2. Honest George, Chronometers and the Mystery of the Disappearing Proto-Orreries

George Graham, Clocks and Chronometers

To clockmakers George Graham was and is well known, even revered, although in this modern age his name does not commonly get a mention in scientific conversations and technology debates. But he was more than just a maker of clocks and of geared models that later became known as orreries. He was a scientist, passionate about astronomy, a socialist and worked with the best of the best. He was not just helpful to so many others but his generosity of spirit and largesse was absolutely crucial to the later successful introduction of a timepiece invention that saved so many lives at sea. No wonder that he earned the kindly nickname of Honest George.

Figure 2.1 shows Graham, born on July 7, 1673 (maybe 1675) in Horsgill, Cumberland, England. This may be Hethersgill, with a current population of around 400, in the city of Carlisle district in the parish of Kirklington, Cumbria. Graham's parents were George and Isobel, who lived as peasant farmers and Quakers (although the Quaker approach to life was taken up more by his son than by him). The father died soon after his son's birth. George was brought up by his brother William (not a Quaker), who was also a good clockmaker and lived nearby in Sykeside.

At an age of only about 14 years, George walked to London, where he apprenticed himself to the clockmaker Henry Aske. After seven years of learning the trade with Aske, Graham must have attained great skills, as he was granted the freedom of the clock-
maker’s company. At this time he became assistant to Thomas Tompion, the leading clock-, watch- and instrument maker of the country. In 1704 he married Tompion’s niece, Elizabeth Tompion, but they had no children.

Little is known of life within the Graham household, although one reference is quoted, but not substantiated, that the marriage may not have run smoothly. Elizabeth was reputed to have had two sons, whose legitimacy George refused to acknowledge. It is possible that the recorded falling out between Tompion and his associate Edward Banger was due to the accusation that Elizabeth’s infidelity might have been with Banger—if, indeed, the rumors were true. Graham later became Tompion’s business partner and was one of the executors of Tompion’s will upon his death in 1713.

**Fig. 2.1** George Graham. (Courtesy of the National Maritime Museum, Greenwich, UK)
Tompion bequeathed his money as well as the land and property at Northhill, Bedfordshire, to his close relatives. Not unexpectedly, Tompion bequeathed his business to Graham, who also, in conjunction with his wife, was a residual legatee. The business included “all of the stock and work, finished and unfinished and to continue the trade at Mr. Tompion’s dwelling house at the sign of the Dial and Three Crowns, at the corner of Water Lane, Fleet Street, London, where all persons may be accommodated as formerly.” Although likely keeping interest in the Tompion residence—probably through Obadiah Gardner, a former apprentice—Graham moved in 1720 across the road to the Dial and One Crown. This was a new house next door to the Duke of Marlborough’s Head Tavern and the Globe. Graham remained there until his death in 1751. A hand-written bill to a Mr. Bennett in 1748 is for the mending and cleaning of a gold watch (Fig. 2.2).

The shop must have looked just like the painting on a modern-day box of chocolates—a quaint little store with two bay windows, one either side of the door. It remained with little alteration the home and premises of future watchmakers Mudge and Duttons for many years. Later it became the offices of the Sporting Life, and huge buildings now stand on the site. But there is still a Blue Plaque there to commemorate the dwelling place of Graham and Tompion.

Graham certainly worked closely with many great instrument makers. From 1720 to 1728 Thomas Wright occupied the shop, with Graham at the room upstairs, in which he remained
until his death. Also in the immediate neighborhood were John Rowley and Richard and E. Cushee, two globe-makers at the sign of the Globe and Sun. Two former assistants to Rowley also worked there, John Coggs, Senior, and William Wyeth.

Graham was buried in the nave of Westminster Abbey with his former partner Tompion. The commemorative floor slab was taken up by the order of the Dean in 1838, at which time the London Saturday Journal of 1842 reported a quote that the men’s memory will last although the slab was gone. It was replaced in 1866 by order of Dean Stanley. The Journal also reported that they were “greater benefactors to mankind than thousands whose sculptured urns and impudently emblazoned merits that never existed.” The re-cut inscription on the slab is: “Here lies the body of Mr. Tho. Tompion who departed this life the 20th of November 1713 in the 75th year of his age. Also the body of George Graham of London watchmaker and F.R.S. whose curious inventions do honor to ye British genius whose accurate performances are ye standard of mechanical skill. He died ye XVI of November MDCCCLI in the LXXVIII year of his age.”

George Graham, “Honest George,” was noted for many things in his lifetime, but a few achievements in particular can be highlighted—his work on the clock escapement mechanism, his association with The Royal Observatory at Greenwich, a mechanical tellurian, later to be dubbed an orrery, and generous support given to John Harrison, which was essential in solving the ‘longitude problem.’ He also invented scientific instruments other than clockworks.

The escapement mechanism that helped drive the train or gears that led to the time or event display was, in the early history of clocks, an enormous leap forward for accuracy over the analog systems such as the flow of water. In such systems balls were counted or weights released from a balance as volumes of water were collected from a ‘dripping tap.’ The large initial inaccuracies of the crown wheel verge escapement (introduced in the late thirteenth century) were not due to the verge itself, but to the foliot-smoothing mechanism.

Replacements for foliots by the spring balance wheels and, in the mid-seventeenth century, pendulums, left the verge as being the ‘weakest link.’ Hundreds of inventions or modifications of
Honest George, Chronometers and the Mystery ...

Escapements were attempted, but only about ten survived to the late seventeenth century. Robert Hooke designed the big advance of the anchor escapement around 1660 (but credit was disputed by William Clement), so called because of its shape. One aspect of the inaccuracy still remaining was the shape of the pallet on the swinging anchor. George Graham made a huge advance in the design of the anchor-shaped escapement, resulting in removal of the wheel backward motion of each 'click' through the design of the pallets or paddles on the anchor (Fig. 2.3). This 'deadbeat' escapement was deemed to be the real beginning of accurate clocks as we know them today.

Although Graham is often credited with inventing the deadbeat mechanism (he likely made a significant improvement to it in 1715), it was actually designed by Richard Towneley and used by Thomas Tompion to build a clock for Sir Jonas Moore. The Towneley mechanism was also used in two regulators made for the Greenwich Observatory in 1676 (when Graham was just three years old) and paid for out of the personal pocket of Moore. Cor-

**Fig. 2.3** Graham deadbeat escapement. ‘a’ is the toothed (escape) wheel driven by the weight or spring; ‘c’ is the pendulum (foliot replacement) that is pushed by the wheel and ‘b’ the pallets, alternately catching and releasing teeth on the escape wheel, whose radial shape was critical in the deadbeat mechanism for the removal of recoil. [Courtesy of Frederick J. Britten From Wikipedia, ‘Escapement’ public domain, derivative work, McSush; (PD-US)]
respondence between Towneley and the Astronomer Royal John Flamsteed included such references.

The cylinder escapement was another brilliant advance that was particularly useful in the confined mechanisms of watches. Again, George Graham is mentioned as the inventor (1726) in some references and Tompion in others. One thread seems to be apparent from researching clock history is that Tompion and Graham, and maybe others of the time, worked so closely together it could be quite difficult to unpick exactly who did and said what when. Knowing how generous in spirit Graham was, he would likely give any advice or involve himself in any discussions over the workbench or a ‘coffee break’ to impart his knowledge.

As clocks became more and more accurate, it was noticed that a change of temperature, in particular on a pendulum, caused errors due to the expansion or contraction of the metal, which lengthened or shortened the pendulum. George Graham’s answer to this was to incorporate a bulb of mercury into the pendulum to replace the customary bob. The amount of mercury could be adjusted to compensate for the variation of length with temperature and therefore maintain a constant center of gravity. A weight-driven clock with a Graham escapement and a mercury pendulum could achieve an accuracy of within a few seconds per day. An alternative compensation mechanism of the bi-metallic gridiron was also variously ascribed in the literature to Graham or Harrison.

Graham had many associations with the Royal Observatory at Greenwich (ROG), London, and its astronomers. In 1884 the ROG became the site of the internationally agreed prime meridian from which all the world’s time is taken. James Bradley originally defined the meridian, $0^\circ$ longitude, as passing through where his telescope stood, and the meridian was adopted by the UK’s first Ordnance Survey map in 1801. Sir George Airy redefined the exact meridian position in 1851 to about 6 m to the east of Bradley’s, since his instrument was in a room next to Bradley’s. At an International Meridian Conference held in Washington, D.C., in 1884 it was decided that this should be the official prime meridian, because the majority of ships were using the Greenwich meridian as their reference point.

The history of Greenwich dates back to antiquity with barrows possibly constructed during the Bronze Age. About 300 coins
were also found in 1902 bearing evidence of the Roman Emperors Claudius and Honorius of the fourth century. However, the town of Greenwich was seen as no more than a fishing village with safe anchorage until as late as Henry V (1386–1422, king from 1413 until his death at the age of only 35). On the site of the current National Maritime Museum and Greenwich Park (incorporating the Royal Observatory) the Plantagenet, Tudor and early Stuart monarchs had built a hunting lodge or palace that was variously used for royal purposes, e.g., royal marriages and births, Henry VIII and his mistresses, and as a prisoner-of-war camp and biscuit factory during the English Civil War (1642–1651). The council of Queen Elizabeth I planned the Spanish Armada campaign here. By the time of the Restoration (of Charles II to the throne in 1660) the palace had fallen into disuse and was pulled down.

Under the new king new buildings began to be established and Greenwich Park was redesigned and replanted. Charles II also commissioned the Royal Observatory to be built and the commission went to Sir Christopher Wren (1632–1723). The reason for the building of the observatory was to increase English supremacy of the seas by improving the lot of sailors and merchants, who were desperate to know exactly where they were when at sea, out of sight of land, to avoid catastrophe. The king designated John Flamsteed (1646–1719) as the first Astronomer Royal and the observatory was built to accommodate him and his work. Flamsteed was to “apply himself with the most exact care and diligence to Rectifying the Tables of the Motions of the Heavens and the Places of the Fixed Stars, in order to find out the so much desired Longitude at Sea, for the perfecting of the Art of Navigation.”

It is interesting to note here that Sir Jonas Moore (1617–1679), mentioned previously, was an English patron of astronomy, a mathematician and a surveyor known for the huge project of draining the Great Level of the Fens. He used his accumulated wealth and influence to become a patron and was the main driving force behind the establishment of the Royal Observatory of Greenwich (ROG). Moore was disappointed with the productivity of Flamsteed’s work at Greenwich and threatened in 1678 to stop Flamsteed’s salary if it didn’t improve. In fact, Flamsteed was so meticulous that he had still not published his data after forty years!
At that time, the key to accurate positioning was thought to be knowing the exact mapping of the movement of the Moon and stars, from which could be calculated the longitude. The latitude was easily found from the height of the Sun at midday. Stellar measurements had not been refined since they had been undertaken by Tycho Brahe before the use of telescopes. The use of second-hand building materials and the sale of old gunpowder enabled the project to be financed. Although the money was still short Wren built the beautiful Octagon Room underneath which was the accommodation for Flamsteed.

Calculating and mapping the exact position of the stars in Flamsteed’s time was difficult if not impossible to the accuracy required. In addition to knowing the exact time of viewing a star the precise position had to be known. One instrument was the transit telescope, possibly invented by the Danish astronomer Ole Christensen Rømer (1644–1710). In essence, the principle was the same as the meridian circle, transit circle or the quadrant. A round plate or frame inscribed with measured angles, or degrees, was directed at the sky, using a pendulum or other means to relate to the horizontal and aligned along a meridian. The height in degrees of the object (a star) viewed through an attached telescope was noted and related to the time for the determination of the coordinates.
of the star. The instrument was usually anchored to the ground and clearly difficult to use at sea, although the hand-held sextant with similar principles and split mirrors was standard nautical equipment. It became usable when clocks with an appropriate accuracy were combined with a sturdy anchorage such as a wall, at which point it was known as a mural quadrant. Many models of the transit telescope itself were made and used until recent times. One superb instrument is housed in the ROG.

Not only did Graham develop clocks of great accuracy, he also used his astronomical interests and skills to produce a mural quadrant in 1725 for Halley’s early years at Greenwich and later for Bradley (first mounted in the house of his Aunt Pound at Wansted in Essex). The quadrant still exists at Greenwich and is shown in Fig. 2.4. Both Halley’s and Bradley’s 8-foot mural quadrants are mounted on
a wall of nine massive stone blocks set into the bedrock of Greenwich hill. Halley, who had made a name for himself studying the less well known stars of the southern celestial hemisphere, originally set his quadrant on the east side of the wall roughly in line with Flamsteed’s first Greenwich meridian and facing south.

Halley actually had a difficult start to his early days at Greenwich because the relatives of Flamsteed, mainly his wife, had comprehensively cleared the building of all Flamsteed’s instruments, which they viewed as being their personal property. Having been granted a sum of money to re-equip his laboratory, one of Halley’s first purchases was a transit telescope, probably first started by Robert Hooke and completed by George Graham. A transit telescope pivots only in one plane, normally north-south, so that as Earth rotates, selected stars become visible in the telescope and the exact time from an astronomical regulator is noted to give the star’s position. The telescope consists of a brass tube 5 ft long with an object glass aperture of 1.5 in. (Fig. 2.5).
James Bradley, the third Astronomer Royal, was granted £1,000 in 1749 raised from the sale of old naval stores to construct a new building and replace instruments that were in poor condition. One of George Graham’s clocks was purchased in 1750 for £39 for use by John Bird alongside an 8.5-foot transit telescope. The clock was known as ‘Graham 3’. Altogether, four of Graham’s clocks were bought for Greenwich. Edmund Halley used the first, bought for £5 in 1721, as a transit clock. The image (Fig. 2.6) is of the Graham clock no. 630 built around 1750 and housed at Greenwich. Several beautifully ornate Graham and Tompion watches are part of the collection at Greenwich. The cylinder escapement is sometimes used to enable the flat mechanism to be employed. The image in Fig. 2.7 is a signed center-seconds watch with cylinder escapement in a silver pair-case. It is believed to have been made for James Bradley, around 1729, who used it for observations on the aberration of light and the fixed stars. The center-seconds

Fig. 2.6 The Graham clock no. 630 built around 1750 and housed at Greenwich. (Courtesy of the National Maritime Museum, Greenwich, UK.)
hand can be stopped by moving a small lever that protrudes through the side of the inner case. This actuates a spring, which bears on the balance and so stops the watch. The image in Fig. 2.8 shows a pocket watch of Graham’s made from brass without dial or hands. It has a full plate fusée movement with a verge escape-ment. In fact, the discovery of the aberration of light was an accident while Bradley and Samuel Molyneux searched for (and failed to find) annual parallax in the position of the star Gamma Draconis from Molyneux’s house on Kew Green, just southwest of London, where Graham’s first high-quality zenith sector was placed.

Graham made a bespoke zenith sector for the French astronomer Pierre Louis Maupertuis, 1698–1759 (the request being facilitated by Anders Celsius meeting Graham). Maupertuis ventured close to the north pole in Lapland in 1736 to measure the value of 1° of latitude. The aim was to compare this with that measured near the equator in Peru to determine the ellipticity of Earth. The telescope of the sector was 9 ft tall and hung from the vertex. The observer rested in a reclining position. Maupertuis did indeed confirm Isaac Newton’s belief that Earth is an ellipsoid flattened at

Fig. 2.7 A George Graham center-seconds watch with cylinder escape-ment in a silver pair-case. It is believed to have been made for James Bradley around 1729. (Courtesy of the National Maritime Museum, Greenwich, UK.)
the poles. He has therefore often been referred to as the man who flattened Earth.

Graham was interested in more than just clocks, certainly in astronomy, as mentioned in the previous paragraphs, but also in Earth science, geomagnetism in particular. He made compasses, and the needles he produced were used by many scientists. By making careful observations of a compass needle through a microscope, he discovered the diurnal variations of the terrestrial magnetic field in 1722/23 and their relationship with auroras. That the variations were not just local was confirmed when Celsius in Uppsala, Sweden, simultaneously detected a large magnetic disturbance, a magnetic storm, in April 1741. So internationally noted was Graham for his inventiveness and precision that his works of all kinds are found in collections and museums all over the world and command very high prices whenever they come up at auction. He was elected as a member of the Royal Society in 1720 and chosen to be a member of its council in 1722.

Possibly one of the most important actions of his life for humanity was his financial and professional support for John Harrison. Harrison solved the ‘longitude problem,’ but not without cost. He devoted his whole working life, against all odds, to the
production of a timepiece that would maintain its accuracy at sea. As the commercial, exploring and warring imperatives of many nations increased exponentially from the fifteenth century on, deaths, wrecks and losses of cargo at sea were commonplace. Some such events could be laid at the door of human-kind’s unfortunate nature to fight and conquer, but many were due to the ships’ navigators ignorance of precisely where they were, which fatally resulted in encountering unexpected rocks or no land at all.

Just two measurements, coordinates, are necessary to locate a position. This was known around 2000 B.C. to the Phoenicians and other ancient civilizations who used the position of the Sun, Moon and stars to give the latitude, and a map of stars to find the longitude. Nautical charts created from experience were helpful, but the accuracy was wanting, and most maritime journeys were coastal, with predictable winds and currents or a wide continental shelf to follow until a few thousand years later. Several of the scientific instruments described in the previous chapter were useful in the right hands, especially the sextant, which was invented at the beginning of the eighteenth century.

A system of latitude and longitude for mapping the world was first proposed by Eratosthenes in the third century B.C. Hipparchus was the first to take this on board and to recognize that longitude could be determined by comparing local time with an absolute time. However, despite all efforts, for almost 2000 years no one came up with a clock sufficiently accurate and usable at sea. Ever increasingly accurate star maps were pursued in an attempt to solve ‘the intractable problem.’ As already noted, Flamsteed was specifically given the task of doing just that, since King Charles II had been keen to investigate a suggestion by a Frenchman, the Sieur de St. Pierre, that a knowledge of the position of the Moon against the backdrop of stars would give the longitude. This was also supported by Robert Hooke, the polymath, who encouraged Flamsteed. It was also being accepted throughout the scientific and maritime community that it would never be possible to produce a marine chronometer, but a great prize was being offered by several nations’ rulers for its solution. Then came the disaster! It was one of the worst in British maritime history and was due to the inability of the navigators to know their precise position.
During the war of the Spanish Accession a combined naval force of British, Austrian and Dutch ships were dispatched to Toulon, but in spite of some success, it did not go well, and the British fleet of twenty-one ships, led by its commander-in-chief with the unforgettable name of Sir Cloudesley Shovell was ordered back to Portsmouth. Toward the latter part of the journey the weather worsened, the ships were blown off course and their location was uncertain. Legend has it that one sailor recognized where they were and let it be known that he thought the navigator was wrong. He was hanged for inciting mutiny! Four of the ships, including “The Association,” on which sailed Admiral Shovell, hit rocks off the Isles of Scilly and all 800 men on board drowned. The commemoration stone for the place of Shovell’s demise on Scilly is shown in Fig. 2.9. Possibly as many as 2,000 souls in total were lost, and bodies were washed ashore for days afterwards.

What a wakeup call this was for the British navy and the government! An incentive was needed to concentrate the best minds of the day, and what better than money? By act of Parliament the longitude prize was offered in three main parts: £ 10,000, £ 15,000 and £ 20,000 for longitude to an accuracy of within 60, 40 and 30 nautical miles, and additional money up to £ 2,000 toward promising lines of research. The Board of Longitude was set up to judge submissions. Many still clung to the precise mapping of the stars and movement of the Sun and Moon as the only solution,
believing that the quest for a suitable seagoing chronometer was doomed to failure. Unfortunately, among the serious doubters was the Astronomer Royal, Nevil Maskelyne, who was appointed to the board and proved to be a major hindrance to progress toward a solution.

Such a large purse was bound to attract all sorts of suggestions and applications, including crackpot ideas. That was not all bad, though, as it raised awareness of the project even if it did cause some embarrassment for those seeking a serious solution. Among the most quoted ‘sillies’ was one that recommended anchoring a huge number of barges across the ocean from which rockets could be fired at ‘known’ intervals of time (actually, an early suggestion that probably led to creation of the longitude prize) and a ‘Powder of Sympathy’ that operated over any distance and included carrying a wounded dog on board that would howl when the dog’s bandages, left onshore, were plunged into the powder. The latter was, apparently, just an anonymous joke. Many suggestions just wasted time, such as including designs for perpetual-motion machines or improving ships’ rudders or sails. By the time a young hopeful arrived in London in 1730 aspiring to present his ideas to the board, the group had given up meeting and was just sending out polite letters of rejection.

The young hopeful was John Harrison. He was born in 1693 in Yorkshire and lived with his parents on the estate, Nostell Priory, of a rich landowner who employed Harrison senior as a carpenter. Little wonder, then, that Harrison junior became a skilled worker in wood. He was also musical, played the viol, became a choirmaster and tuned church bells. He enjoyed learning and was encouraged to do so. Something in that learning sparked his obsession with clocks, and, using his knowledge of carpentry and the properties of wood, he made his first almost entirely of that material, in which even the teeth were durable.

Harrison had his share of personal bad luck when his first wife Elizabeth died and their son John followed her later at only eighteen years old. However, Harrison married another Elizabeth just six months after his first wife died, and they produced two children, John, who later gave great support to his father, and Elizabeth, about whom little is known. John (senior) worked closely with his brother James to produce some fine clocks, each with
their new inventions to further develop the accuracy of timekeeping. John began thinking about the longitude problem, and when he was happy with his ideas of springs and counterbalances, he set off to London.

As a last resort to gain access to the board he sought out one member and knew just where to find him—in the Royal Observatory at Greenwich. Halley was a congenial and generous man and generally open-minded. He listened to Harrison’s design for a marine clock with great interest. But he knew it would be difficult to get the board to even vaguely consider a mechanical solution when most were hell-bent on using the stars.

As Harrison had never been great with words, Halley sent him to Honest George Graham with instructions on how to approach one of the most revered clockmakers of the age, who was kindly and would understand the proposal. At the meeting Harrison feared that Graham would steal his ideas and Graham feared having to deal with another crackpot. In the history of clocks and the lives of sailors the day was most significant. Once they broke the ice, both horologists began to trust each other and discussed and studied the inventive designs before them. The mighty George Graham and the young carpenter then had dinner together, finally resulting in Graham giving great encouragement and a loan from his cash box, without interest or time limit. Without this most productive of meetings and the generosity of Honest George the world might have had to wait for many more decades to see an improvement in the safety of mariners.

After about five years, Harrison produced H1, a marvel to behold in mechanical science and appearance. It looked like no other before it with its shiny brass fittings and contra movements of springs and levers (Fig. 2.10). In spite of the resistance of the board, mostly from Maskelyne, Harrison persisted with design improvements and the production of glorious clocks (H2, 3, 4 and 5). This eventually led in 1772—with the assistance of his son, Parliament and King George III (“by God Harrison I will see you righted!”)—to the award (in parts over many years) of the Longitude Prize money.

Harrison died in 1776 at age 83. Larcum Kendall (1721–1795) produced further watches, K1, 2 and 3 as part of the Harrison legacy, but John Arnold (1736–1799) was responsible for designing an
acceptably accurate and practical watch for general use. H1 is now safely housed and displayed in the Royal Observatory at Greenwich and is priceless. Even a modern replica was sold at auction to the director of Charles Frodsham & Co., London, for $904,000.

George Graham made another, albeit indirect, improvement to the marine chronometer. He took on an apprentice, 14-year-old Thomas Mudge (1715–1794), who was clearly so well trained by Graham that he became a freeman in 1738. In 1750 he moved to his own premises in Fleet Street where Matthew Dutton joined him as a partner four years later. He was another of Graham’s apprentices. Mudge’s new lever escapement mechanism was a major advance and he retired from the business in 1771 to work on a marine chronometer, for which he was granted £500 to develop. In 1779 he produced two such instruments.

Once again, Maskelyne attempted to block the progress and deemed the chronometers unsatisfactory. However, in 1776
Mudge was made clockmaker to the King George III. Mudge was nearly blind when he made the last two of his famed three marine timekeepers in the late 1770s. The first one, known as “Mudge No. 1,” is in the collection of the British Museum. The second, “Mudge Blue,” is in the Mathematisch-Physikalische Salon in Dresden, and there is a third one, “Mudge Green,” which was completed in 1779 and was sold for $1,240,000 in 2004. All three are celebrated in the history of the pursuit of the elusive Longitude Prize.

“Blue” and “Green” are identical except for the corresponding colors of their shagreen (tough leather) cases. They covered their cases with different colors so that they could tell them apart. The twinning enabled Mudge to determine if variations in the timekeepers’ rates were caused externally or internally. Making two identical timekeepers was also a requirement of the board that was in charge of issuing the major prize, which they never did in Mudge’s lifetime. Only after Mudge’s son championed his father’s work was a kind of consolation prize awarded.

Thomas Mudge’s portrait in his later years is shown in Fig. 2.11. Two years before his death a committee of the House of Commons overruled the board and awarded £2,500, thus ensuring the Mudge clocks to be part of the story of chronometers available to mariners. Mudge 1 is shown in Fig. 2.12. The British Museum’s description includes the following:

In a letter to his patron, Count Maurice von Brühl, dated 23 August 1774, Mudge wrote, “I acknowledge it [the case] would have been better of brass. My only reason for making it of wood, was to save money, of which I have had, at no time, much to spare.” The machine was tested in private trials at Greenwich between June 1774 and February 1778 but failed because the mainsprings kept breaking. On 1 March 1777 Nevil Maskelyne, the Astronomer Royal, stated that it had gained 1 min and 19 s while on trial at Greenwich for 109 days—an average of less than one second per day. He said that the machine was “greatly Superior in point of accuracy to any timekeeper which hath come under my inspection.” As a result of its performance Mudge was awarded a payment of £500 by the Board of Longitude. Following a report by a House of Commons Select Committee in 1793, Mudge was awarded a further £3,000, but his death the following year precluded any further work. It was not to be the end of the story, though: using the money, Thomas Mudge junior set up a small manufactory where some twenty-seven copies of his father’s chronometer were made.
Fig. 2.11  Thomas Mudge’s portrait in his later years. (Courtesy of the Trustees of the British Museum.)

Fig. 2.12  Mudge clock number 1, ‘Mudge 1’. (Credit: © Trustees of the British Museum.)
The legacy of the pioneering clockmakers continued. Figure 2.13 shows a chronometer made by the famous Frenchman, Breguet. The British Museum writes:

Towards the end of the eighteenth century improvements in the timekeepers used for finding longitude at sea were, to a large extent, achieved by English chronometer makers, particularly John Arnold and Thomas Earnshaw. Nevertheless, the great French clockmakers were also striving for the same goal, and makers such as Ferdinand Berthoud, Pierre Le Roy and Henri Motel all played their part. One of the most celebrated of French clock and watch makers was Abraham-Louis Breguet, and although his workshops were primarily concerned with the making of watches, he also made a number of marine chronometers. This example was completed in 1813 and used as an experimental piece by Breguet himself until 1822. It was presented to his friend Monseigneur Belmas, Bishop of Cambrai, to whom it was inscribed.
Two other names strongly associated with the development of usable chronometers are John Arnold and Thomas Earnshaw.

John Arnold was a watchmaker and principle chronometer maker of his day. His business was in Devereux Court, The Strand, thus adding to the concentration of clock-making history in the nearby Fleet Street area. He made a repeating watch set in a ring for King George III. Figure 2.14 shows one of his chronometers with eight-day movement and a spring detent escapement. The beautifully crafted mahogany case is typical of the care taken by craftsmen of the time.

Thomas Earnshaw (1749–1829) was Arnold’s rival in an argument as to who invented the spring-detent escapement. The British Museum writes of Earnshaw:

Born in Ashton-under-Lyne [Greater Manchester, England] in 1749, Earnshaw served an apprenticeship in London, which he completed in 1770; he then worked as a trade watch-finisher and escapement maker of extraordinary ability. In contrast to John Arnold, who had
a somewhat privileged early career, Earnshaw came up the hard way. He married before he had finished his apprenticeship, and within four years had three sons. By 1774 he was facing the debtors’ prison and fled to Ireland, but in the end his conscience overcame him and he returned to the Fleet Prison in December 1774.

However, Earnshaw survived all this to create a thriving and successful business in 119 High Holborn, well away from Arnold. One of his chronometers is shown in Fig. 2.15, a one-day spring-driven movement with Earnshaw’s split-bimetallic temperature balance.

All of the clockmakers described had their own masterful influence on clocks, watches and chronometers right up to the twentieth century.
Graham the Scientist and Astronomer

Should we say George Graham the clockmaker or George Graham the astronomer? Some say that his contribution to astronomy was of even greater importance. The construction of sectors and quadrants, now taking pride of place in prestigious museums and observatories, and the company he kept, Molyneux, Hooke and Astronomers Royal, already give hints. Indeed he was one of the few clockmakers to reach the dizzying heights of the Fellowship of the Royal Society, which boasted many of the top names in astronomy as members.

Not only did Graham support astronomers through the production of instruments, he also made detailed observations and produced such works as “An Occultation of Alderbaran by the Moon.” This paper, from 1722–1725, was part of his project to test the suitability of his newly invented temperature-compensating mercury pendulum. Even Maskelyne, so antagonistic toward Harrison and his marine chronometer, praised the device as “an excellent astronomical clock with a gridiron pendulum made by Mr. John Shelton under the direction of George Graham ... by which transits of the heavenly bodies over the meridian are observed.” By altering the length of the pendulum, Graham bridged the gap between ordinary clocks based on solar mean time and sidereal time (calculated from the apparent movement of the stars) that was of essential use to astronomers. The Gentleman’s Magazine for 1751 described the best such instruments in France, Spain, Italy and the West Indies as copies by English artists of Graham’s originals. Toward the end of his life Graham devoted almost all of his time to astronomy.

Reading histories and descriptions of Graham’s life and works is fascinating, but to get a feeling of the times, one can become a little closer by perusing the original Royal Society’s Philosophical Transactions of the time through the old English writing, grammar and sentence construction. Here are titles of a few transcripts of submissions to the Royal Society relevant to Graham, although in modern type:

1. “An account of some observations made in London by Mr. George Graham, F.R.S. and at Black-River in Jamaica, by Colin Campbell,
Esq; F. R. S. concerning the going of a clock in order to determine the difference between the lengths of isochronal pendulums in those places. Communicated by J. Bradley, M. A. Astr, Prof. Savill. Oxon. F.R.S.”

2. “The same eclipse observed in Fleetstreet, London. By Mr. George Graham, F.R.S.Phil.”

3. “Observation of an extraordinary height of the barometer, December 21, 1721. By Mr. George Graham, Watchmaker, F.R.S.”


5. “An account of some Magnetical Observations made in the months of May, June and July, 1723, in the Atlantick or Western Ocean; As also the description of a water spout, By Mr. Joseph Harris. Communicated by Mr. George Graham, F.R.S.”

6. “An occultation of Jupiter and his satellites by the moon, October 28, 1740, in the morning, observed at Mr. George Graham’s, F.R.S. house in Fleetstreet, London, by Dr. Bevis and Mr. James Short, F.R.S.”

Clearly, what was possible then would not be so easy now with the current levels of light pollution.

The Proto-Orreries

Models or depictions of the Solar System have been attempted since antiquity, even though early examples involved erroneous or extremely limited contents. The physician, antiquary, archeologist and friend of Sir Isaac Newton, William Stukeley (1687–1765), reported that Richard Cumberland (1631–1718) had made a planetarium (not in the current sense of an astronomical theater). He was rector of All-Saints, Stamford, and later bishop of Peterborough. Some references suggest that his grandchildren played with the model until it dropped to pieces and was lost. Stukeley also drew a diagram of a geared model of the Sun/Earth/Moon system mounted inside a circular tablestand that was made by Dr. Hale, a fellow of Corpus Christi College, Cambridge, in 1705.

Stukeley claimed that Dr. Hale was the true inventor of the ‘orrery.’ There was some bitterness and rivalry as to who could claim to be the first constructor of the model. In an account of the life of Stephen Hales, D.D., F.R.S., it was mentioned that “Mr. Hales was equally assiduous and successful in the study of Astronomy, for, having acquired a perfect knowledge of the Newtonian
system, he contrived a machine to demonstrate it, which was con-
structed of brass, and moved by wheels, so as to represent the
motions of all the planets, upon the same principles, and nearly
in the same manner as the machine afterwards constructed by
Mr. Rowley, master of Mathematics to King George I, which was
absurdly called an Orrery, because an Earl of Orrery was Rowley’s
patron.”

As more astronomical awareness developed, more complex
displays became possible. These became known as planetaria
(planetariums) or telluriums (tellurions, tellurians), some display-
ing the whole of the sky as seen. As clockmakers led the way
in constructing beautiful and accurate timepieces, one maker
in particular created the first geared model (but see the Antiky-
thera mechanism previously described and Dr. Hale, above) that
became known as an orrery or proto-orrery. Although it was a
most intricate and ornate instrument, it displayed just the Earth,
with its orbiting Moon, going around the Sun. The mechanism
was made by the recognized genius of his time, George Graham.
Thomas Tompion had some influence as they worked very closely
together in their clock-making business.

Had it not eventually been blessed with the prestigious name
of ‘orrery,’ the device might never have made such a splash in
history, although it additionally became popular for educational
and demonstration purposes due to the underlying principle of the
universal theory of gravity published by Newton in 1687. A brief
delving into its history often throws up firstly that the model was
due to the fourth Earl of Orrery, thereby implying that he made
it. Eustace Budgell, a writer of the day, is quoted as follows on the
subject: “The Instrument which was invented by him, and bears
his name, is an undeniable Proof of his [the Earl of Orrery] me-
chanick Genius.” Others say that the model was built at the re-
quest and patronage of the Earl of Orrey, both possibilities leading
to the label orrery. Graham’s geared model was built around 1710
(1704 or 1703–1709 in some references) and was given to the emi-
nent instrument maker John Rowley of London to send to Prince
Eugene of Savoy along with other Rowley instruments. Rowley
was commissioned to make a copy for his patron, Charles Boyle,
fourth Earl of Orrery, and the completed instrument was present-
ed to Charles’ son John. These stories illustrate the confusion as
to what really happened, and even now there is uncertainty in
the literature concerning some details. It is known that Graham produced two geared models, one just signed Graham (let’s say the G model; Fig. 2.16) and another signed Graham and Tompion, (G & T model; Fig. 2.17). It is likely that Charles Boyle, fourth Earl of Orrery, was a patron of George Graham.
These first models, G & T and G, could not be called true orreries, since the geared models had not been so named until after their production. They cannot, strictly, be called planetaria either, since they do not have planets other than Earth. Therefore they have been referred to as proto-orreries.

The G & T model is now in the Museum of the History of Science, Oxford. It was probably signed Tompion as well as Graham, because all objects for sale made on the premises had to have Tompion included in the signature.

The clockwork-driven G model is now displayed in the Adler Planetarium and Astronomical Museum in Chicago in the United States. As it is not as ornate and has some flaws, it was probably a prototype of the G & T, hence only signed and kept by Graham. Although made by clockmakers, the motion of orreries was often driven by a handle, not a clockwork mechanism.

The G & T model was constructed for the Julian and Gregorian calendar, while the G model was only for the Julian, although the latter was, in 1752, converted to the Gregorian, probably for ease of trade with Europe. Prince Eugene and John Rowley were involved.

More will be said in the next chapter about the Earl of Orrery, but who were Eugene and Rowley?

Prince Eugene

Whatever else is uncertain, it seems a certainty that Prince Eugene, a prominent and revered warrior and statesman, played his part in the procurement, ownership and care of the G & T proto-orrery. But why should he be the recipient of one of the first prestigious models? Why was he so worshipped?

To give him his full title, Prince Eugene Francis of Savoy-Carignan-Soissons was born in Paris to Italian parents in 1663. He was the youngest son of Olympia Mancini, the niece of Cardinal Mazarin, and Eugene Maurice of the Savoy-Carignan-Soissons. He had four elder brothers and two younger sisters. His mother was favored at the court of Louis XIV, where Eugene was brought up, but she fled to Brussels in 1680 when she was accused of being a poisoner. For the next three years he was under the care of his grandmother, Marie de Bourbon, who threw him out of the house for refusing to become a priest, after which he fled Paris (disguised as a girl), as he was refused entry into the army of King Louis XIV.
on the grounds of a weak constitution. Leopold, of the Habsburg monarchy, allowed him to join the imperial Austrian army as a Volontar in 1663, where his cousins protected and financed him, as did the head of the house of Savoy, Duke Victor Amadeus II. At last he was a soldier and not a priest as his parents had intended; indeed, he was known as the Abbe de Savoye in 1678.

He first gained fame in Europe after his victory against the Ottomans at the battle of Zenta in 1697. Prince Eugene is shown in the stunning portrait (Fig. 2.18) by the painter Jacob van Schuppen. Eugene was best known for his courage and success in battles such as against the Turks laying siege to Vienna, campaigning in Hungary and even against the French in the Spanish War of Accession, when he joined forces with the First Duke of Marlborough (John Churchill) at Blenheim (1704), the main confrontation of the war. A celebration of the victory at Blenheim is shown in Fig. 2.19 and is described in the attached legend at the British Museum:
Responding to appeals from Vienna, which was threatened by French and Bavarian forces, the English commander, John Churchill, Duke of Marlborough, marched his army from the Netherlands to Bavaria and joined forces with the Austrian general, Prince Eugene of Savoy. At Blenheim their combined army overwhelmed a Franco-Bavarian
force under Marshall Tallard and the Elector of Bavaria. For the first time in two generations the French suffered a crushing defeat, and the results were immediate and far-reaching. Bavaria was conquered and Vienna saved. The territorial ambitions of Louis XIV beyond the Rhine were checked, and France was placed on the defensive.

More than once Eugene, using his recognized skills in war, joined with the duke in battle, which clearly resulted in their close friendship. Figure 2.20 is a print of a 1709 etching of the Duke of Marlborough and Prince Eugene of Savoy on horseback, foreground left, surveying the bombardment of Tournay in 1709. Figure 2.21 shows a portrait of John Churchill, Duke of Marlborough, in 1704.

The last engagement fought by the two commanders together was the battle at Malplaquet in France (1709). Probably harking back to his resentment of King Louis XIV, Eugene in his capacity as general of the Austrian cavalry led his army to remove the French from northern Italy. This belonged to Spain at the time. Acknowledged as one of the greatest war strategists and generals of his time, he spent the last years of his life on his great project of reforming the Austrian army and lived in luxury in the Great Palace of the Belvedere in Vienna.
When the Treaty of Rastatt (1714) ended hostilities between France and Austria, Eugene mixed with scholarly men (such as Gottfried Leibniz, Jean-Baptiste Rousseau and Montesquieu), who were always keen to obtain patronage from the now wealthy prince. His art collections comprised sixteenth and seventeenth century Italian, Dutch and Flemish masters, and his library contained over 15,000 books, 237 manuscripts—he was particularly interested in natural history and geography—and a huge collection of prints. In 1726 he bought Schloss Hof, a beautiful tract of land near the Austrian/Slovakian border, and hugely extended and developed it into a stunning summer palace and hunting lodge. Prince Eugene’s baroque palace gardens with their vast terraces, ornamental shrubbery, lovely fountains and fine sculpture were known as the most beautiful gardens of the Danube monarchs by 1730. When he died in his city palace in Vienna in 1736, probably from pneumonia, most of his accumulated collections went to his
niece, Princess Maria Anna Victoria. She immediately sold every-
thing since she had no interest in, or respect for, her uncle and his 
exploits.

John Rowley

It is easy when scanning written works on astronomy to receive 
the impression that the only thing Rowley ever did was to be as-
sociated with the first geared models of orreries. Nothing could be 
further from the truth. The following information is a combina-
tion of facts gleaned from several sources.

John Rowley (1668–1728) was born in Lichfield, Staffordshire, 
and had three older brothers and a sister. His father, William Row-
ley, was a sword cutler (a maker of sword blades). At the age of 
14 he became apprentice to the London mathematical and optical 
instrument maker Joseph Hone in the Broderers Company (or 
maybe to the instrument-maker W. Winch). He became a freeman 
of the Broderers in 1691 and began his own business in 1704 (or 
possibly 1698) in his shop, The Sign of the Globe, in Fleet Street. 
His patron was Prince George of Denmark, the husband of Queen 
Anne of Great Britain, from 1704 until the Prince’s death in 1708.

Rowley produced a wide range of mathematical, drawing, 
surveying and gunnery instruments to be given to Christ’s Hospi-
tal mathematical school and other groups. He made a sextant and 
other instruments for the observatory at Trinity College, Cam-
bridge, which led to him being recommended for membership of 
the Royal Society. He was then asked to report on the instruments 
of John Flamsteed during 1711–1713. He made large sundials for 
Blenheim Palace and St. Paul’s Cathedral. He became the principle 
supplier to one of the finest collections of instruments amassed 
by the Earl of Orrery, who probably commissioned Rowley to pro-
duce a tellurian of the type built by Graham, but larger.

Again for the Earl, he created (Fig. 2.22) a most pleasing But-
terfield Dial for latitudes 40–55° north. The central section is en-
graved with the arms of the house of Orrery, which includes lions 
and the family motto: HONOR VIRTUTIS PREMIUM, honor is 
the reward of virtue. The compass has cardinal points and the north 
point is offset 10° west of north to allow for magnetic variation, 
among other attributes. It is signed J. Rowley LONDINI. In fact, he
made a second almost identical dial for the Duke of Marlborough, which has a black leather case and his coat of arms on the dial. The place names on the back are connected to Marlborough’s campaign in the Low Countries during the War of the Spanish Succession.

Rowley also produced magnificent orreries for the Habsburg emperor Charles VI, for Peter the Great, and for the East India Company. For the price of £1,000 he created an elaborate model in 1722 called the great solar system, which included Mercury and Venus. The orrery ebony case with silver ornaments was sold for £500. It is likely that this model never actually reached India and never even left England due to the death of an intermediary in the purchase. Rowley left his shop, which he gave to Thomas Wright, so that he could concentrate on his duties as ‘Master of the Mechanicks’ to George I, in particular, for the repair, maintenance and building of water engines (water pumps). While collaborat-
ing with the Board of Ordinance he made a great contribution to standardizing the measure of the English yard and standardizing calibration of land and sea cannon. One scientifically worrying aspect was that during a scholarly meeting, Samuel Johnson praised Rowley for his perpetual-motion experiments!

**On the Trail**

It does appear that Prince Eugene visited England, possibly to assist his friend the Duke of Marlborough in recovering his reputation and standing in court, which failed. Then he went to London on a scientific instrument and art collecting spending spree. He popped into both the Tompion/Graham establishment (the Dial and Three Crowns) as well as into the nearby Rowley shop (Sign of the Globe). The purchased G & T model was to be shipped by Rowley to Austria, along with some of Rowley’s other instruments. While the model was with Rowley, he was commissioned by the Earl of Orrery to make a copy for him, and Rowley then named the model an orrery after his patron.

It had been suggested that Sir Richard Steele (Irish essayist, 1672–1729) came across Rowley’s model in a presentation delivered by Rowley and, knowing nothing of the Graham model, named it an orrery in honor of the Earl of Orrery to popularize it. In his newspaper, one of the precursors of *The Statesman*, Steele wrote: “All persons, never so remotely employed from a learned way, might come into the Interests of Knowledge, and taste the Pleasure of it by this intelligible Method [the orrery]. This one Consideration should incite any numerous Family of Distinction to have an Orrery as necessarily as they would have a clock. This one engine would open a new Scene to their Imaginations; and a whole Train of useful Inferences concerning the Weather and the Seasons, which are now from Stupidity the Subjects of Discourse, would raise a pleasing, an obvious, an useful, and an elegant conversation.”

However, Steele even referred to Rowley as ‘the Honest Man,’ which might also indicate some confusion with ‘Honest’ George Graham.

These facts were rectified by the lecturer and writer Desaguliers (1683–1744), who was also a scientist and inventor of high repute, although he continued to attribute the actual naming of
Desaguliers stated in “A Course in Experimental Philosophy, 1734” that “Mr. George Graham (if I am rightly informed) was the first person in England, who made a movement to [show] the Motion of the Moon round the Earth, and of the Earth and Moon round the Sun, about 25 or 30 years ago. In this machine everything was well and properly executed.” He continued to detail its features; to show the phenomena of day and night and their gradual increase and decrease, the seasons, the place on Earth where the Sun is successively vertical and so on.

Desaguliers was generous over Steele’s lack of awareness of Graham, “Sir Richard Steele, who knew nothing of Mr. Graham’s Machine, in one of his Lucubrations, thinking to do justice to the first Encourager, as well as the inventor, of such a curious instrument, call’d it an Orrery, and gave Mr. J. Rowley the Praise due to Mr. Graham.” A suggestion had also been made that Queen Anne commissioned it as a presentation to Marlborough. Then, either Marlborough gave it to Eugene, or Queen Anne changed her mind and gave it to Eugene instead of Marlborough, who was falling out of grace with the court. However, historical circumstances make the involvement of Queen Anne difficult to believe.

There are several references that add weight to the fact that the G & T model was commissioned by Prince Eugene. What is certain is that the G & T model arrived in Eugene’s stunning Stadtpalais in Vienna or Belvedere Palace in the city’s outskirts to join the rest of the vast collection sometime between 1705 and 1712, depending on the truths of the stories of gifts or purchases. Figure 2.23 shows the palace in 1753.

Prince Eugene was unmarried. Upon his death in 1736, since he had not made a will that might have benefitted those who had served him, his huge fortune, buildings and collections passed to Princess Anne Victoria of Savoy, the daughter of his oldest brother. As mentioned earlier, she had felt no fondness for her uncle and promptly sold the lot, sometimes for knock-down prices. No records of the sales were made, making tracking of the provenance of some of the artifacts difficult or impossible. However, it seems certain that the G & T model was acquired from Eugene’s estate by Emperor Charles VI, as a ‘Copernican Planetary System’ was included in a record of royal possessions obtained from the
estate of Prince Eugene. The listing of emperors below might assist in following the trail. Note that much confusion can occur, since Charles and Karl, and Francis and Franz, are same names, and where the numbers for the same monarch differ it is because the ‘countries’ that they represented changed during the constant round of wars and takeovers.

Holy Roman Emperors from the House of Habsburg from Ferdinand II to Karl I

<table>
<thead>
<tr>
<th>Emperor</th>
<th>Reign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferdinand II</td>
<td>1619–1637</td>
</tr>
<tr>
<td>Ferdinand III</td>
<td>1637–1657</td>
</tr>
<tr>
<td>Leopold XII</td>
<td>1665–1705 (also known as Leopold I)</td>
</tr>
<tr>
<td>Joseph I</td>
<td>1705–1711</td>
</tr>
<tr>
<td>Karl (Charles) VI</td>
<td>1711–1740 (also known as Karl [Charles] III)</td>
</tr>
<tr>
<td>Maria Theresia</td>
<td>1740–1780 (“Habsburg-Lothringen” or “Hapsberg-Lorraine”)</td>
</tr>
<tr>
<td>Joseph II</td>
<td>1765–1790</td>
</tr>
<tr>
<td>Leopold II</td>
<td>1790–1792 (also known as Leopold XIII)</td>
</tr>
<tr>
<td>Franz (Francis) II</td>
<td>1792–1806 (resigned and started his own empire)</td>
</tr>
</tbody>
</table>
Habsburg Emperors of Austria

<table>
<thead>
<tr>
<th>Emperor</th>
<th>Reign</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Franz (Francis) I</td>
<td>1806–1835</td>
<td>(same person as Franz II)</td>
</tr>
<tr>
<td>Ferdinand I</td>
<td>1835–1848</td>
<td></td>
</tr>
<tr>
<td>Franz Joseph I</td>
<td>1848–1916</td>
<td></td>
</tr>
<tr>
<td>Karl I</td>
<td>1916–1918</td>
<td></td>
</tr>
</tbody>
</table>

The next likely appearance of the G & T was in the possession of Stephan, Grand Duke Francis III of Tuscany, husband of Maria Theresia (Theresa). When he became Emperor Francis (Franz) I Stephan asked Johann Georg Nesstfelt, a master carpenter and cabinet maker, to repair an English planetary model whose mechanism had been spoiled. Nesstfelt completed the repair in 1753, and the model was placed in the exhibition of the Imperial Library. There was some postulation that it was a Rowley model, but most likely it was the G & T. After the emperor’s death the royal collections were divided up and redistributed by his wife. In 1765 she ordered that the Kunstkabinett collection must be relocated in several salons next to her newly established Augustinerergang in the Hofburg. The collections were displayed in nine rooms. In 1791 the collection was moved from the Hofburg to a hall of the Schweizerhof. Over the next several years the collections were brought together in the left wing of the Hofbibliothekgebäude. In 1806 the collections were divided once more and the Mechanisch-Physikalische Kabinett was transferred to the Physikalisch-Astronomische Kabinett. In 1810 it appeared in the Schweizerhof under the astronomical tower in the Imperial City until the Kabinett was disbanded in 1886.

The G & T model could have been moved at any time from where it had been on display in the Imperial Library. The English instrument vanished from the collections sometime during the moves, a guess being that it was ‘nicked’ and sold by a member of the staff. It is no wonder that from the above complex sequence of events, an instrument in the collections would not be accompanied by precise provenance; and it is all just a best guess anyway. Then there was historical silence with regard to the G & T proto-orrery until around 1930, when it was purchased by a dealer, Jesse Myer Botibol. Botibol, possibly of Austrian extraction, resided at various locations in London and sold artifacts at Christie’s auction sales.
Botibol had purchased the model from a monastery that had owned it from a date that coincided closely with the date of its disappearance from the Imperial Library. It was not unusual for monasteries to collect astronomical instruments. The monastery was the Benedictine monastery Erzabtei St. Peter in Salzburg. Ownership by the Salzburg monastery was confirmed in correspondence from Pater Berthold Egelseder of the nearby Benedictine monastery in Michaelbeuern. In a personal communication during the preparation of this work Dr. Hirtner of the Archiv der Erzabtei St. Peter generously scanned the diaries and account books from 1886 to 1930, but no relevant record revealed itself.

Several dealers were involved in attempts to acquire the model, but it eventually appeared with a dealer, Francis Harper, residing at Wickin’s Manor, Charing, Kent, England, who had purchased it from either Botibol or the London dealer Solomon Nathan Nyburg. Much prevarication continued between dealers and, on the advice of Sir Geoffrey Callender, first director of the National Maritime Museum, the curator of the Museum of the History of Science, Oxford, Frank Sherwood Taylor was to visit Harper in 1943. Unfortunately, Harper died unexpectedly and his wife consigned the instrument to be sold at Sotherby’s auction sales in 1948, Lot 174. The Oxford Museum bought the model using funds and private donations. It is now on permanent display there.

The church of St. Peter within the monastery of Erzabtei in Salzburg was founded by St. Rupert, a Franconian missionary, around A.D. 700 and may have been built upon, or expanded, an existing local religious faction created a few centuries before. It is the oldest community of monks on the Austro-Germanic soil. The buildings were entirely destroyed by fire in 1127 but resurrected between 1130 and 1143 by Abbot Balderich. Many modifications were made over the centuries to produce the stunning church it is today (Fig. 2.24), housing the oldest library of Austria as well as many musical and other collections. Its ancient cemetery is famous, and among those resting here are Maria Anna, or Nannerl, Mozart (Mozart’s sister) and Michael Haydn (composer Joseph Haydn’s younger brother).

Michaelbeuern Abbey dates back to at least 736, when it was apparently damaged during the Hungarian wars. A fire caused much destruction in 1346, but the abbey saw much better days from the seventeenth century on, and the magnificent baroque
high altar (Fig. 2.25) was built in 1691. Today it is a thriving Benedictine abbey and owns many businesses such as a farming complex, heating device project and a part share in a brewery. It is the cultural and economic center of Dorfbeuern.

The labeled outline map of Austria (Fig. 2.26) indicates the known places associated with the G & T proto-orrery.

The G model had a much simpler and known history. It was likely that it passed to Graham’s benefactors following his death in 1751, but nothing more was heard of it until it appeared, then promptly disappeared, some years before the G & T model, only to appeared again in 1915 in a purchase by the dealer Simmons from the Stevens Galleries in London. It was then sold again at auction in New York, Lot 1288, at a sale of The American Art Association of the properties of Henry Symonds for $825 to an agent, Otto Bernet. ‘Honest George Graham’s Famous Orrery
**Fig. 2.25** The magnificent baroque high alter in Michaelbeuern Abbey, Austria, built in 1691. (Courtesy of Creative Commons Attribution-Share Alike 3.0 Unported license. Attribution; Werner 100359.)

**Fig. 2.26** An outline map of Austria indicating the known places associated with the G & T proto-orrery. [Illustration by the author.]
Clock’ again disappeared until 1941, when it was offered for sale to the Adler Planetarium and Astronomical Museum in Chicago. The offer was made by an importer of antiques, Samuel Wilson, on behalf of the owner, Byron de Forest, an engineer in the Line Design Section of the Commonwealth Edison Company. The offer was not taken up at that time and the instrument was stored in the company’s vault. Five years later the G model was offered once more by de Forest to the Adler museum’s F. Wagner Schlesinger, accompanied by a fantastical story of provenance by de Forest that was totally untrue, involving complete tracking of the model through families and heroes. When the price had been reduced, the Adler museum bought it, and it is there to this day on permanent display.

A cursory glance at the history of the orrery and the trail of the G & T model could easily throw up a smokescreen as to who visited England to see whom about the Graham orrery. In addition to the above story the brilliant French scientific instrument and clockmaker Philip Vayringe, having been appointed to the royal position of watchmaker and mechanist at Luneville, visited the same place as Eugene to collect instruments of the orrery kind. He even resided in London around that time with the eminent Desaguliers while he learned more about the model’s mechanism, possibly from Graham himself.

Vayringe was also commissioned to build more such ‘planetaria’ as well as repair an ‘English model’ in the royal collection. In particular he was commissioned to build a copy of Graham’s clockwork design. He produced one with just a few modifications and with an elaborate case and pedestal that pleased Duke Leopold of Lorraine so much that he had Vayringe present it personally to the Archduchess Maria Theresia. It can currently be seen in the Naturhistorische Museum in Vienna. In 1725 he worked on his own complex orrery with many planets and satellites that remained unfinished, and more. Vayringe died in 1746 of malaria.

Chance has clearly played a hand in the naming of these geared models of the Solar System. They could easily have been named rowleys or eugenes or even savoys, although the latter might cause some confusion with cabbages!

Much of the story of clocks mingled with royalty that constantly changed. Table 2.1 shows monarchs of the era as a reference while following the trail.
<table>
<thead>
<tr>
<th>Monarch</th>
<th>Royal House</th>
<th>Born/Died</th>
<th>Reigned</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henry VIII</td>
<td>Tudor</td>
<td>1491–1547</td>
<td>1509–1547</td>
<td>Noted for his battles with the Church and his six wives</td>
</tr>
<tr>
<td>Edward VI</td>
<td>Tudor</td>
<td>1537–1553</td>
<td>1547–1553</td>
<td>Nine years old when he succeeded to the throne and only 15 when he died, probably of tuberculosis</td>
</tr>
<tr>
<td>Lady Jane Grey</td>
<td>Tudor</td>
<td>1537–1554</td>
<td>1553</td>
<td>‘Nine-Days Queen’, executed at age 16</td>
</tr>
<tr>
<td>Mary I</td>
<td>Tudor</td>
<td>1516–1558</td>
<td>1553–1558</td>
<td>Known as Bloody Mary, because 300 protestant martyrs were burned at the stake. Married Philip II of Spain. Died of influenza</td>
</tr>
<tr>
<td>Elizabeth I</td>
<td>Tudor</td>
<td>1533–1603</td>
<td>1558–1603</td>
<td>The Virgin Queen. Defeated the Spanish Armada</td>
</tr>
<tr>
<td>Charles I</td>
<td>Stuart</td>
<td>1600–1649</td>
<td>1625–1649</td>
<td>Charles dissolved Parliament for 11 years. Executed in 1649</td>
</tr>
<tr>
<td>Interregnum</td>
<td>Commonwealth Protectorate</td>
<td>1649–1653</td>
<td></td>
<td>Empowered by Parliament</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Led by Oliver Cromwell</td>
</tr>
<tr>
<td>James II</td>
<td>Stuart</td>
<td>1633–1701</td>
<td>1685–1689</td>
<td>Married Italian princess, Mary of Modina. Ousted in 1689</td>
</tr>
<tr>
<td>Monarch</td>
<td>Royal House</td>
<td>Born/Died</td>
<td>Reigned</td>
<td>Notes</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------</td>
<td>-----------------</td>
<td>----------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>William and Mary</td>
<td>Orange</td>
<td>1650–1702</td>
<td>1689–1702</td>
<td>William III (II of Scotland) was a Dutchman ‘invited’ to England. Mary was the daughter of deposed James II</td>
</tr>
<tr>
<td></td>
<td>Stuart</td>
<td>1662–1694</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anne</td>
<td>Stuart</td>
<td>1665–1714</td>
<td>1702–1714</td>
<td>Married Prince George of Denmark. No surviving heirs. Queen of Great Britain, France and Ireland</td>
</tr>
<tr>
<td>George I</td>
<td>Hanover</td>
<td>1660–1727</td>
<td>1714–1727</td>
<td>German. Great grandson of James I. Married cousin Sophia Dorothea of Celle</td>
</tr>
<tr>
<td>George IV</td>
<td>Hanover</td>
<td>1762–1830</td>
<td>1820–1830</td>
<td>Married German princess, Caroline of Brunswick. His only daughter, Princess Charlotte, died young</td>
</tr>
<tr>
<td>William IV</td>
<td>Hanover</td>
<td>1765–1837</td>
<td>1830–1837</td>
<td>Age 64 at succession. Married Adelaide, daughter of the Duke of Saxe-Meiningen. No surviving legitimate heirs</td>
</tr>
<tr>
<td>Victoria</td>
<td>Hanover</td>
<td>1819–1901</td>
<td>1837–1901</td>
<td>The longest reign in British history. Ruled the biggest empire the world has ever seen</td>
</tr>
</tbody>
</table>
Orrery
A Story of Mechanical Solar Systems, Clocks, and English Nobility
Buick, T.
2014, XXIII, 299 p. 249 illus., 70 illus. in color., Softcover
ISBN: 978-1-4614-7042-7