tutor in London, and wrote a textbook on the subject (**Arithmetick**, 1650), then worked as a surveyor for fen drainage schemes in Cambridgeshire. For other aspects of his work, see the section below on ASTRONOMY.

Abraham Sharp (1651-1742) learned some maths at Bradford Grammar School, then at various times taught maths in Liverpool and Bradford, making models to teach solid geometry and writing a book, **Geometry Improv'd**, 1717. See also ASTRONOMY.

John Dawson (1734-1820) of Sedbergh was born in Garsdale, and as a result of the most strenuous efforts, rose from minding sheep on the local hills to a medical qualification. But he had a gift for maths, and soon found he could earn more as a private tutor. Such was his reputation that students made the five-day journey from Cambridge to study with him during the summer (for which he charged 5s. per week). Those he taught included John Haygarth (later a prominent physician in Leeds), Richard Sedgwick (later Vicar of Dent), Richard's son Adam (later famous as a geologist), and no less than eight Cambridge senior wranglers during the 1780s/'90s.

These are all people who taught maths. We also need to consider schools.

Grammar schools lived up to their name and taught little but grammar (especially Latin grammar), though sometimes tuition in arithmetic was available on payment of an extra fee. Individuals who gained some competence in maths at school, and who did not depend much on private tutors nor go to university, include Abraham Sharp (see above, in **Bradford**), and Jesse Ramsden, a brilliant instrument-maker (see ASTRONOMY below), who went to school in **Halifax**.

Miles Gale (1647-1720), Rector of Keighley (see p. 7), was the driving force behind the foundation of **Keighley Free School** in 1713. He was a great admirer of Abraham Sharp, and wanted to ensure that some maths teaching was available. The school founded at **Bolton Abbey** in 1700 with money left by Robert Boyle (1627-91) had Latin and Greek taught by the curate to the sons of gentlemen, and writing and arithmetic taught by an usher to the children of the poor. From some time before 1825, girls were admitted. By contrast, the master of a tiny school at **Halton Gill** between 1737 and 1776, Miles Wilson, attempted to teach simple astronomy through a fictional work he wrote on "the man in the moon". Demands made before 1800 that girls be taught here were at first rejected, but by 1825 girls were being admitted.

Other schools were successful academically, not because they taught maths well, but because they had access to Cambridge scholarships. **Threshfield** Grammar School in Wharfedale was founded under the will of a local clergyman who also provided scholarships for pupils from the school to go to his old college, St. John's at Cambridge. Over 20 local boys thereby went to Cambridge prior to 1732. One was Richard Leadal who became master at **Skipton** Grammar School in 1715. In the north of our area, **Sedbergh** Grammar School also had links with St. John's College, with graduates from there coming back to teach.

The buildings of three Upper Wharfedale grammar schools survive, two of them still in use as [primary] schools, and they are of considerable architectural interest. See the illustrations of the grammar school at **Burnsall** (c.1605), and the building of similar plan erected under Boyle's will at **Bolton Abbey** (1700). **Threshfield** Grammar School was based on the same concept, but there was no master's house to the left of the main porch. Instead, accommodation for the master was on the first floor.

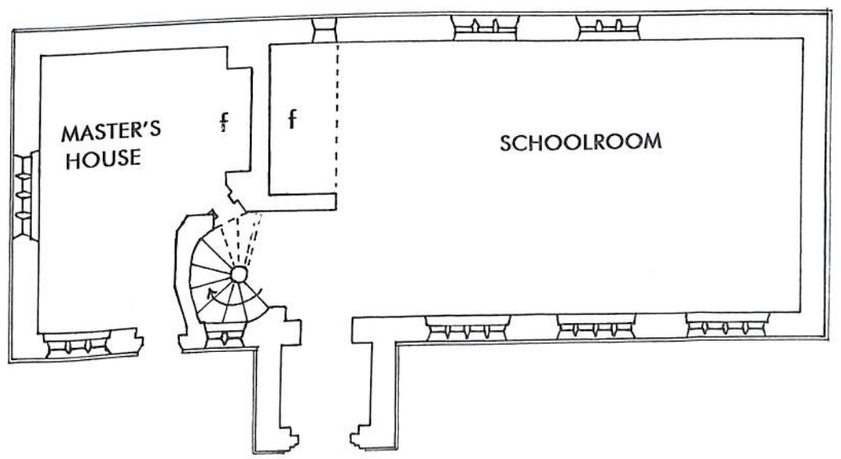
BURNSALL GRAMMAR SCHOOL
(now BURNSALL PRIMARY SCHOOL)

The school was founded c.1605 and was the earliest school in Upper Wharfedale. It thus became a model for others, notably the Boyle School. The ground plan, showing the master's house to the left and schoolroom to the right, is drawn as a reconstruction of the original layout, and may not be correct in every detail. Pupils from outlying areas were provided with boarding accommodation on the upper floor.

approximate scale of metres

WEST ELEVATION (as existing)

GROUND PLAN (reconstruction, with f = fireplace)



THE BOYLE SCHOOL, BOLTON ABBEY

(now BOLTON ABBEY RECTORY, with the school continuing on another site)

Figure 1: THE SCHOOL AS BUILT c.1700
There is a close similarity with Burnsall Grammar School: master's house to left of porch, schoolroom to right. Both buildings are about the same length (c.20 metres), but the Boyle School is not so wide, probably because constrained by the foundations of former monastic buildings on which it stands.
(Redrawn from sketches made by Samuel Buck before 1720. See Samuel Buck's Yorkshire Sketchbook, Wakefield Historical Publications, 1979, pp. 189-190.)

Figure 2: PRESENT APPEARANCE OF THE BUILDING (not to scale) as seen from the PUBLIC FOOTPATH TO THE SOUTH. The master's house has expanded to become a large rectory, absorbing the former schoolroom.

THE "NORTHERN ASTRONOMERS"

During its early years, the Royal Society lacked expertise in astronomy and wondered whether there had been any work going on elsewhere in England. Enquiries led to identification of what became known as the "northern astronomers", some of whom had passed away two decades before the Royal Society was founded. These people were as follows:

Jeremiah Horrox (or Horrocks, 1618-1641), a Lancashire clergyman who died young after making crucial observations confirming Kepler's theories of planetary motion. His papers were published posthumously by the Royal Society (in 1672), and were very important for Newton's work on planetary motion.
William Crabtree (1610-44) from near Manchester, who worked with Horrox.
William Gascoigne (1612-44) of Middleton, near Leeds, who invented a micrometer and improved telescopes (which he made himself) for more accurate determination of positions of stars.

The Royal Society was able to benefit from Gascoigne's instruments and publish Horrox's papers because Christopher Towneley (1604-74), historian, scholar and Roman Catholic, of **Towneley Hall**, Burnley, had carefully collected the papers and instruments of these tragically short-lived men, for example, by visiting Crabtree's widow to ensure that records were not lost.

Richard Towneley (1628-1707), Christopher's nephew, had an all-round interest in the sciences, and is especially notable for his long series of rainfall records and his work with Henry Power (see MICROSCOPES & BAROMETERS below). He was also a skilled astronomer and collaborated extensively with John Flamsteed (see below). He used and improved the Gascoigne micrometer, and devised more accurate clocks for use when making observations. Other astronomers (Moore and Shakerley as well as Flamsteed) were also indebted to Towneley for his advice or tuition, and for use of his library, which contained the best collection of books on this subject in the country.

Jeremiah Shakerley (died 1653) of Colne (Lancs.), was part of the household at Towneley Hall for a while, and then sailed to India to observe a solar eclipse in 1651.

Jonas Moore (1627-1679) came from Burnley, but at an early age went to work as a clerk in Durham where he studied with William Milburne, Vicar of Brancepeth and an active astronomer. Milburne worked on Kepler's tables and is sometimes included in lists of the "northern astronomers". After working as a maths tutor and surveyor (pp. 11-12 above), Moore gained a government position in London as "Surveyor of Ordnance". This gave him influence which he used to press the king to found a "royal" observatory to help with improvements in navigation. He selected the site at Greenwich, asked Wren and Hooke to design the buildings, and appointed Flamsteed to run it, advising him first to seek Richard Towneley's advice.

John Flamsteed of Derby (1646-1719), Astronomer-Royal from the opening of Greenwich Observatory in 1675, prepared himself for the job by making visits to Towneley Hall. Equipment for the observatory included a clock, and an improved Gascoigne micrometer system, both of Towneley's design. After 1675, there was regular correspondence between Flamsteed and Towneley (mail took five days from Greenwich to Burnley), and seventy of Flamsteed's letters survive. Some sets of observations were run in parallel at both Greenwich and Towneley Hall, notably with respect to the variations in the length of the day as measured by the sun.

Abraham Sharp (1653-1742; see also pages 2, 3 and 12) worked at Greenwich as Flamsteed's assistant and instrument-maker during the 1680s, then continued to work with Flamsteed from his home at Horton Hall, Bradford, from 1694 until Flamsteed's death in 1719. As with the earlier parallel observations at Greenwich and Towneley Hall, Flamsteed sees to have appreciated the opportunity to compare observations made at the different latitudes of the Pennines and Greenwich. Sharp later helped Flamsteed's widow, Margaret, to complete and publish the great star catalogue to which Flamsteed had devoted his life.

John Smeaton (1724-90), famous as an engineer, built an observatory at his house at Austhorpe, Leeds, and studied perturbations of the moon's orbit which were important as a check on Newton's theories (published in **Philosophical Transactions**, 1768). He wrote of Abraham Sharp as the first person to make really accurate instruments, a tradition carried on in a small way by Smeaton himself, and on a larger scale by: Jesse Ramsden (1735-c.1800), professional instrument-maker, born at Salterhebble, Halifax. He owed something, through his father, to Abraham Sharp's example, and devised more accurate ways of marking graduated scales on instruments.

William Herschel (1738-1822), possibly the best known of eighteenth-century astronomers, does not really count as a Pennine man of science because he was born in Germany and then worked mainly in Bath and Windsor. However, he was a musician by profession, and for a short time in 1765-66 was organist at Halifax Parish Church. His sister, Caroline Herschel (1750-1848), also an astronomer (responsible for discovery of eight asteroids), published an "Index to Flamsteed's Observations of the Fixed Stars", with errata based on more recent observations, in 1798. This was a review of the star catalogue on which Abraham Sharp had laboured so long.

Northern makers of astronomical instruments (Gascoigne, Towneley, Sharp, Smeaton and Ramsden) consistently aimed for greater precision, and it is equally noticeable that northern observers were constantly seeking to make more accurate measurements of planetary and lunar motions. This made the northern group especially important for checking the theories of Kepler and Newton, testing and identifying small anomalies which theory did not explain. Newton himself made use of observations by Horrox, Towneley and Flamsteed.

MICROSCOPES AND BAROMETERS

Henry Power (1623-1668) spent his youth in Halifax, and was there influenced by Sir Thomas Browne. He studied at Cambridge, then came back to the area to practise as a physician. He had a distinctive view of how science should be an **Experimental Philosophy** and wrote a book with this title while living in New Hall (see title page and end of preface, p. 17). The best work in it was his pioneer observations of insects using a microscope, which stimulated Robert Hooke to produce the more famous book **Micrographia** in 1665. Power's book is enchantingly written, but poorly illustrated; Hooke's work is much better illustrated, not least because Christopher Wren did much of the drawing (an accomplishment related to his architectural skills).

Power's book also described how (inspired by Blaise Pascal) he had taken barometers up "Halifax Hill" in 1653 to observe the lower atmospheric pressure at higher altitudes. He repeated this experiment with Richard Towneley on Pendle Hill in 1661, then did it again with a little air in the top of the barometer tube, noting how the volume of this air varied with pressure.

EXPERIMENTAL

PHILOSOPHY,

In Three Books:

Containing

New Experiments { *Microſcopical*, *Mercurial*, *Magnetical.*

With ſome *Deductions*, and Probable *Hypotheſes*, raiſed from them, in Avouchment and Illuſtration of the now famous *Atomical Hypotheſis.*

By *HENRY POWER*, Dr. of Phyſick.

Perſpicillum (Microſcopicum ſcilicet) *ſi vidiſſet* Democritus, *exiluiſſet fortè*; *& modum videndi Atomum* (*quam ille inviſibilem omninò affirmavit*) *inventum fuiſſe putâſſet.* Fr. Verulam. lib. 2. *Novi Organi*, ſect. 39.

Hinc igitur facillimè intelligere poſſumus, quan ſtultè, quam inaniter ſeſe venditat humana ſapientia, quóve ferantur noſtra Ingenia, niſi rectâ ratione, experientiáque (*ſcientiarum omnium magiſtra*) *nitantur & opinionis ſalebras accuratè vitent.* Muſſet. De Inſect. *cap.* 15. *pag.* 115.

LONDON,

Printed by *T. Roycroft*, for *John Martin*, and *James Allestry*, at the Bell in *S. Pauls* Church-yard. 1664.

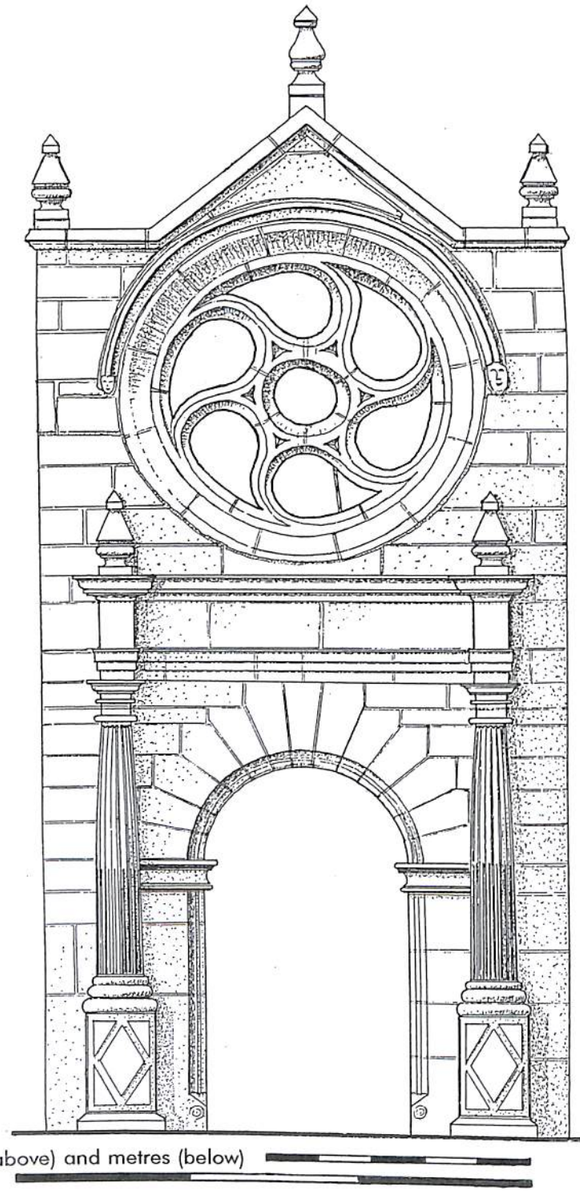
The Preface.

DIoptrical Glaſſes (which are now wrought up to that height and curioſity we ſee) are but a Modern Invention: Antiquity gives us not the leaſt hint thereof, neither do their Records furniſh us with any thing that does Antedate our late diſcoveries of the Teleſcope, *or* Microſcope...

...the Foundation being ſolid, a more wary Builder may be very much further'd by it, in the erection of a more judicious and conſiſtent Fabrick.

HENRY POWER.

From New-Hall,
near Hallifax,
1. *Aug.* 1661.



PORCH
at
NEW HALL
built for
HENRY
POWER,
1656/7

Scale of feet (above) and metres (below)

Results from the Henry/Power experiments on Pendle Hill were passed to Robert Boyle by Richard Towneley. The observations made with air in the barometer tube, and the measured changes in its volume, were published by Boyle as "Towneley's hypothesis". But it has become known to history as "Boyle's Law".

Henry Power lived at Elland, south of Halifax, in a remarkable late medieval house known as New Hall (mentioned at the end of the preface to Power's book, see previous page). In 1656, Power began to modernise the house by adding a large window (which would give good light for work with the microscope), and also a porch of great architectural interest, illustrated above.

☆ ☆ ☆

ARCHITECTURE AND SCIENCE

Buildings erected for scientific purposes in the Pennine region prior to 1800 are limited to two astronomical observatories (Sharp's and Smeaton's), and two hot-houses or greenhouses in which botanical research was pursued (Richardson's and Hailstone's). However, schools are part of the story too, and examples of their architecture have already been illustrated (pp. 13-14) and discussed (bottom of p. 12).

There are also one or two other buildings designed for (or by) people with scientific interests which clearly reflect their tastes and ideas - one is illustrated opposite. To appreciate the architecture of these buildings we need to understand how the word "device" was used at this time, particularly in artistic contexts, where a device could just be an interesting visual shape imposed on something to which it did not really belong.

If
I lay
out words
on the page
to create a triangle, that
imposes a device on my paragraph.

This is easy enough to do with prose, but try writing a poem which makes a shape on the page while keeping the rhymes always at the ends of lines. Lady Margaret Clifford's friend and business partner Richard Cavendish wrote such poems, one of which was published in a book entitled: **The Paradise of Dainty Devices** (first edition 1576, with five more editions before 1600; see DNB on Cavendish's authorship).

In architecture, devices take the form of unusual shapes applied to the plans, windows or other features of buildings. Thus Elizabethan houses include some laid out to represent letters of the alphabet (e.g. owners' initials), one or two triangular buildings (symbolising the Trinity), and a handful of circular buildings.

In the Pennine region, we first encounter an Elizabethan device in the form of a circular window at a grammar school in Halifax, built with the support of the Savile family in 1597. It is likely that the window design was supplied by the great architect-mason Robert Smythson (died 1614), although the rest of the building was designed and erected by a local stone mason, John Akroyd (1556-1613), who later worked for Sir Henry Savile at Merton College, Oxford.

It is not known what, if anything, the unusual window at the **Halifax (Heath) Grammar School** was intended to symbolise, but it was placed in the west wall so that the main schoolroom was lit dramatically at sunset. However, it established a local fashion, and round windows were used several times in local houses during the next century, notably at the Sharps' house in Bradford (illustrated on p. 2). The "apple-and-pear" design at the grammar school was repeated more exactly in the porch which Henry Power added to his house in 1656-7 (p.18). There is nothing to suggest any particular symbolism, and Power was probably just following the local fashion. The stone mason who built it for him was Robert Fearnley (died c.1661), whose will contains a fascinating list of the tools of his trade.

Beamsley Hospital is a more striking example, located 6 miles east of Skipton on the modern A59. It provided almshouse accommodation for twelve elderly women plus a

warden (or "mother"), and was founded by Lady Margaret Clifford (referred to on a tablet at the entrance as Lady Margaret Russell, Countess of Cumberland).

Land was bought for the hospital in 1593, but progress was slow. It seems that construction did not begin until after 1600, and was still incomplete when Lady Margaret died in 1616. The project was finished by Lady Anne Clifford in 1631. Of the two structures we see today, the circular one was Lady Margaret's brainchild. It contains seven rooms for residents, one relatively large for the warden. The rooms are arranged around a tiny circular chapel equipped with a lectern and pews.

Architectural historians have suggested that Lady Margaret knew the round churches at Northampton and Cambridge and used the same idea in designing the hospital. However, the most recent writer to mention Beamsley sees it much more convincingly as an Elizabethan "device" (see Mark Girouard, **Robert Smythson and the Elizabethan Country House**, Yale U.P. 1983, pp. 21-5, Beamsley mentioned p. 25). If we take this interpretation a little further and ask what Lady Margaret may have intended by it, we may note the interest of her business partner Richard Cavendish in poetic "devices", and also his translation of Euclid's geometry. The circle was regarded as the perfect or ideal geometrical shape -- just the sort of device for somebody interested in geometry. So perhaps the hospital was another project, apart from mining, that Lady Margaret worked on with Cavendish. Or perhaps it was intended as a tribute to him, after his death in 1601. Lady Margaret also placed a memorial in Cavendish's home church near London.

Another link between science and architecture in the seventeenth century is that drawing/draugtsmanship were important in both subjects. Many branches of science needed skill in drawing as a means of making records or communicating information - see p. 6, and the comments about Christopher Wren on p. 16. In Bradford, the brothers Thomas Sharp (nonconformist minister) and Abraham Sharp (astronomer) were both good draughtsmen with similarly neat styles of drawing. Thomas used this skill to make architectural drawings for the reconstruction of his house, **Horton Hall,** in 1676. He gave the house a round window in the Halifax fashion, and employed the stone mason Nathan Sharp of Wike (no relation?) to build it for him.

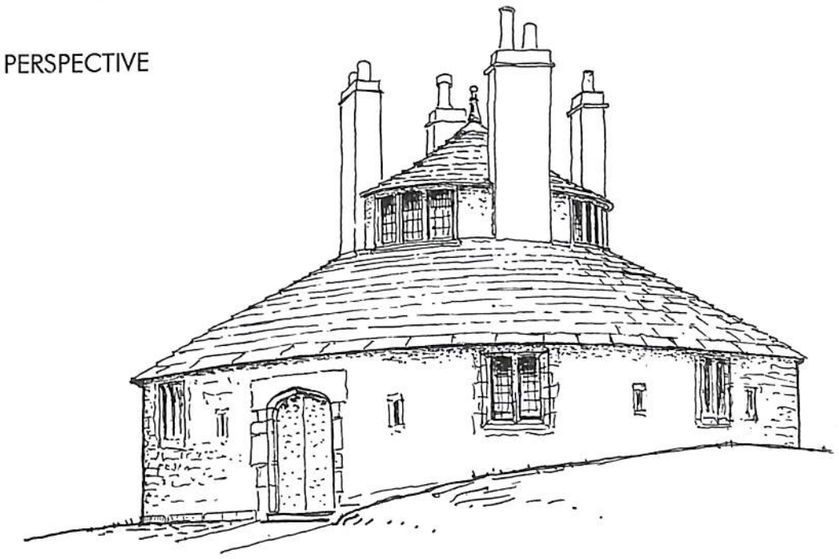
Abraham Sharp, by contrast, used his ability as a draughtsman to make geometrical drawings, and to lay out the scales and grids he etched onto his brass instruments. However, we may guess that he did some architectural drawings when he arranged to enlarge the porch at Horton Hall to create an observatory tower on which he could mount his telescope. A visible change in the masonry just above the round window, illustrated in p. 2, showed where Sharp began when he added the extra storeys. At the top was a balustrade, behind which a platform or deck measuring about 3.5 x 4.5 metres provided space for a telescope. Lead roofing on this structure bore an inscribed date, 1712, but the tower may have been built a few years earlier. Behind the platform, a pitched roof sheltered the head of a staircase built against the main chimney stack of the house. The drawing (p. 2) shows the gable formed by this roof in which was a doorway (not visible) leading onto the observatory platform.

This amazing building was demolished by a vandalistic bureaucracy in 1963; the drawing was made on the basis of a personal visit prior to demolition, supplemented by photographs taken for Bradford Museums, and illustrations published by the Royal Commission on Historical Monuments (England) in 1963 and 1986. An excellent history of the house and the people who lived there has been written by Astrid Hansen and was recently published by Bradford Libraries (see bibliography).

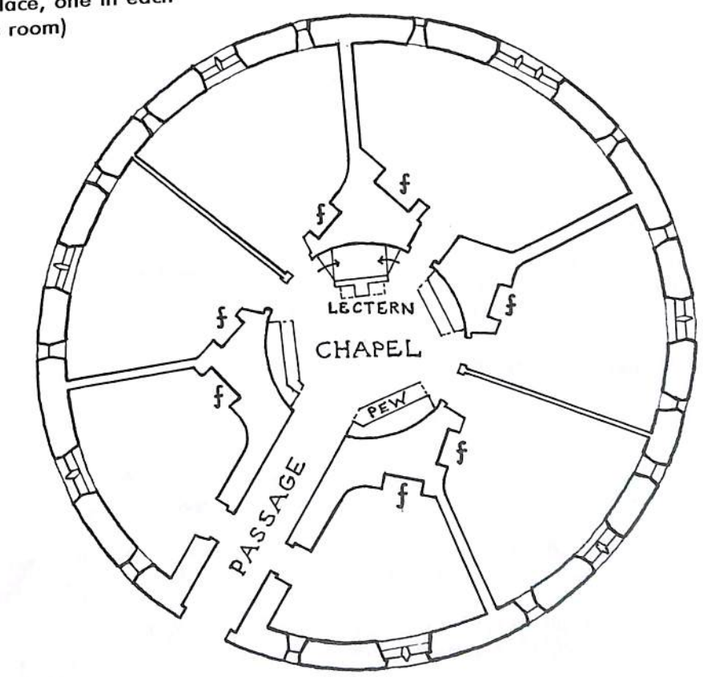
BEAMSLEY HOSPITAL

Building erected for Lady Margaret

PERSPECTIVE



GROUND PLAN
(f = fireplace, one in each resident's room)



scale of metres

Henry Power, Experimental Philosophy, London, 1663 (in Brotherton Library, University of Leeds; see also modern edn. by Johnson Reprint Corporation, introduction by Marie Boas Hall, listed above).

John Webster, Academiorum Examen, or The Examination of the Academies, London: Giles Calvert, 1654 (in British Library, London).

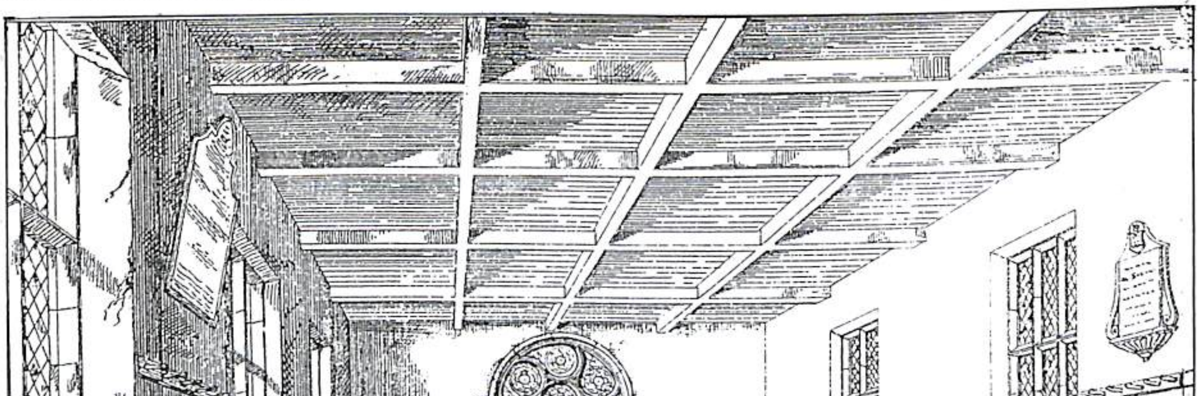
John Webster, Metallographia, or A History of Metals, London: Walter Kettilby, 1671 (in Cambridge University Library).

Also important, but not seen at the time of writing:
Eric G. Forbes, Lesley Martin and Frances Willmoth (eds.), The Correspondence of John Flamsteed, vol. 1, 1666-1682, Institute of Physics Publishing, Bristol and Philadelphia, 1995. (Contains about 70 letters from Flamsteed to Towneley, as well as correspondence with Sir Jonas Moore.)

SCHOOLROOM at HALIFAX
in HEATH GRAMMAR SCHOOL, 1597,

showing the device of a circular window with a central "apple" and six surrounding "pears"; compare Henry Power's porch at New Hall, p. 18.

Drawing by W.H. Stopford and C.J. Fox-Bell made prior to demolition and rebuilding of the school, c.1880, published in:
Thomas Cox, A Popular History of the Grammar School of Queen Elizabeth at Heath near Halifax, published in Halifax, 1879.



Whiteman & Bass Photo-Litho London