University of Central Lancashire

Great Astronomers in History

AA1066

Available as a *University Certificate*
and a module for *CertHE*, *DipHE* and *BSc in Astronomy*.

Sample Notes

These sample pages from the Course Notes for the module *Great Astronomers in History* have been selected to give an indication of the level and approach of the course. They are not designed to be read as a whole, but are intended to give you a flavour of the syllabus, style, diagrams, images, equations, mathematical content and presentation. They are a subset of the colour, navigable on-line version of the learning materials.

All enrolled students will be sent a CDRom with all the Course Notes and learning materials, in addition to having access to them via the course website.

- All sections of notes will be available in modest colour and basic navigation in pdf format suitable for downloading and printing at home. It is anticipated that most students will prefer to use the notes in the colour pdf files on the CDRom.

- B/w paper copies will be sent out to anyone who has notified us that they have special educational needs.

July 2008

Section 8

Icon Key

Background Info

Biography

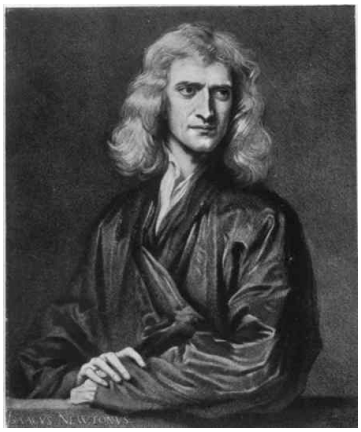
Work & Ideas

Activity for you

Questions

Common Myths

Isaac Newton



Newton (1642-1727) age 46

"By the time of his death in 1727 Newton stood as the representative figure of modern science…He became a key figure in the Enlightenment of the eighteenth century, and his work correspondingly aroused unease among Romantics who saw his science as inhuman and reductive A mythical Newton, a new Adam born on Christmas Day and nourished by an apple from the tree of knowledge, came to obscure the real man who had worked in dynamics, astronomy and optics, and less successfully in chemistry, to synthesize the work of great predecessors." David Knight[1]

The English civil war started in September 1642, the Royalists were defeated in 1647, and King Charles I was executed in 1649. The Commonwealth under Cromwell then ruled until the Restoration of Charles II in May 1660.

Francis Bacon died in 1626, well before the Commonwealth was established, but many of his ideas were influential throughout the period. Bacon advocated a radical break with earlier scholastic approaches to science. He says:

> "Those who have handled sciences have been either men of experiment or men of dogmas. The men of experiment are like the ant: they only collect and use; the reasoners resemble spiders, who make cobwebs out of their own

Francis Bacon (1561-1626)

[1] From the preface to Rupert Hall's *Isaac Newton Adventurer in Thought* (1992)

> substance. But the bee takes a middle course; it gathers its material from the flowers of the garden and of the field, but transforms and digests it by a power of its own. Not unlike this is the true business of philosophy; for it neither relies solely or chiefly on the powers of the mind, nor does it take the matter which it gathers from natural history and mechanical experiments and lay it up in the memory whole, as it finds it but lays it up in the understanding altered and digested. Therefore from a closer and purer league between these two faculties, the experimental and the rational, (such as has never yet been made) much may be hoped."[2]

Bacon's empiricism recognised that observation was not haphazard, and that it needed to go along with reason. He emphasized methodical, empirical work, in which experimentation would be used to interrogate rather than to simply observe nature. Hypotheses should not be jumped to quickly for:

> "The human understanding is of its own nature prone to suppose the existence of more order and regularity in the world than it finds. And though there be many things in nature which are singular and unmatched, yet it devises for them parallels and conjugates and relatives which do not exist, Hence the fiction that all celestial bodies move in perfect circles; spirals and dragons [*dracos*] being (except in name) utterly rejected."[3]

Bacon was probably not aware of Kepler's ellipses (published in 1609), but he is wary of prior assumptions as part of the "idols" he describes, which can prevent science reaching the truth. The title page of his *Novum Organum Scientiarum* shows a ship symbolically setting out through the pillars of Hercules, into the uncharted waters of new knowledge. This "millennial" aspect of his work (sometimes linked to a kind of religious millennialism) found a resonance in the Commonwealth. New knowledge and science, linked to technology, would improve the general lot of humankind. In his last work *The New Atlantis* (1626) he elaborated on the kind of scientific community which would be instrumental in bringing in this new age.

The reality was less exhilarating. We have noted the dearth of much astronomy in the times of Horrocks, and the next generation of astronomers saw little improvement. Figures like Thomas Streete (1622-89) and Jeremy Shakerley, carried on some of the Horrocks material and traditions, but are not well known. The nearest anything came to Bacon's vision was Gresham College, founded in London in 1598 with professors in music, rhetoric, divinity, law, physics, astronomy and geometry.[4] Puritan in tone, their work did encourage experimentation, and it was the professor of astronomy Henry Gellibrand whose commendation had focussed Horrocks on Lansberge as we noted. Gresham College was in decline in the 1630's but revived in the 1640's and from 1645 a group was meeting which later (under the leadership of Christopher Wren, Professor of Astronomy from 1657-1661)

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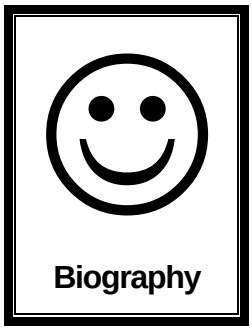
[2] Bacon *Novum Organum* (1620) xcv.
[3] *Ibid* xlvi
[4] See David Goodman and Colin A Russell *The Rise of Scientific Europe 1500-1800* (1991) ch. 8.

provided a basis for the foundation of the Royal Society in 1660. The other major root for the Royal Society was a group meeting in Wadham College Oxford from about 1645. Under the Commonwealth, Puritans received preferment in Oxford, including as Savillian Professor of Geometry from 1649 John Wallis (who had matriculated with Horrocks and later edited his papers). Wallis, as we shall see, was a major figure in mathematics and mechanics, being described as the "most influential English Mathematician before Newton."[5] All branches of the sciences were pursued experimentally. Robert Boyle led this Oxford axis after some of its leaders left in 1558 to revive the Gresham group. Members of these groups favoured religious toleration and were permeated by a Baconian spirit which was both anti-authoritarian and deeply Christian. Even when not actual Puritans, they tended to have deep religious convictions and led ascetic lives.[6] John Wilkins, for example, was central. A leading figure at Gresham College, he became Warden at Wadham College from 1648, reconnected with the Gresham group from 1654, married Cromwell's sister, was one of the first secretaries of the Royal Society (which he was a driving force in founding), and later became bishop of Chester. He also wrote about possible space travel to meet inhabitants on the moon![7]

The Royal Society[8] was founded on 28th November 1660 at an informal meeting after an astronomy lecture at Gresham College. Since scientists in Gresham, in Oxford and in Cambridge[9] tended often to be either Puritans or Anglican Whigs, the newly restored Charles II was unenthusiastic about giving his support. The society received a Royal charter in 1662, but, unlike its foreign counterparts, received little or no Royal patronage. The Society, however, became a focus for science across all disciplines. It was also practical, the sometime Professor of Astronomy Christopher Wren and the Royal Society Curator of Experiments Robert Hooke doing much to help design the rebuilding of London after the great fire in 1666.



Newton's Life

Formative Years

Isaac Newton was born in the year Galileo died, on Christmas day 1642.[10] At least, if you are English he was born that year. Italian friends of Galileo would have placed it as 4th January 1643, since on the Continent (unlike in England) they had accepted the reformed calendar. Any account like this can hope only to outline some key points in such a long productive life, and leave those interested to seek more detail in the various secondary works on Newton.[11]

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[5] From the entry in *Encyclopaedia Britannica.*
[6] This includes Robert Boyle at Oxford who, though like Newton, remained nominally Anglican.
[7] *Discovery of a World in the Moone* (2nd Edn 1640)
[8] Full title: "Royal Society of London for the Promotion of Natural Knowledge"
[9] The great naturalist John Ray (1627-1705) lost his fellowship at Trinity College Cambridge for refusing to sign the Act of Uniformity.
[10] For great detail of Newton's background etc see Richard Westfall *Never At Rest* (1980)
[11] Copious footnotes will be avoided, but the account is mostly indebted to Richard Westfall *Never At Rest* (1980) and A Rupert Hall *Isaac Newton (1992)* – though also to various other books as in the bibliography.

Like Horrocks's, Newton's family were "yeomen" rather than either gentlefolk or peasants. The place of his birth was the substantial farm house at Woolsthorpe, Lincolnshire. This was sturdy and spacious, though its title of "Manor House" should not bring to mind a picture of a stately home! His father, also Isaac Newton, was a prosperous though illiterate farm owner, and had married Hannah Ainscough who was from a more genteel and educated but less prosperous background. Isaac senior died two months before Isaac was born, leaving the house, lands, and also goods and chattels worth £459 12s 4d – quite a sum. By his own later account, the baby Isaac was premature, tiny, and the general view was that he would be unlikely long to survive. He was baptised on 1st January 1643 (O.S.)[12] in Colsterworth Parish Church. The area is about seven miles south of Grantham, a market town.

Woolsthorpe – With Apple Tree!

Colsterworth Parish Church

Three years later Hannah Ainscough-Newton, aged thirty, remarried to a sixty-three year old minister Rev. Barnabas Smith, rector of the next parish about a mile and a half away. Smith was the son of a minister, an Oxford graduate, and owned a large library particularly of the early fathers (which Isaac later inherited). Rev Mr Smith was well off, but did not want young Isaac with his mother, so from age 3 until Smith's death in August 1653 Isaac was brought up by his grandparents in the Woolsthorpe house. Biographers sometimes link Newton's later neuroses with this traumatic maternal separation (albeit only to a distance of under two miles), and in a list of his sins he compiled nine years after being reunited with his mother he reported one as:

Rev Barnabas Smith's Church and House

> "Threatening my father and mother Smith to burne them and the house over them."[13]

School – and Graffiti

[12] O.S. means the "Old Style" Julian calendar, Since then England too has added ten days to bring us back into line with Europe's new calendar as noted above.
[13] Quoted eg in Westfall, *Op Cit*, p. 53.


Grantham Now - With Newton's Statue

At age twelve Isaac went to the Free Grammar School of King Edward VI of Grantham – lodging with the apothecary Mr Clark. Previous pupils included the Cambridge Platonist Henry More, and the school was a respected institution. We presume it covered the standard curriculum, which was mostly Latin with some Greek and not a lot else. At least this made him fluent in the language of scholarly Europe, and (as with Horrocks) opened up possibilities of self-learning in subjects like mathematics. He apparently left his mark on the school – a graffiti carved on a windowsill.


A Newton Sundial

Young Isaac enjoyed making mechanical contrivances, many of them found in a book by John Bate *The Mysteries of Nature and Art.*[14] An early interest in the heavens was manifested in an interest in sundials. One, reputedly made by Isaac, is on the wall of the Colsterworth church. He seems to have got on better with girls than lads, and the girl with whom he came closest to a romance in these adolescent years remembered him as a "sober, silent, thinking lad."[15] He seems also to have had a great ability to teach himself, and a high level of concentration on what interested him.


Colsterworth Sundial

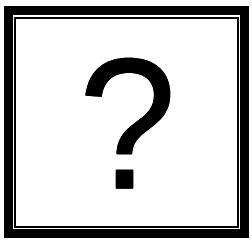
Newton left the school at just 17, his mother's intention apparently being that he would now learn to manage the farm. By all accounts he was pretty hopeless at it! The sheep got out, the pigs trespassed on other people's corn fields, and the fences fell down! Mercifully, by the intervention of his old schoolmaster Mr Stokes and his uncle Rev William Ainscough, his situation was altered. He had a brief period back at school, and then he was off – at the rather late age of 18 – to Trinity College Cambridge where his uncle had also studied. Ironically (in view of the suppositions of poverty made for Horrocks in similar case and the undoubted affluence of Newton's mother), he entered as a subsizar.[16] It was June 1661, and he was joining a community of some 400 scholars and students in the richest college in Cambridge where he was to spend most of the next 35 years. Socially (perhaps especially in the heady days of the Restoration of the monarchy) the university was very stratified, with sizars and subsizars socialising little with the gentry. Newton, whose home background was affluent, must have found it galling to be classed in such a group. He seems to have been friendly with a number of pensioners (the middle ranking group), and shared a room with one, John Wickins, from the

[14] *Ibid* p 61.
[15] *Ibid.* p. 59.
[16] Westfall in *Never At Rest* explains the difference between sizar and subsizar – which were of equally low status (p. 71).

Trinity College Great Court (The Chapel opposite now contains Newton's statue)

beginning of 1663. His room-mate also helped Newton with his various experiments – though later they seem not to have maintained much contact.

In his personal life, biographers differ about the extent to which they portray Newton as the tortured melancholy lonely genius. He was certainly ascetic in his personal life, and devout in his faith which was Puritanical in aspect. Some kind of religious crisis in the summer of 1662 was related to his near obsession with listing his sins. Manuel, followed in this by Westfall, sees all this as indicative of a "sense of guilt, doubt and self denigration."[17] In a sense this is self evident, but we must also be aware of any implicit assumption (in a Freudian religious world which sees Newton's root problem as separation from his mother) that such guilt is a "Bad Thing". In Newton's religious circles it might not be so seen, depending on what it led to. From his second year Newton was also influenced by the Cambridge Platonists, especially Henry More. On "*mind*" their view was that it was definitely *not* like a blank sheet - a *tabula rasa* – as later asserted by Locke. Perception was interactive. On "*matter*", Descartes's version of the mechanistic philosophy seemed to More to remove the need for a God.[18] More (and later Newton) moved away from this to a form of Christian Platonism that saw the spiritual as permeating all things. Newton's early notes on atomism refer to the More version of it. This approach is quite central to Newton's science, and also pervades his astronomy.



Modern writer Michael White[19], who has little empathy for any such religious views and emphasizes the 'alchemy' aspect of it all, opines that "mainstream modern atomism could not be further removed from More's idea of a personal all-pervading deity" and to unite faith and quantum theory is a "strange marriage". Yet central twentieth century physicists like Arthur Eddington[20] seem to have taken a not dissimilar "spiritual" view. Is it so strange?

The curriculum was out of date and addressed almost none of the scientific concerns of the previous half-century. Learning outcomes were to understand Aristotelian logic, ethics, physics and cosmology, and the fundamental object was to be able to dispute successfully in Latin about these. The still-operative Elizabethan statutes prescribed rhetoric (in effect classics) for the first year, logic for the second, and third and philosophy for the fourth. Mathematics (along with

[17] Frank E. Manuel, *The Religion of Isaac Newton* (1974) pp. 15-16, Richard Westfall *Never At Rest* p. 78.`
[18] Descartes himself was, of course, a devout Catholic, and God is basic to his system in underwriting the reliability of human sense/intuition – but the mechanical system itself seemed self-contained.
[19] Michael White *Isaac Newton, The Last Sorcerer*, p. 57.
[20] Arthur Eddington *The Nature of the Physical World* (1928)

logic and moral or natural philosophy) could provide the matter for the third year disputations in the run up to the final public "Acts" which concluded the degree. Tutors varied in the mathematical content offered, but John Ray lamented in 1660 the lack of both experimental science and mathematics in the curriculum.[21] The system became increasingly empty and fairly pointless, but academics whose lives have been focussed on such a system are not always quick to change it – either then or today! In 1663 Henry Lucas founded a Lucasian Professorship of Mathematics, and Isaac Barrow (a fellow of Newton's own Trinity College) moved from the chair of Greek to that of Mathematics.

Newton's notebooks show the usual undergraduate preference for pre-digested works, but also a growing interest in mathematics and experimental philosophy. His interest was reflected in his notebook after a heading (probably late in 1664) *"Questiones quaedam Philosophcae"*. This and other notes show him reading carefully eg Descartes[22], Galileo[23], Gassendi[24], Boyle[25], and John Wallis.[26]

Newton's interest in mathematics was obvious, and, in April 1664 he was required to pass an examination to register for his BA degree to be taken the following Spring. According to his early biographer Conduitt, Newton's Trinity tutor, Benjamin Pulleyn, referred him to the newly appointed Lucasian Professor Isaac Barrow (also a Trinity Fellow) for examination. Unfortunately Barrow examined him on Euclid, which Newton had neglected, and it never occurred to Barrow that Newton could have read the more advanced material without Euclid, so he obtained no high view of Newton's abilities. In spite of this Newton was made a "scholar"[27], but he resolved to go back and remedy the deficiency. In fact, his elevation from subsizar to scholar meant a path to the MA degree and possible Fellowship beyond this, which seems to have confirmed Newton in his pursuit of natural philosophy. His interest in mathematics increased, and Newton's experiments on optics seem to have begun after he bought a glass prism at a fair in 1664 – by his own later account to try out some of Descartes ideas on colours. Newton graduated BA in January 1665 – though he seems to have done little formal study on the official curriculum and achieved only a second-class degree.

In Summer 1665 plague hit Cambridge. The problems of sanitation and crowding in cities made them unhealthy places to be during plague, and Newton left for Woolsthorpe in June or July. He returned in March 1666 (no deaths having been reported for six weeks), but plague broke out again in June and he went back to Lincolnshire until April 1667. Later Newton looked back:

> "In the beginning of the year 1665 I found the Method of approximating series & the Rule for reducing any dignity of any Binomial into such a series. The same year in May I found the method of Tangents of Gregory & Slusius, & in November had the direct

[21] Hall (1992) p. 15; Hall notes also eg that More used Descartes *Dioptics* at Christ's.
[22] Descartes *La Geometrie* (1637) and *La Dioptrique* (1637)– Descartes had died in 1650.
[23] Galileo *Dialogue on Two World Systems* (1632)
[24] Walter Charleton's epitome and translation of Gassendi – possibly some Gassendi in Latin too
[25] Boyle *History of Colours* (1664)
[26] Newton noted his debt to *Arithmetica Infinitorum* (1655), and *Opera Mathematica* (1656), *Mathesis Universalis* (1657) and *Tractatus de Sectionibus Conicis* (1659) were also important works.
[27] Westfall suggests at the intercession of some powerful fiend, perhaps Babbington. Hall seeeems to discount Conduitt's account, and speculates that Barrow himself spotted Newton at his lectures.

method of fluxions & the next year in January had the Theory of Colours & in May following I had entrance into y' inverse method of fluxions. And the same year I began to think of gravity extending to y' orb of the Moon & (having found out how to estimate the force with w^{ch} [a] globe revolving within a sphere presses the surface of the sphere) from Keplers rule of the periodical times of the Planets being in sesquialterate proportion of their distances from the center of their Orbs, I deduced that the forces w^{ch} keep the Planets in their Orbs must [be] reciprocally as the squares of their distances from the centers about w^{ch} they revolve: & thereby compared the force requisite to keep the Moon in her Orb with the force of gravity at the surface of the earth, & found them answer pretty nearly. All this was in the two plague years of 1665-1666. For in those days I was in the prime of my age for invention & minded Mathematicks & Philosophy more then at any time since."[28]

The years from about 1664-1668 were fertile times for Newton.

Myth

Manuel's "psychological" account of Newton[29] fostered the idea that Woolsthorpe and the "bosom of his mother" were crucial to an "*anna mirabiles*" of scientific breakthrough. Westfall seems rightly to cast some doubt on this, since the productivity predated his departure north and continued after his return. His BA may have been more to do with it. What, however, about the most famous incident in scientific history? Did a falling apple really inspire him, and if so where? The story circulated early, but was related best by his friend William Stukeley:

> "After dinner, the weather being warm, we went into the garden and drank tea, under the shade of some apple trees, only he and myself. Amidst other discourse, he told me, he was just in the same situation, as when formerly, the notion of gravitation came into his mind. It was occasion'd by the fall of an apple, as he sat in a contemplative mood. Why should that apple always descend perpendicularly to the ground, thought he to himself. Why should it not go sideways or upwards, but constantly to the earth's centre? Assuredly, the reason is, that the earth draws it. There must be a drawing power in matter…. If matter thus draws matter, it must be in proportion of its quantity. Therefore the apple draws the earth, as well as the earth draws the apple. [And thus] there is a

Woolsthorpe: Present View of the Orchard From Newton's Window

[28] Quoted in Westfall *Op Cit* p. 143, also Hall p. 19.
[29] Frank E Manuel *A Portrait of Isaac Newton* (1968).

> power, like that we here call gravity, which extends its self thro' the universe."[30]

Few people would be brave enough to sit under an apple tree in Lincolnshire when the apples were falling – not from fear of being struck but from fear of being stung by wasps. At Woolsthorpe he could, of course, have been sitting nearer the house, and an account given by his half-niece and longtime housekeeper Mrs Conduitt to Voltaire has him *walking* in the garden.[31] On the other hand Hall suggests it may all have been in Babbington's orchard in Boothby Pagnell. Michael White says the whole story was "almost certainly fabricated by Newton to disguise the truth" ie that his ideas derived from disreputable alchemy.[32] In any event, the idea of gravity as mutual attraction did not spring out of nowhere. The works of Kepler and others contained more than a germ of the idea. Newton's genius was not merely to universalise it, but to be able to work out the mathematics. Some, like Robert Hooke, might do the former but could not do the latter. Others, like John Wallis, may have been able to develop the mathematics, but did not get interested in quite the same mechanical problems. Newton once said that he could see further because he stood on the shoulders of giants. Too often people have magnified his undoubted genius as though his ideas sprang almost from nowhere – ignoring the brilliant men on whose ideas he drew. The history of science almost always shows development rather than any sudden revolution or total novelty in ideas.

Established in Cambridge (1667-1702)

Newton was just 24 years old when he went back to Trinity College in 1667. He was elected to a minor Fellowship in 1667, and following his MA, a major Fellowship in 1668. Newton's wardrobe and his social engagements increased. Although he could forget to eat when he was engrossed on some experiment or thought, he was still a youth who could enjoy a game of bowls or an evening at the tavern.

In 1668 we find Newton high in Barrow's esteem. Barrow was a part of that group of communicating scholars developing with the Royal Society. John Collins was an FRS and government clerk in London, acting as a kind of mathematical interchange. He sent Barrow a copy of a new book published late 1668 by Nicholas Mercator: *Logarithmotechnia,* and in July 1669 Barrow wrote to Collins saying that he had a friend who had written an unpublished paper on similar issues but more general.[33] Newton was apparently reluctant to allow his work to venture into any public domain – but was persuaded to let Barrow send it to Collins. Only after Collins had indicated his approval was Barrow allowed to reveal the name of the author:

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[30] William Stukeley *Memoirs* (1936) pp. 19-20.
[31] Rupert Hall *Isaac Newton Eighteenth-century Perspectives* (1999) p. 18.
[32] Michael White *Isaac Newton the Last Sorcerer* p. 214 – seemingly linking Newton's ideas with alchemy.
[33] For this episode see Westfall *Op Cit* p. 202 etc, Hall (1992) p. 79 etc.