranoid episode must surely to have been exacerbated by an extended period of sleep deprivation: "I had not slept an hour a night for a fortnight," he wrote to Locke a month later, "& for five nights together not a wink." Manuel and others have suggested that the episode may have been precipitated by Newton's disappointment when his protegé, the young Swiss mathematician and religious mystic Nicolas Fatio de Duillier, decided not to come to Cambridge to live near his mentor; this seems far-fetched but by no means impossible.

In any case, Newton was soon to be preoccupied with other work outside academe. The debasement of the currency during the civil wars of the 1600s had finally forced the government to take far-reaching measures which included the founding of a Bank of England, the issuing of new sterling coinage manufactured by horse-powered mills running 120 hours in the week, and a concomitant raising of the purity required of silversmiths to the 95+% "Britannia" fineness in order to discourage melting down the new coins into plate. Newton, Locke, and Halley all were asked to come to work for the mint, Newton being given the office of Warden and charged with enforcing statutes against coin-clipping and counterfeiting, which he did with punctilious severity.

Though Newton's work as an active scholar was greatly curtailed when his job at the mint began, he kept his hand in nevertheless: After a long day at the office in 1697, he stayed up most of the night working on a problem (called the "brachistochrone") posed by the Swiss scientist Johann Bernoulli, which the latter had been unable to solve, and which had confounded Leibnitz as well. Arriving at his solution at four in the morning, Newton promptly dispatched it to the Royal Society, asking that it be published anonymously in the group's *Philosophical Transactions*. Few were fooled, Bernoulli himself remarking to a friend that the reader could "tell the lion by the mark of his claw."

It was in the *Transactions* that Newton's earliest optical paper was published in 1672. The result of experiments arising from his attempt to solve the problem of chromatic aberration in telescopes (he had been grinding his own lenses for nearly a decade), his conclusion that white light contained all colors and that different colors were refracted to different degrees drew heated opposition from Hooke, who accused him of believing that light was a material substance.

That Newton came to think so later, if he did not at that time yet realize it, can be seen in his consideration of the relative velocities of light through different media in the tenth proposition of the second book of *Opticks*, beginning "If Light be swifter in Bodies than in Vacuo. . . ." In fact, such a belief was all of a piece with the atomistic worldview of Newton's predecessor, René Descartes; given the spectacular success with which the corpuscular paradigm could be used to explain a wide range of terrestrial and celestial phenomena, it is no wonder that Newton embraced it with zeal.

Meanwhile, his efforts to solve the problem of chromatic aberration yielded a valuable practical result still in use today: Having determined that a very long ratio of aperture to length would result in spyglass tubes of unwieldy size, he solved the problem by inventing the reflecting telescope, described in Book I, Proposition VII, Problem II.

As Thomas Kuhn has pointed out in his *Structure of Scientific Revolutions*, the mythologizing tendency in "normal" science is to represent its own history as a linear journey down the highway of progress without detours into roadside rest areas, let alone wrong exits. The publishing history of *Opticks* suggests a different story. By Newton's own admission, most of the research described in the book had been completed long before the first edition reproduced on this CD. Indeed, anecdotes from Newton's Cambridge days include the story that an earlier draft of this work was destroyed in 1692 by a fire in his room, caused by a candle left burning while the scientist went to supper (though even some of his contemporaries viewed this tale with skepticism).

Opticks was reprinted several times early in the 1700s. Editions included Newton's Latin translation of 1706 and several other English printings culminating in a posthumous one dated 1730, advertised as "corrected by the author's own hand and left before his death with his bookseller." But though it was well known and highly praised throughout the century, the book would fall into relative obscurity a few generations later. Once the scientific community had generally adopted the wave-centered paradigm expounded by Augustin Jean Fresnel and others at the beginning of the 1800s, Newton's vigorous and thorough exposition of a corpuscular theory of light, to the exclusion of any other model, came to be seen as something of an embarrassment: a wrong turn by a brilliant researcher and theoretician, of which the less said the better. (Newton's alchemical writings, as well as his theological/historical discourse, likewise underwent benign neglect.)

Only with the 20th century, and its realization that light can and does behave both as if it were a wave phenomenon and as something made up of particles, do we see *Opticks* pulled from the back of the shelf, dusted off, and presented to the English-speaking world again by the British publisher Bell and Sons in 1931 – now shorn of the two Latin mathematical treatises curiously appended to the 1704 edition.

A reasonable proficiency in written Latin, the common language of European scholarly discourse since the founding of the medieval universities, remained a prerequisite for communication between educated people across national and linguistic borders well into the 18th century; so it is not surprising that among the earliest surviving manuscripts in Newton's own hand are a set of Latin exercises written when he was in his teens, nor that several careful translations he made into English of Latin geometry papers by his revered college professor, Isaac Barrow, are included in the canon of Newton's own works.

The modern reader may nevertheless find it odd that the edition of *Opticks* reproduced on this CD includes the two

Latin essays, and still odder on discovering that their subjects bear virtually no relation to the optical treatise preceding them. The "Tractatus de Quadratura Curvarum" and the "Enumeratio Linearum Tertii Ordinis" are excursions into higher mathematics: the classification of conic sections and the earliest published version of Newton's exploration of binomial theorem (including the earliest statement of the infinite series now called the "Taylor Expansion" – an example of which is log(1+x) $= x - \frac{1}{2}x^2 + \frac{1}{3}x - \frac{1}{4}x^4 + \ldots$).

Arguably, these two papers would better have been appended to an edition of the *Principia*. Yet it would be an error to dismiss them as mere speculations in pure mathematics, for as the first paragraph of the "Tractatus" points out: "Here I consider mathematical quantities, not as static entities of very tiny parts but as continual motion…lines from continual motion of points, surfaces from continual motion of lines, solids from continual motion of surfaces, and so on. These have their origin in nature…and are seen in the everyday motion of bodies." These speculations, Newton adds, arose from his examinations of velocity back in 1665-66, the year of the plague during which he stayed home from college (and began figuring out gravity and the calculus instead; in all likelihood no undergraduate has ever spent a more productive vacation).

Why were these two Latin essays unpublished till 1704? We do not know, though E.T. Whittaker, in his introduction to the 1931 edition of *Opticks*, suggests that Newton's dislike of criticism may have caused him to put off publication of that work until after "his most pertinacious antagonist Hooke had been removed by death in 1703;" perhaps a similar abhorrence of controversies in which Newton was not sure of victory in advance might have delayed the appearance of its mathematical appendices as well.

On the other hand, any modern reader with a cluttered desk might be forgiven for wondering if the simpler explanation might not be that the busy Master of the Mint and chair of the Royal Society simply hadn't got around to it, or even to imagine the absent-minded professor in him quite forgetting that he had the mathematical works virtually ready for the press until, in that day of far dearer paper than is manufactured by industrial pulp mills nowadays, the Royal Society's printer came to show him proofs for *Opticks* and asked him if, by any chance, he had something else on hand for make-weight to fill out the book's final few signatures.

But we must resist the temptation to add to an already robust Newton myth. What is certain is that in publishing *Opticks* Newton contributed to the growth of our knowledge about how light works even in his errors, for his work prompted a whole generation of scientists to attempt to reproduce his results and, eventually, to refute some of them. "A professor," anthropology professor Irven Devore once said – only partly in jest – "is a book's way of making another book."

Nicholas Humez

Nicholas Humez A Massachusetts-born and Harvard-educated silversmith, Nicholas Humez is the co-author, with his brother Alex, of a half-dozen books on the linguistic and cultural roots of the English language, including *Latin for People/Latina pro Populo* (Little, Brown: 1976) and, with Alex Humez and Joseph Maguire, *Zero to Lazy Eight: The Romance of Numbers* (Simon and Schuster: 1993); for seven years he was also the principal classical music critic for the *Portland Press Herald* and *Maine Sunday Telegram*. He now divides his time between Maine and New Jersey.

Opticks Binding

The binding of *Opticks* is of contemporary stained brown calfskin over pasteboard measuring 9 7/8 by 8 inches (251 x 202 mm). The front and back boards have blind double rules on the four edges with blind rules creating an interior panel. Blind arabesque decorations are on the outer corners of the panel with flower tooling in the inner corners. The spine is divided into six panels with blind rules outlining the bands. The gilt title is on the red leather label of the second panel, with blind scallop decoration at the head and tail of spine.

Click here to see binding

Collation 4^0: π^2, A-S^4, 2A-2B^4, 2D-2S^4, 2T^4 (2T1 + *2T1), 2U-3D^4, 3E^2 [$2 signed]; 181 leaves, pp. *[4]* 1-144, 1-137 [1] 138 [1] 139-211, *212* [=362] [misnumbered 120 as 112; var: page ^{2}138 inserted on separate leaf].

Contents: **π1^a**: title. **π1^b**: blank. **π2^{a-b}**: 'ADVERTISEMENT'. **A1^a-K4^b**: The FIRST BOOK | OF | OPTICKS. | PART I. **Insert**: plates. **L1^a-S4^b**: The FIRST BOOK | OF | OPTICKS. | PART II. **Insert**:

plates. **2A1^{a}-2E3^{b}**: The | SECOND BOOK | OF | OPTICKS. | PART I. **2E4^{a}-2G4^{b}**: The | SECOND BOOK | OF | OPTICKS. | PART II. **2H1^{a}-2M3^{b}**: The | SECOND BOOK | OF | OPTICKS. | PART III. **2M4^{a}-2P4^{b}**: The | SECOND BOOK | OF | OPTICKS. | PART IV. **Insert**: plates. **2Q1^{a}-2T1^{a}**: The | THIRD BOOK | OF | OPTICKS. | PART I. **2T1^{b}**: blank. **Insert**: plate. ***2T1^{a}-2Y1^{b}**: ENUMERATIO | LINEARUM | TERTII ORDINIS. **Insert**: plates. **2Y2^{a}**: TRACTATUS | DE | *Quadratura Curvarum.* **2Y3^{a}-3E2^{a}**: INTRODUCTIO. **Insert**: plate. **3E2^{b}**: ERRATA.

Plates: 19 double-folded plates: Book I, Part I, Plates I-V facing p. **K4^{b}** (p. 80). Book I, Part II, Plates I-IV facing **S4^{b}** (p. 144. Book II, Plates I-II facing **2P4^{b}** (p. ^{2}112). Book III, Plate I facing **2T1^{b}** (p. ^{2}138). Curvarum Tab. I-VI facing **2Y1^{b}** (p. 162). Quadr. Tab. I facing **3E1^{b}** (p. 210).

Why Latin?

Why did Newton choose to write and to publish in Latin? How did Latin come to be, and remain the common tongue of European scholars up to the nineteenth century?

The glib answer: "Because the Carthaginians lost." Carthage, founded by Phoenicians (in Phoenician, *Krt-hdsht* literally meant "Newtown"), in turn spawned colonies on the Iberian Peninsula, with its sailors making voyages out into the Atlantic Ocean trading for tin and other commodities down the African coast and as far north as Cornwall. But in the course of the three Punic Wars, several centuries before the Christian era, Carthage was utterly destroyed by Rome, which thus disposed of its only serious rival for regional hegemony and eventual empire.

Had Scipio and the other Roman generals not prevailed against Hannibal and his elephants, we might all be speaking local dialects of Phoenician to this day. As it is, once the Romans conquered Carthage, it was only a matter of time and military engineering before they consolidated their hold on the Mediterranean Sea and much of Europe besides. At the height of the empire Latin was spoken from Persia to Scotland and from Gibraltar to the Black Sea (see map below). Local languages might have been the vernacular, but anyone who want-

The Roman Empire at its height; a description of its unraveling, with accompanying maps, can be found at www.ancienthistory.miningco.com/msubpunic.htm ed to get ahead had to learn at least some Latin; and if their version lacked the niceties of Ciceronian oratory or Senecan tragedy, at least the legionaries and the locals could understand each other after a fashion. Rome reached its greatest expansion by about 200 A.D. From then on, the imperial borders were gradually whittled away; and a split with the largely Greek-speaking eastern half of the empire, while it allowed the latter to prosper until the end of the Middle Ages, left the western half to unravel under repeated assaults by the barbarian hordes. By the sixth century the Roman Empire teetered and toppled for the last time – but not before the Catholic Church had become its official state religion, and the guardian of literacy in the bargain. To this period belong St. Jerome (d. 420 A.D.), translator of the Bible into Latin – the Vulgate, so called because it rendered the Greek and Hebrew scriptures into Latin, the language spoken by the *vulgus*, i.e., the general populace – and his younger near-contemporary Priscian of Constantinople, author of a Latin grammar which was still being read in Shakespeare's day (when "to break Priscian's head" was a colorful synonym for committing a grammatical solecism).

Meanwhile, the local dialects of Latin had taken on regional flavor over the centuries until they became proto-French, proto-Spanish, proto-Romanian and so on – that is, the oldest forms of what are known today as the Romance languages. (The "Serment de Strasbourg," a document from the time of Charlemagne's sons, is revealing for being a French so old that it is late Latin or vice versa: It begins "Pro deo amur, et pro Christano poblo, d'ist di en avant…" – that is, "For the love of God and for the Christian people, from this day forward….") Literary Latin was still alive and well on paper by the sixth or seventh century, except that there were no native speakers of it: It had become a second language for everybody throughout Christendom, in every monastery and abbey and local parish church.

With the rise of the medieval universities in the great cathedral towns, Latin remained the language all learned people had in common. Whether scholars hailed from England, Germany, Italy, France, or Spain, they could be assured of understanding and being understood so long as they kept to Latin, whose highly inflected grammar fortunately makes synthesis of new terms very easy: Even if a speaker used a new word he had just made up by attaching an unaccustomed ending to an existing Latin root, he could be reasonably sure that the hearer or reader could figure out what was meant.

Although one important result of the Reformation was to undo the compulsory relationship between the Roman Catholic Church and Europe's universities, Latin continued to be used by scientists and speculative philosophers across the continent; hence it was part of the standard curriculum for anyone considering higher education. (So was Greek – a close second – both for biblical studies and for reading classic works by such writers as Plato and Aristotle in the original language as more of these earlier works came to light during the Renaissance.) It was only natural that Newton learned Latin before going to college, and though never a florid stylist, he shows a command of the language which never leads the reader astray. Newton's concepts are often complex, but the Latin in which he couches them is no more difficult than Livy's (and considerably easier reading than, say, Sallust or Suetonius).

Thanks in part to the rise of European nationalism in the 1800s, and individual countries' pride in their own tongues, by the turn of this century Latin had lost the privileged position it occupied for so long among educated people throughout the Western world. Still, certain disciplines hang onto it to this day, notably biological taxonomy (largely due to the monumental work of Carl von Linne, a Swede better known by his Latin name, Linnaeus), anatomy and medicine, and the law. So when we speak of Tyrannosaurus Rex, or a fracture of the femur, or a writ of habeas corpus, we continue to participate in the tradition of Latin as the common-denominator second language of the learned, a practice with a solid pedigree going back a millennium and more.

Nicholas Humez

Isaac Newton. *Opticks*. London, 1704. THE WARNOCK LIBRARY

OPTICKS:

OR, A

TREATISE

OF THE

REFLEXIONS, REFRACTIONS, INFLEXIONS and COLOURS

OF

LIGHT.

ALSO

Two TREATISES

OF THE

SPECIES and MAGNITUDE

OF

Curvilinear Figures.

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