The nocturnal and other early scientific instruments

Leonard Honey looks at Humphrey Cole - his instruments and their reproduction

'Old Humfric Cole' was the first English-born instrument maker of Elizabethan England and the foremost practitioner of the London scientific instrument trade. Twenty-six of his instruments have survived, six of which are now in the British Museum. One, device number 12 of Cole's known pieces and signed by him in c1570, a combined nocturnal and tide predictor, is the inspiration for a modern reproduction.

This article gives an insight into the remarkable career and craftsmanship of Humphrey Cole, as he is better known; describes the of use of the nocturnal; and briefly explores the process of re-making early scientific instruments.

Cole (c1530–1591) was active at a time when England's wealth was greatly increasing and the need for accurate measurement was being felt. He was by no means an isolated figure, and a group of makers appeared nearly simultaneously in late sixteenth-century Elizabethan England. He is thought to have come from Yorkshire, and was employed in the Royal Mint at the Tower of London, in the office of Sinker (die maker). This post allowed him to perfect his skills and employ them on the instruments he made, helping to make his name and augment his income. Cole also had a number of commissions, including a map for Richard Jugge (1547–1577), printer and publisher of Bibles, to illustrate the 1572 edition of the *Bishops' Bible*.

Another printing commission undertaken by Cole came from Thomas Digges, who republished his father's *A Prognostication of Right Good Effect*, London, 1576, to which he added his own *A Perfit Description of the Caelestiall Orbes*., the first discussion in English of the Copernican world system.

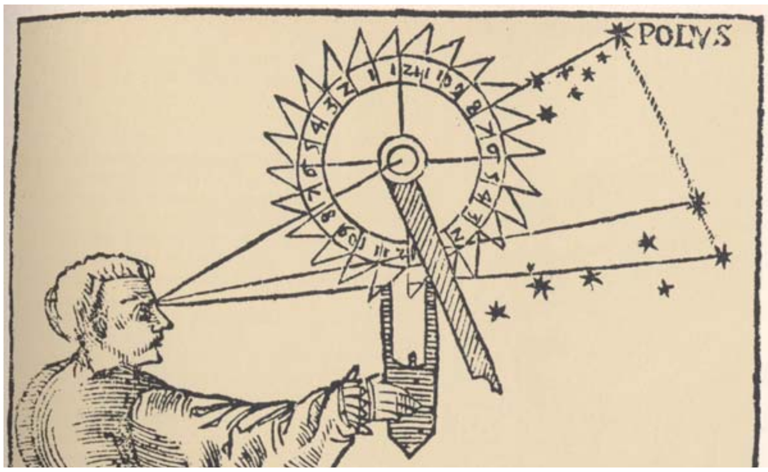
The heavens were no longer thought of as bounded by the sphere of the fixed stars. On the contrary, the stars stretched out to infinity. A diagram to illustrate this novel view was printed, and Humphrey Cole has been identified as its engraver.

He was also knowledgeable about mining and minerals and was selected to supply and repair (after each trip) all the instruments for the 'Frobisher Voyages', early attempts to discover the Northwest passage to India and *Cathay*, China. These instruments included: a great globe of metal, an armillary sphere (celestial globe), an early theodolite, a universal dial, an astronomical dial to establish the time by the sun's altitude at a particular latitude, and an astrolabe. He was paid £7 11s. Further Humphrey Cole devices cover the whole range of mathematical instruments of the day; sundials and nocturnals for telling the time by day and night, astrolabes, and a 'universal instrument' for the same purpose, and additionally for measuring the positions of heavenly bodies.

This diagram is the first English representation of the Copernican world system. The Engraving is attributed to Humphery Cole, published in 1576 in Thomas Digges's 'A Perfit Description of the Caelestiall Orbes'.

About the Nocturnal

Horologium noctis is the Latin name of the instrument known in English as a nocturlabe, or nocturnal. From the moment of sunset, sundials are of no use, and for a long time man depended on stellar observation to tell the time by night. It was



The Use of a Nocturnal, by Petrius Apian, Antwerp 1545. The drawing of this very simple nocturnal does not show the months circle.

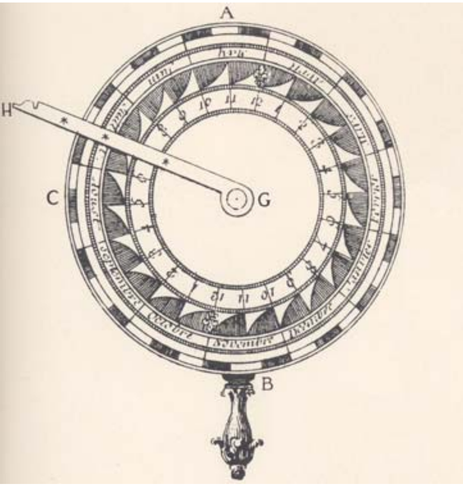
known that certain boreal constellations rotated around the Pole Star about once per day, as if a giant clock hand were keeping time around the celestial sphere. Observers began to record the positions of the most significant stars visible to the northern hemisphere at different times during the night and over the course of the seasons. The origin of the nocturnal astrolabe, however, is unclear.

One legend says that Raimund Lull invented the nocturnal to administer doses of medicine to patients during the night. This is the concept that gave birth to the nocturnal as we now know it, the instrument first appearing at the beginning of the 16th century. It began to disappear in the 18th century, coincident with the proliferation of accurate mechanical clocks and watches.

Whilst the astrolabe can be used to determine the solar hour at night directly using any star found in the firmament, the nocturnal, being simpler, can only be used on those stars that are circumpolar. A star meets this requirement when its declination (height above the equator) is greater than its co-latitude. In the 16th century, navigators from the Mediterranean area chose circumpolar stars by which to tell the time. In Mediterranean latitudes three stars meet this test: *Kochab ß* of Ursa Minor, also known as the Little Bear or Little Dipper, *Dubhe* α of the constellation Ursa Major, and *Shedir* α of Cassiopeia.

When *Kochab ß* is used, the star α of the same constellation is the Pole Star (the one to be sighted through the central aperture of the instrument). *Kochab ß* is preferred because of its very high declination, +74° 09', allowing it to be used in latitudes as low as the Canaries, 28° 06'N, a fundamental concern for seafarers. At this parallel the other two stars, because of their lower declinations, cannot be used.

There are versions of the nocturnal that use two or all three of the major stars, but this one by Cole is designed only for *Kochab ß*. As it is visible from so much of the Northern hemisphere, the absence of indicators for other stars is no great disadvantage. The operation is very simple. The main plate, sometimes called the *mater*, or mother, is marked with the months and dates of a full year, and often with a zodiac scale too. Each of the twelve zodiacal constellations represents 30º of the ecliptic, and it is generally a very efficient co-ordinate system. On the edge is a handle, which in this case is meant ▸▸



A simplified diagram of a traditional nocturnal. We see only one set of symmetrical indices on the hour volvelle, so the instrument is designed for the observation of only one star, which from the position of the handle, near 'November' we know that it should be used with Kochab ß.

⏩to be oriented vertically downwards.

Concentric with the main plate is another, smaller, disc, pivoted upon a pierced rivet. The disc is marked 1–12 twice along its edge. On Cole's instrument, the numbers run anti-clockwise, so the time can be read directly off it, but the diagram above shows the figures running the other way round, meaning the time has to be derived by subtracting the indication from 12. The hours, and often the half-hours, are marked with prominent teeth, so that the operator could feel the time at night.
A further vital feature is the index, marked in this case by a smiling sun, and in the drawing by fleurs-de-lis. On more complex instruments, more indices are provided, inscribed with the names of the stars they are designed to measure.

Also pivoted at the centre is a movable straight index, the alidade, the key edge of which lines up with the centre of the instrument. The alidade must, of course, protrude well beyond the edge of the main disc. In use, the observer chooses which star he wishes to sight, and sets the appropriate index on the inner disc to correspond with the current date (in the case of Cole's nocturnal there is only one, as has been stated before, for *Kochab ß*). The instrument is held up by the handle, and, while sighting the Pole Star through its centre, the alidade is swung round to intersect with the chosen star. The time is then read off the smaller disc.

Such an instrument can be used in any latitude, and remains operationally accurate for many years, as the variation in direct ascension varies very little over the centuries.

About the tide computer

The reverse of Cole's nocturnal is a device used to determine the time of high tide, based on the age of the moon.

The main plate has three zones. The outer is divided into 360º in 1° intervals, the middle into twice 12 hours, and the inner into 32 compass directions. Within this is a *volvelle*, or rotating ring, with a small pointer, and divided into 30 days. This is meant to represent the age of the moon, but as the lunar cycle is markedly different to this, the limited usefulness of the instrument becomes apparent. When considered in conjunction with a timekeeper that displays the time in 'quantum leaps' of about half an hour, we can begin to appreciate the problems facing navigators in the late middle ages. The centre of the device has a lunar volvelle, with an aperture to visually represent the moon's age, and a large pointer, and is engraved with symbols representing the four quarters of the age of the moon.

The tides, with their constantly changing levels, greatly affect navigation due to the energy generated by the immense quantity of water in motion, and its effect on submarine currents. Moon and Sun both exert gravitational attraction over water on Earth, the Moon's effect being more obvious because of its proximity to the Earth. The change of the water level is produced about every 6 hours, so that in one day the water level will rise twice and fall twice. Although, astronomically, the high and low tides are related to the position of the Moon, there is in fact a difference between the time that the Moon passes over a given place on the Earth and the rise or fall of the water level at that place; this difference in time is called the 'establishment of the port' and is defined as the interval between the passage of the Moon and the high tide over the local meridian.

Spring tides, happening at the full moon and new moon, produce the greatest range in height between high and low water; this is because of the *syzygy*, where the Moon, Sun, and Earth are aligned in space.

At neap tides, in the first quarter and last quarter of the Moon, the Moon and Sun form a right angle with the Earth, the attraction of the Moon is partly counteracted by that of the Sun, and the difference between high and low tide is at its least. It is therefore clear that a knowledge of the moon's age is vital to mariners, especially those active in Humphrey Cole's era.

A critical point with the use of a tide predictor such as this is that it can only determine the time of the passage of the moon over a certain point. In order to discover the actual time of high tide, a separate chart recording the 'establishment of the port' must be consulted, in much the same way that the equation of time must be known before a sundial can be put to good use.

The production of a replica scientific instrument

The primary technical consideration is, of course, to make the instruments work as they were originally intended. Once it has been decided which instrument is likely to be of commercial interest, and to capture the imagination, the engineering process can begin. Engineers, mathematicians and astronomers have all been employed to perform the required calculations, in order, for example, to ensure that a given instrument will work at a certain new latitude. The skills of graphic designers, illustrators and modelmakers are also harnessed to ensure that the final moulds we make represent the piece accurately.

The obverse face of a replica of Humphrey Cole's nocturnal. The description in the text pertaining to the use of the nocturnal neatly relates to this instrument.

Sometimes an item is available to be examined, in which case photos or drawings can be obtained. In the case of the Humphery Cole instrument described here, plans were based on pictures from a book. Missing or unclear parts require further research and comparison with similar items, extrapolating the information where necessary, so that a working instrument can be made.

In nearly every case it is impossible to effectively make the reproduction instrument in the original material. These early devices were made of brass, copper, and bronze, and would be prohibitively expensive to cast today: zinc and aluminium alloys are used instead, with gold plating to improve the appearance. Such a reproduction takes considerable time, especially the research and the correction of errors after the prototypes are made. About six months mathematical and historical research is required, including finding and making drawings. Once all the technical aspects are resolved, master plans are drawn in 3D

The reverse face of the Cole's nocturnal, showing the basic tide predictor, which, when combined with a table of 'Establishments of Port' will read with reasonable accuracy.

using 'Autocad'. Prototypes for the casting process are then made, which takes up to a month.
Then the silicone moulds are made, from which are pulled about ten proofs. At this point, if anything needs to be corrected, the whole month's process could be repeated. Once all the details are settled and deemed to be correct, the development of the steel mould is begun, followed by an initial production run of 250 pieces. The presentation boxes and the multi-language instructions. For an instrument like the astrolabe the development process will take a year's enjoyable work! It is no wonder that masters like Cole without access to CAD, silicone or modern production techniques were so very highly regarded.□

References

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F.A.B. Ward, *A Catalogue of European Scientific Instruments in the Department of Medieval and Later Antiquities of the British Museum* (London, The British Museum Press, 1981), p. 74 f., no. 208.
Reproductions by **Hemisferium** www.hemisferium.net

Members' Offer

The nocturnal featured (H31) is available from: **Science Replicas, 22 Heath View, London, N2 0QA**, but we have obtained a special deal for members on 3 reproduction instruments:

H84 (right) key-ring nocturnal: £17.00;
H85 (left) miniature nocturnal: £17.00;
H27 (below right): perpetual calendar: £22.50.

Prices include VAT, postage and packing, and are for *UK-based members only*. We will do our utmost to make sure your order arrives before Christmas, but we can only accept orders received by 15th December. To order, **contact Upton Hall.**

Should these be on your Christmas list?