WHO INVENTED RACK-AND-SNAIL STRIKING?

THE EARLY DEVELOPMENT OF REPEATING AND RACK STRIKING

by John A. Robey

An investigation into a very unusual, and possibly unique, early rack-striking longcase clock by Henry Young of London has prompted a re-evaluation of the development of rack striking. The traditional view is that it was originally invented about 1676 by Edward Booth/Barlow (1636-1719), and this has been stated in almost every work on horology, but the evidence for this merits re-evaluation. In order to untangle the very meagre evidence it is necessary to first discuss early repeating work, which was the precursor of rack-and-snail striking, as the development of the two is inextricably linked. In particular mis-interpretation of the evidence has been largely caused by not making a clear distinction between repeating work on timepieces and on striking clocks.

The main advantage of rack striking over the countwheel, which had been used since medieval times, is that provision may be made for repeating the hours and/or the quarters, and it avoids resetting of the countwheel if the strike does not correspond to that indicated by the hour hand. The long descriptions given in early horological books of how the latter was done, indicate that this was a serious problem, and not readily understood by the general public. It is possible that rack striking was favoured owing to its ability to always strike the correct hour, rather than being able to repeat the strike, although it was certainly used for this purpose, as shown by the pull cord sometimes fitted to rack-striking longcase clocks.

It should be noted that timepieces with a separate pull-repeat system that sound the quarters and hours on demand, known as 'silent-pull' (i.e. they are silent until pulled), usually employ a snail, but not a gathered rack. On the other hand clocks that strike the hour and also have quarter repeating, normally (apart from a few rare clocks that strike the hours with a countwheel and have an independent silent pull-repeat system[1]) use a rack for both striking and repeating the hour, irrespective of the method for repeating the quarters. The author knows of only one silent-pull timepiece that uses a gathered rack for repeating the hours. This is a possibly unique eight-day weight-driven hooded wall timepiece by Joseph Kirk of Nottingham, of about 1740.[2]

Although methods of locking and warning are mentioned in passing, it is the development of the gathered rack in conjunction with a snail for counting the number of hammer blows that is the primary concern in this article.

EARLY REPEATING SYSTEMS

A four-page chapter titled: 'Quarter Repeating, and Chime Clocks, their use and management' in John Smith's *Horological Dialogues* (1675), contains the earliest mention of repeating. This, as will be discussed later, is earlier than the quoted date of Barlow's involvement.[3] After talking about quarter-chiming clocks (using countwheels, although this is never specifically mentioned), the question 'How doth the repeating Clock strike?' is answered by:

> They not only strike the hour and quarters, but also, immediately after the striking of each quarter, it repeats or strikes over again, on a different bell, the last hour that was strucken, by which you are given to understand that it is 1, 2, or 3 quarters past that hour which is repeated; this Clock is of excellent use for the night.

This does not refer to a clock that repeats at will, but rather a *grande sonnerie* system of

1. For example the Swansea Tompion (discussed here), and L. Harvey & C. Allix, *Hobson's Choice*, (1982), p.84.
2. J. Webster, to be published.
3. J.S. [John Smith], *Horological Dialogues*, (1675), pp.49-52.

chiming and striking, using countwheels, of the type made by Joseph Knibb. While it certainly tells the time to the nearest quarter of an hour by sound alone, it would not allow a light sleeper much rest during the night.

The continuation of Smith's answer describes what must be the earliest type of true repeating clock:

> There is another sort of repeating Clocks, which differs much from this before spoken of, the quarters and repeating, being both performed at the same time, and on the same bells; it strikes the quarters on three bells, and the hour never strikes above six; to understand the striking of this Clock you must observe this rule. Look how many quarter bells strikes whether on 1, 2, or 3, for so many quarters are passed since the strikeing of the last hour, as if it strike on one bell, then one quarter is passed; on two bells, then two quarters are passed, if on three bells, three quarters are passed: then again, look how many times it strikes on any number of the aforesaid three bells, that is the hour that was strucken last; as suppose it strike five times on two bells, this signifies its two quarters past five or eleven as the time is, again suppose it strikes six times one [on] three bells, this signifies its three quarters past six or twelve, according to the time.

This description states that the number of quarters being sounded during the repeat is recognised by how many bells are struck simultaneously during the hour repeat, but it is difficult to envisage that a half-asleep person would be able to tell how many bells were sounding. The actual clock described by Smith appears not to have survived, and it is intriguing to speculate who might have made it. The fact that the method 'differs much from this before spoken of' indicates that it is not just grande sonnerie striking using countwheels, but a true repeating mechanism, and it had some of the features used on Thomas Tompion's earliest surviving repeating clock, where indeed 'the hour never strikes [repeats] above six'.

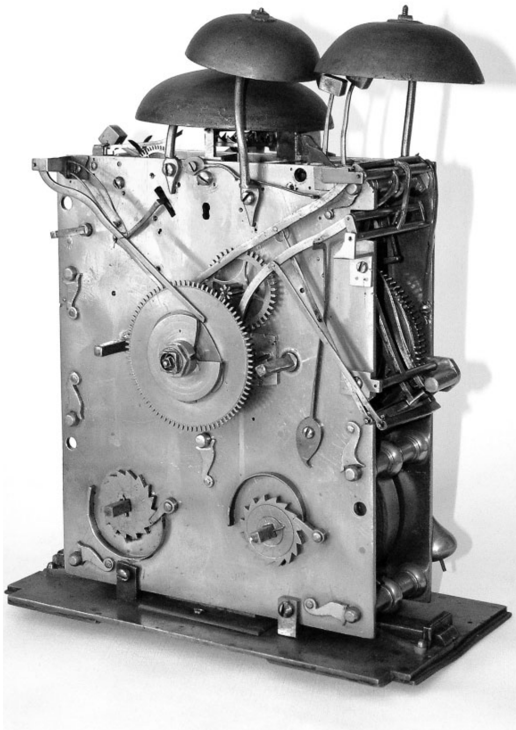

Fig. 1. The movement of the 'Swansea Tompion', with the earliest known repeating mechanism, made about 1675. Hour strike on the large bell uses a conventional countwheel, with separate bells for the hour and quarter repeat.

This is an unnumbered bracket clock (known today as the 'Swansea' Tompion, on loan to the Manor House Museum, Bury St Edmunds) with normal hour striking controlled by a countwheel, but a separate mechanism for repeating the hours (on the double-six principle) and quarters. It has been dated to about 1675-80, and is one of Tompion's earliest known clocks.[4]

The repeating mechanism employs a snail (and appears to be the earliest use of a cam with steps to determine specific set angles) with a follower that shunts a lever into the path of pins of graduated lengths on a train wheel (Figs 1 & 2). The snail has two sets of six steps, not only to reduce the power needed to drive the repeat train, but also because a larger lateral shift would have been impractical. A similar system was used on Tompion's metal-cased timepieces Nos 21 & 23 (the latter converted to a twelve-step snail some time later), which date from the

4. R.W. Symonds, *Thomas Tompion his Life and Work*, (1951), p.118, Figs 110, 168, 205. Symonds dates the clock to about 1675, while Jeremy Evans believes it to be nearer 1680.

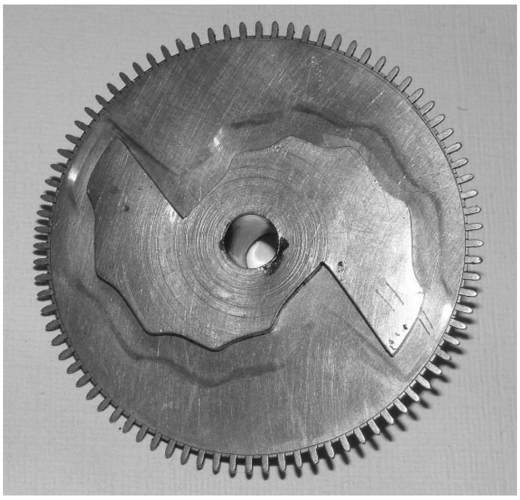

Fig. 2. The double-six snail from the Swansea Tompion, probably the first made for use on a clock. The low steps count one strike, the high steps count six strikes, being the reverse of the later conventional arrangement.

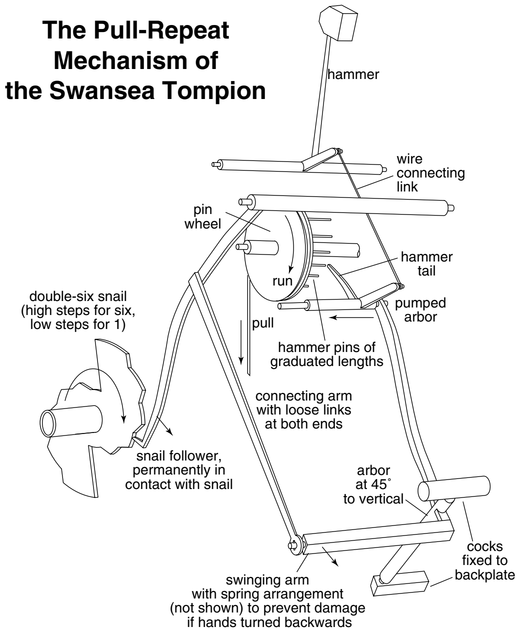

Fig. 3. The principle of the hour-repeating mechanism on the Swansea Tompion. A follower runs continually on the double-six snail. As it is lifted by the steps of the snail it rotates, via a connecting arm, a swinging arm pivoted at 45 degrees to the vertical. This then pumps across a hammer tail into the path of a series of trip pins of graduated lengths. A wire links the pumped tail arbor with the actual hammer arbor, which does not move transversely. In practise the mechanism is complicated by fail-safe arrangements to prevent malfunction, such as damage if the hands are turned backwards.

same period, or only slightly later afterwards.[5] In these three clocks the follower is in contact with the snail all the time, and the snail is the reverse of the later conventional arrangement, so that the follower drops down the high step, rather than jamming against it. These details are significant when discussing Henry Young's mechanism.

An ingenious arrangement of levers and pivoted arbors, connected by an arm with loose links at the ends, converts rotation of the snail follower in the plane of the front plate to movement at right angles to it, so as to pump over a hammer tail (Fig. 3). The quarters are counted by a similar follower, levers and arbors, but moving in the opposite direction. Later clockmakers sometimes counted the quarters with a similar arrangement of graduated hammer pins, but the hammer tail was pumped with a wedge-shaped block or a face cam on the minute (cannon) wheel, rather than a lever system. While this was satisfactory for the small number of steps needed for quarter repeating, the larger number of hours would have necessitated a greater overall lateral shift than would be practical with a wedge or face cam. This is the only Tompion repeating clock with a spring barrel (which is between the plates), as he later used a blade spring to power his repeating work. The workmanship of the movement does not show the attention to detail (such as the bevelled edges to cocks, etc) found on his later clocks, and clearance has had to be filed at several places in the top right-hand pillar and on some of the repeat arbors. This indicates that the repeating work was experimental, modifications had to be made as the system was under development, and he was not working to a tried and tested design.

About 1680 Joseph Knibb developed a simple silent-pull repeating mechanism where a twelve-step snail, in conjunction with a toothed sector and pinion, was used to determine how many pins on the train-wheel tripped the hammer tail (Fig. 4).[6] Despite miscounting

5. P.G. Dawson, C.B. Drover, & D.W. Parkes, *Early English Clocks*, (1982), pp.346-7, 431; also information from Jeremy Evans.

6. Dawson, Drover, & Parkes, *op. cit.*, p.344; Harvey & Allix, *op. cit.*, pp.36-7.

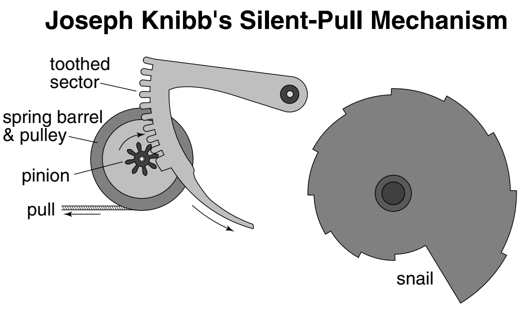

Fig. 4. The principle of Joseph Knibb's simple silent pull for sounding the hours. The pull cord rotates the pinion and at the same time winds the spring and also turns the pinwheel clockwise (on the same arbor, but a loose linkage with the hammer tail allows it to turn without sounding the bell). The sector rotates until the extension contacts a step on the snail. On release the pinwheel rotates anticlockwise, so that the appropriate number of pins trip the hammer tail.

if not given a full pull, Knibb's was the most widely used method of repeating the hour on timepieces. Later, clockmakers such as Daniel Delander and Francis Gregg, made variants of Knibb's system that incorporated an 'all-or-nothing' piece, so that the mechanism would only operate if fully pulled.[7]

About the same time Thomas Tompion developed his 'standard' highly complex silent-pull repeating mechanism (most of the complexity is to raise the teeth that trip the hammer tails into position just before they are required to operate, so as to avoid miscounting due to a short pull). None of these systems incorporate a saw-toothed rack and gathering pallet, which appear to have been developed separately from the invention of the snail. Although Tompion's silent pull repeating mechanism seems to have a rack,[8] it actually only acts as a sophisticated pinwheel to trip the hour and quarter hammer tails. Confusingly, the toothed sector that winds the main pinion (as in the Knibb system) has been called the 'internal motion rack',[9] but it is not a gathered rack at all, and this imprecise terminology has done little to assist in the clear understanding of the operation of these mechanisms.

Another repeating system employs two snails

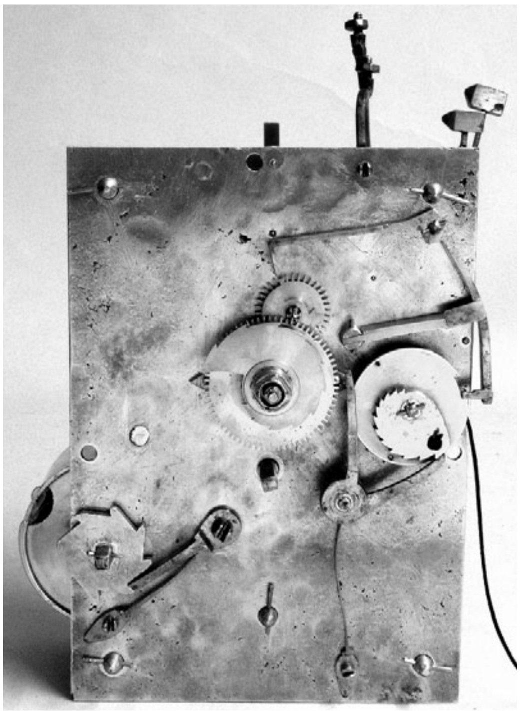

Fig. 5. Silent-pull clock by Gabriel Smith, Nantwich, about 1730. When the cord is pulled one arm of the V-shaped lever falls onto the hour snail, while the other arm intercepts one of the edges of the snail-like cam, so counting the number of hour strikes. On this example the steps on the secondary snail only extend round two-thirds of its circumference, but they often occupy the full disc and it then has the appearance of another snail.

instead of a sector-and-pinion. Figure 5 shows an example by Gabriel Smith of Nantwich, Cheshire, about 1730. One end of an L-shaped lever falls onto the circumferential steps of a snail, as usual, while the other end intercepts the radial edges of the steps of another snail, to determine how far the pin barrel can be pulled and how many times the hammer tail will trip when the pull cord is released. The second snail is sometimes replaced by a disc with a spiral of pins, as shown on a pull-repeat timepiece by Joseph Blundell of Dublin, about 1715-20 (Fig. 6).[10] This double-snail method was in use by about 1690 on a bracket clock signed by Samuel Watson of London (but characteristic of the work of Daniel Quare) to repeat the quarters, with normal rack striking for the

7. For example, Harvey & Allix, *op. cit.*, pp.76-80.
8. Symonds, *op. cit.*, p.214, Fig 211; Dawson, Drover & Parkes, *op. cit*, p.378; Harvey & Allix, *op. cit.*, p.12.
9. Harvey & Allix, *op. cit.*, p.13.
10. J.A. Robey, 'An Irish Pull-Repeat System', *Horological Journal*, (December 1997), 415-19.

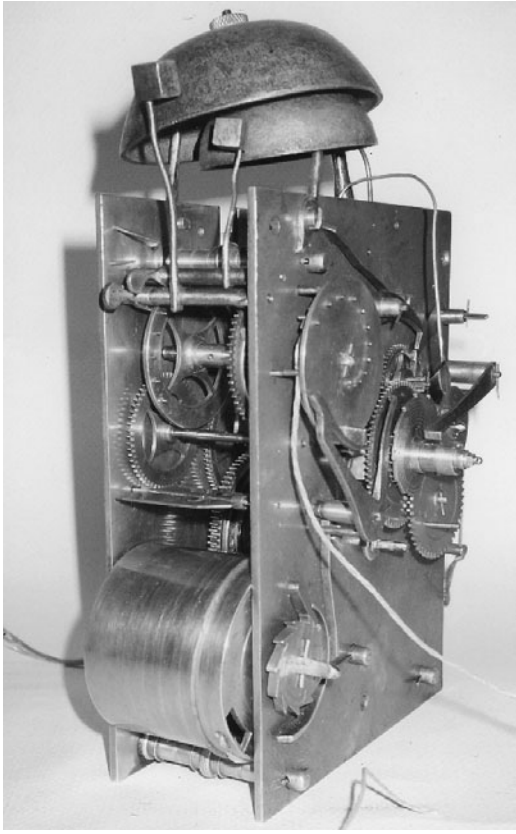

Fig. 6. Silent-pull bracket clock by Joseph Blundell, Dublin, about 1715-20. This uses the twin snail method, except the secondary snail is replaced by a disc with a spiral of pins. Some of his other clocks used a solid secondary snail.

hours,[11] although it may have been employed earlier. It is described as 'the most commonly used method of obtaining the quarter blows in repeating work', but as the examples by Gabriel Smith and Thomas Blundell show, it was also used for repeating the hours on silent-pull timepieces.

EDWARD BARLOW AND THE REPEATING CLOCK

The often quoted statement that Barlow invented rack-and-snail striking, followed shortly afterwards by the repeating mechanism,[12] is not borne out by the very scanty evidence. The extent of Barlow's involvement and exactly what he invented is unclear, as there is only the statement of Derham, written twenty years after the event.[13] It is significant that Derham is talking about repeating and not striking the hours, and his chapter on the calculation of the striking train refers throughout to the countwheel and not the rack or snail. There is no mention of rack striking anywhere in his book. Although they have been often quoted, Derham's exact words are worth stating again:

> **CHAP. IX**
> ***The Invention of Repeating Clocks***
> The clocks I shall now speak of, are such as by pulling of a String, &c. do strike the Hour, Quarter, or Minute, at any time of the day and night.
> These Clocks are a late Invention of one Mr Barlow, of no longer standing than the latter end of K. Charles II. about the year 1676.
> This ingenious Contrivance (scarce so much as thought of before) soon took air, and being talked of among the London Artists, set their heads to work; who presently contrived several ways to effect such a performance. And hence arose the divers ways of Repeating work, which so early might be observed to be about the Town, every man almost practising, according to his own Invention.

About ten years later in February 1687/8 Edward Barlow made a patent application 'for the sole makeing and manageing [of] all pulling Clocks and Watches, usually called Repeating Clocks'. The main objector was the Clockmakers' Company (who opposed any horological patent as a matter of course at this time) and a patent was not granted as 'the same [were] being now made by severall Clockmakers.'[14] Derham states that Barlow's application was for the use of his

11. Dawson, Drover, & Parkes, *op. cit.*, pp.399-400.
12. H. Cescinsky & M.R. Webster, *English Domestic Clocks*, (1913), p.287; C. Clutton, *Britten's Old Clocks & Watches and Their Makers*, 9th edition, (1982), p.98; H.A. Lloyd, *The Collector's Dictionary of Clocks*, (1964), p.152. The attribution of rack striking to Edward Barlow has been repeated without checking in virtually every horological book.
13. W. Derham, *The Artificial Clock-maker*, (1696), p.106.
14. G.H. Baillie, *Clocks and Watches: An Historical Bibliography*, (1951, reprinted 1978), p.115; J. Bromley, *The Clockmakers' Library*, (1977), p.79.

repeating system in watches, when the latter 'endeavoured … to get a Patent for it. And in order to it, he set *Mr Tompion*, the famous Artist, to work upon it: Who accordingly made a Piece according to his directions.' Derham enlarges on this and states that Barlow's patent application was contested by Daniel Quare and the king gave 'the preference to Mr *Quare's*: of which, notice was given in the Gazette' (i.e. the *London Gazette*), but no such patent was actually granted to either Barlow or Quare.[15]

There is conflicting evidence here, as the Clockmakers' Company opposed the patent because repeating work was already being use by others, while Derham states that it was Quare's simpler system of one push piece for both hours and minutes, compared to Barlow's use of separate pieces, that won favour with the king (or in reality his officials). Barlow may have had more chance of success with his patent if it had been restricted to repeating watches, as there is no evidence for them before this date. The Clockmakers' Company would then not have been able to claim prior use, as it was repeating clocks, not watches, that were 'now made by severall Clockmakers', but no doubt they would have come up with other objections. There is still no mention in the records of any new system of striking, using a rack or otherwise.

William Derham concludes his short chapter on repeating clocks with:

> It would (I think) be very frivolous, to speak of the various contrivances, and methods of Repeating work, and the Inventers of them; and therefore I shall say nothing of them.

to the constant frustration of historians of horology ever since.

It is not known which part of the repeating mechanism was Barlow's invention. Even the actual date of Barlow's invention is not certain, for, although Derham quotes 'about the year 1676', he was writing twenty years after the event. He is not always reliable, for instance his date for the introduction of the pendulum is in error by four years.[16] If a similar error occurred in relation to Barlow's mechanism and Derham's date is, as is most probable, too late, then Barlow may have only devised the snail, with the gathered rack developed by others later. There is always the possibility that Barlow was involved with the now lost clock described by John Smith in 1675, or even the Swansea Tompion. If Derham's date is too early, Barlow may have applied the rack to the snail, which was already in use,[17] but as the use of the rack for quarter repeating was not general until later, this is less likely. Whatever his involvement, it is known that Barlow and Tompion worked closely together on repeating watches (and probably repeating clocks), as well as twenty years later on watch escapements.

ROBERT HOOKE'S CONTRIBUTION TO RACK STRIKING

Virtually the only known documentary references to developments in strikng are included in Robert Hooke's enigmatic diary entries:

> Friday 10th Nov. 1676. At Tompions, told him of my new striking clock to tell at any time howr and minute by sound.
>
> Sunday 24th June 1677. Tompion here instructed him about the King's striking clock about bells and about the striking by the help of a spring instead of a pendulum, as also the ground and use of the fly and of the swash teeth.[18]

The first reference is clearly to a repeating clock, while the second reference to swash teeth is intriguing. In June 1674 Hooke had 'Told Tompion the way of swash wheels', which are wheels set at an angle to their arbors so that they wobble and can be used to convert rotation into reciprocating motion, but the swash teeth referred to in 1677 appear to be quite different. It is unlikely that Thomas Tompion would need instructions from anyone, even the great Robert Hooke, about the use of a fly in striking

15. B. Woodcroft, *Alphabetical Index of Patentees of Inventions 1617-1852*, (1854, reprinted 1969).
16. E.L. Edwardes, *The Story of the Pendulum Clock*, (1977), p.58.
17. Jeremy Evans is the first to appreciate that the snail was developed earlier than, and probably independently of, the gathered rack.
18. Quoted in several sources, e.g. Edwardes, *op. cit.*, pp.104-5.

work, and it is difficult to envisage how a swash wheel could be of practical use in a striking or repeating mechanism. Hooke is clearly talking about striking, rather than repeating, so is his 'fly and of the swash teeth' a prototype gathering pallet and rack with saw-shaped teeth? One of the definitions of 'swash' in the *Oxford English Dictionary* is 'derived from aswash = aslant', and refers to something that is slanting or sloping, which would apply to the saw-shaped teeth on a rack. It must be remembered that Hooke was referring to new types of components for which there were no words in common usage at the time, so it is not surprising that he did not use terms such as 'rack' and 'gathering pallet', which were not in general use until much later.[19]

On this very meagre documentary evidence and from surviving clocks, a possible scenario is that Edward Barlow collaborated with Thomas Tompion just before 1675 to use the snail in the earliest repeating clocks, and a couple of years later, based on Robert Hooke's suggestions, Tompion used the rack in conjunction with the snail for hour striking.

Edward Barlow invented a form of repeating hours and quarters, rather than striking the hours, and as rack striking can repeat on demand, it has been assumed that Barlow's system was the use of the rack and snail. But, as has been seen, there are several methods of repeating that use a snail, but not a rack, and it is probably one of these arrangements that was Barlow's invention.

THE DEVELOPMENT OF RACK-AND-SNAIL STRIKING

While each tooth of the silent-pull sector does not correspond to one strike of the bell, it may have inspired the development of the gathered rack. It was a logical step to adapt this mechanisms devised for hour repeating to strike the hours on the hour, rather than on demand. To use the sector and pinion in this manner there had to be some means of allowing the sector to drop onto the snail, before being lifted off again to strike the required number of hammer blows. When used in a repeat system the pull is against a ratchet and pawl as well as a one-way hammer tail linkage, and while this is practical with a manual pull, where the act of pulling provides ample force to overcome the ratchet, it is less so if it has to take place of its own accord. It might be possible with a spring to overcome the ratchet during the drop of the sector, but it would have to be quite strong and reliability would not be guaranteed. (In the early twentieth century the Gustav Becker company ignored the developments in rack striking that had taken place over the previous two centuries and produced a rarely-seen striking system involving a sector and pinion.[20])

The solution was to remove all the teeth of the pinion except one, so that the sector was not permanently in mesh, but could fall freely, either under gravity or with the aid of a light spring, except when it was being 'gathered' at every revolution of the single-toothed pinion, which later became known as the gathering pallet. Instead of the pinion being on the pinwheel arbor, as usual with a pull-repeat system, the gathering pallet was now situated on the next arbor up the train, the locking wheel arbor. This was very convenient, as one turn of the locking arbor resulted in one tooth of the sector being gathered and one blow struck, analogous to the traditional countwheel system.

The rounded teeth of the sector were replaced by a saw-shape to give more positive action, and it became the now familiar gathered rack. The pallet was also given a sharper profile to aid gathering, although a rounded end was occasionally used until the end of the eighteenth century. Also there had to be an arrangement

19. *The Oxford English Dictionary* gives the earliest mention of the rack in mechanics (as in rack-and-pinion gearing) as the 1797 edition of *Encyclopaedia Brittanica*, but the term was used in both mechanics and horology long before then. J.T. Desaguliers mentions the rack-and-pinion for a lifting jack in his *Course of Experimental Philosophy* (2 volumes, 1734 and 1744). Although Humphrey Hadley, a Birmingham clockmaker, used the word 'hillex' or 'hilex' for the rack in his early eighteenth-century notebook, which implies that the word 'rack' was not then in general use, D.J. Allexandre used rateau (literally 'rake') in his *Traité général des Horloges* of 1734.

20. The pinion and sector (although with saw-shaped teeth on both the sector and pinion) for striking was used on a very unusual two-train weight-driven 'Vienna regulator' movement by Gustav Becker. The teeth are on the under side of the sector/rack, which has an articulated joint to allow it to be lifted clear of the gathering pinion so the tail can fall onto the snail. This was an attempt to produce an alternative to the very well establised rack and snail striking, but it has few, if any, advantages.

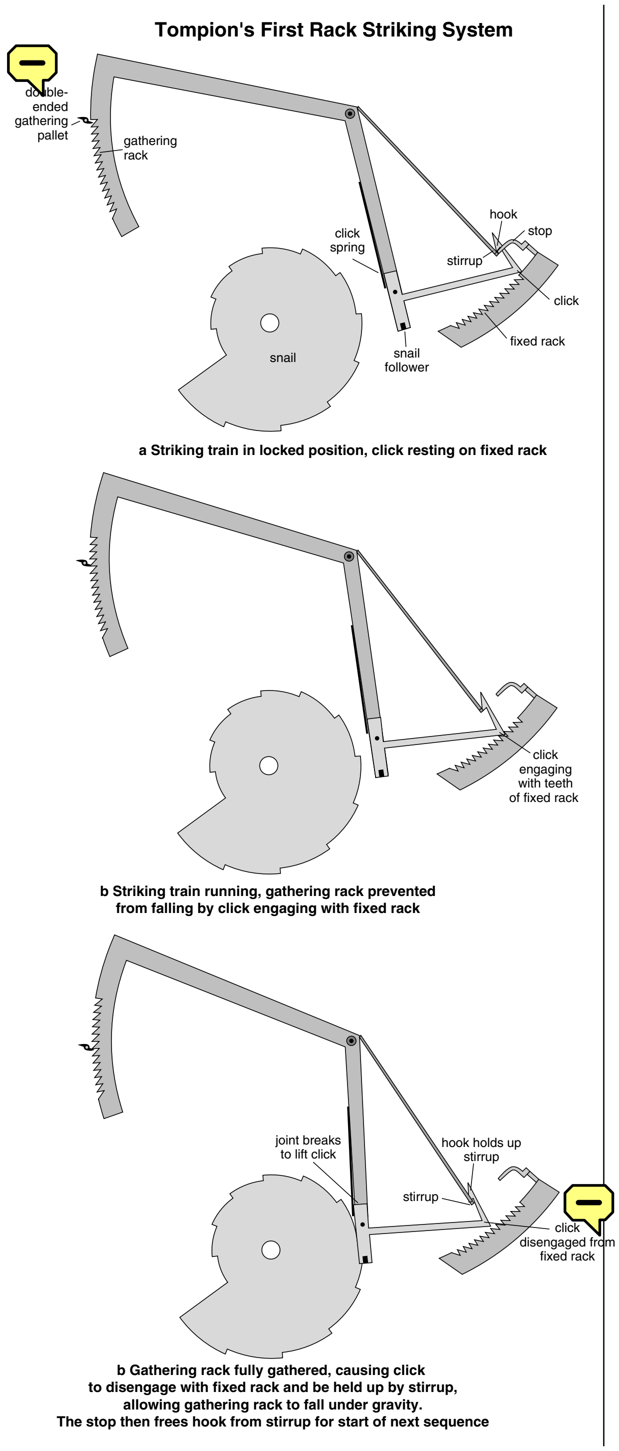

Fig. 7 (left). The earliest known rack-striking system, as used on Thomas Tompion's 'Castlemaine/Tulip/Sussex' series of grande-sonnerie bracket clocks. This simplified diagram excludes the safety device that prevents damage if the snail follower jams on the snail. a The system is at rest with the train locked. b When the train is released the rack is gathered until the rack follower contacts the snail. A click engaging with a fixed rack prevents the gathering rack from falling back during gathering. c The final gather of the double-ended pallet causes a hook on the click to engage with a stirrup, holding the click clear of the fixed rack and allowing the gathering rack to fall. This locks the train and also causes the stirrup to disengage so that the click is free to act on the fixed rack during the next sequence.

to prevent the rack from falling while it was not being gathered by the pallet, and this was done by what later became known as the rack hook. Initially two racks were used to separately gather and hold, then two sets of teeth on one rack, finally just one set of teeth for both gathering and holding. With the earliest racks a separate pivoted lever was used to sense the steps of the snail and convert this to movement of the rack. Later the much simpler rack tail was developed.

Rack-and-snail striking (as opposed to pull-repeat) was first used on bracket clocks, and only later applied to longcase clocks. Traditionally it has been regarded that the rack was initially situated between the plates, then later moved outside the front plate, where it became the standard position, but as will be seen, this may not have been the case.

The earliest use of the gathered rack for striking is usually regarded as being the 'Castlemaine/Tulip/Sussex' series of *grande sonnerie* bracket clocks made by Tompion about 1680.[21] The basic principles of the rack striking employed on these clocks are shown in Fig. 7.[22] This mechanism is different to what later became the norm, and as it has features that were not incorporated into later clocks, by either Tompion or other clockmakers, this supports the claim for it to be the earliest manifestation of rack-and-snail striking. There are separate racks: a gathering rack which can fall freely by gravity, and a fixed rack with a complex click

21. M. Hurst, & J. Evans in *Horological Masterworks*, exhibition catalogue (2003), pp.156-61. There are also the remains of two other clocks in this series.

22. John C. Taylor, 'Thomas Tompion's Spring Clock Innovations', *Antiquarian Horology*, (June 2004), 153-72; also George Daniels, 'Tompion's Two-train Grande Sonnerie Mechanism', *Antiquarian Horology*, (September 2004), 370-3. Fig 7 is a simplification of the hour-striking part of this clock, and is based on diagrams in these two articles.

arrangement to prevent the gathering rack from falling while it is being gathered, but allowing it to return to its rest position after gathering has been completed. The rack is gathered until a follower contacts the snail and the train then locks, i.e. the snail determines the finishing position of the rack, whereas in the later 'standard' arrangement it determines the start position of the rack. This clock is extremely complex, with *grande sonnerie* striking and repeating, and numerous sophisticated details to ensure that these functions would not, or could not, malfunction under almost any circumstances. What is remarkable is that with this high degree of sophistication, there are no known simpler versions with just the basic rack-striking function.

This first Tompion rack-striking system, even stripped down to its fundamental hour-striking capabilities, was too complex for general use, so it was modified and simplified. These changes included combining the separate gathering and fixed racks into one, and the spring-loaded follower, click and stirrup arrangement was replaced the much simpler rack tail. The major change was that the steps of the snail now determined the start position of the rack for the strike, rather than its finishing position. These modifications appear to have been made before Tompion started numbering his clocks, and No. 16, for example, has a conventional rack tail.[23]

Tompion himself may well have made these changes, but the Reverend Barlow should not be completely written out of the story. The year 1678 in particular was a dangerous time to be a Catholic in London, when the radical Puritan Titus Oakes, was spreading false rumours of Papist uprisings. As Edward Barlow was a Catholic priest and chaplain to William Houghton (co-patentee with Tompion and Barlow of a new watch escapement in 1695) of Park Hall, Charnock Richard, near Chorley, Lancashire, he probably spent most of his time in the north, away from the religious and political strife of the capital.

Despite a determined effort by the author, no significant additional information about Edward Barlow has come to light to expand on what is already generally known about his life, and in particular his horological interests. It is surprising that although he was a Lancashire Catholic with amateur scientific interests, there appears to be no record of any contact with the 'Townley Group' of Lancashire Catholic scientists. Richard Townley collaborated with Thomas Tompion on the development of the deadbeat escapement for the Royal Observatory at Greenwich, so it is highly probable that Barlow and Townley were acquainted with each other's work and interests. In spite of being a Catholic priest at a time when conformity was expected, Barlow appears to have kept on the right side of the law, and there are no records of any transgressions. Notwithstanding, he is one of the main characters in an historical novel, and probably the only one where Thomas Tompion also appears.[24]

If Barlow wanted to develop further his ideas on repeating clocks and watches to encompass striking clocks that were simpler than those of Tompion, then he needed the assistance of a local Lancashire clockmaker. The only clockmaker working in the region at that time was Henry Webster from Aughton, near Ormskirk, about 10 miles from Charnock Richard, who made a rack-striking lantern clock in the 1680s (Fig. 8).[25] While a lantern clock may seem an unusual choice on which to fit experimental striking, it was the only type known to have been made by this clockmaker. Note that it has the early arrangement of separate sets of teeth on the rack for holding and gathering. This lantern clock, the only one known from the seventeenth century with rack striking, may have been a prototype made by Webster for Edward Barlow. Is this an early attempt to develop rack striking from repeating, or just a northern interpretation of London developments? It is certainly a much neater solution to the problem than Tompion's

23. Symonds, *op. cit.*, p.215, Fig. 214. Other early Tompion spring clocks with rack striking include a pre-numbered example now in Holland, a group of two-train grande sonnerie clocks, most of which are unnumbered, and No.7 (information from Jeremy Evans).

24. Robert Neill, *Moon In Scorpio*, (Hutchinson, 1952). While it must be remembered that this book is fiction, it does give a good impression of the religious tensions in London during the period under consideration.

25. B. Loomes, *Clockmakers of Northern England*, (1997) pp.48-52. This book contains several other pictures of the movement.

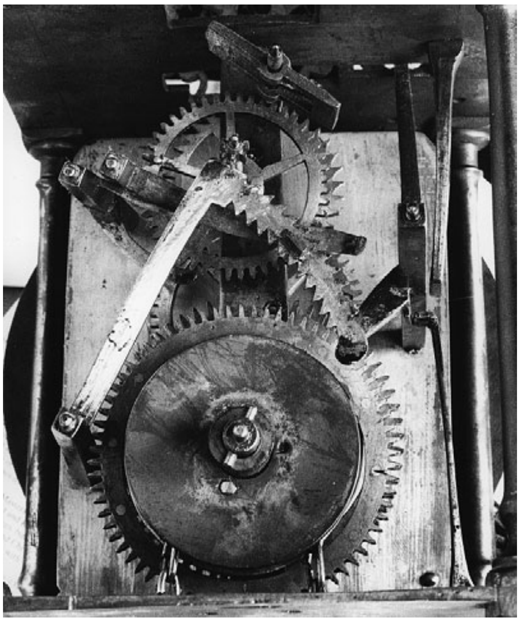

Fig. 8. Rear view of an early rack-and-snail striking lantern clock by Henry Webster, Aughton, Lancashire, from the 1680s, possibly made using ideas brought from London by Edward Barlow. The rear movement bar and the locking wheel are removed to show the rack with teeth on both edges for the rack hook and for gathering. The snail is on the front of the movement, behind the dial. (Brian Loomes)

first arrangement – although he was never one to use a simple method if a more complex one could be devised. Barlow clearly remained on good terms with Tompion, as evidenced by their later joint patent for a new watch escapement, and it is unlikely that he would have been unaware of the latter's ideas on the subject of rack striking, so he may have realised that there was further potential for modification or simplification.

Tompion was very conservative in the application of rack striking to longcase clocks, where he normally used countwheel striking until the early years of the eighteenth century. The type of rack striking usually employed by Tompion for his weight-driven clocks was also used by George Graham and Daniel Delander (Fig. 9), and may well have been the work of Graham, rather than his master. This arrangement used the principles of the internal rack system, but with the strikework arbors extended forwards and pivoted in cocks on the front plate, so that the rack, rack hook, and gathering pallet are external to the front plate. Locking is by a flag on the rear of the rack passing through a long

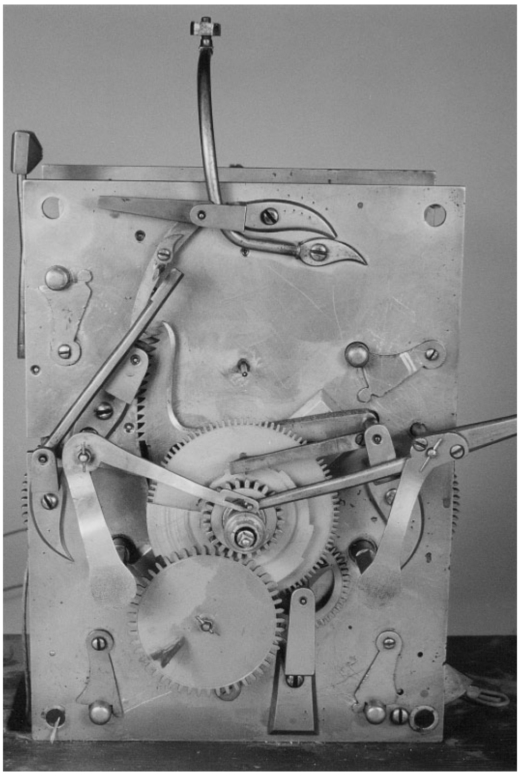

Fig. 9. Tompion/Graham rack striking on a clock signed by Daniel Delander, about 1710. The rack, hook, gathering pallet and lifting piece are all on arbors pivoted between the back plate and cocks on the front plate. The rack falls under gravity without a spring, while the rack hook is assisted by a counterweight. The strike is let off by a pin on the minute wheel, rather than on the reverse minute wheel. The warning detent is internal on the same arbor as the lifting piece. Locking is by a flag on the back of the rack, passing through a slot in the front plate to intercept a pin on the third wheel (train shown locked with the rack in the fully raised position).

slot in the plate to intercept a pin on the pallet or locking wheel. Other clockmakers simplified this by mounting the strikework on collets pivoted on posts or studs screwed into the front plate, while the pin on the pallet wheel was replaced by an extended tail to the gathering pallet, locking against a projection on the reverse of the rack. This superseded the alternative method of 'deep-tooth' locking using an internal locking detent, and pallet-tail locking became the most popular method until the demise of the longcase clock.

EARLY JOSEPH KNIBB RACK STRIKING

Two early bracket clocks by Joseph Knibb with experimental rack-striking are known: one with

Fig. 10. Backplate of a quarter repeating and striking bracket clock by Joseph Knibb, about 1685.

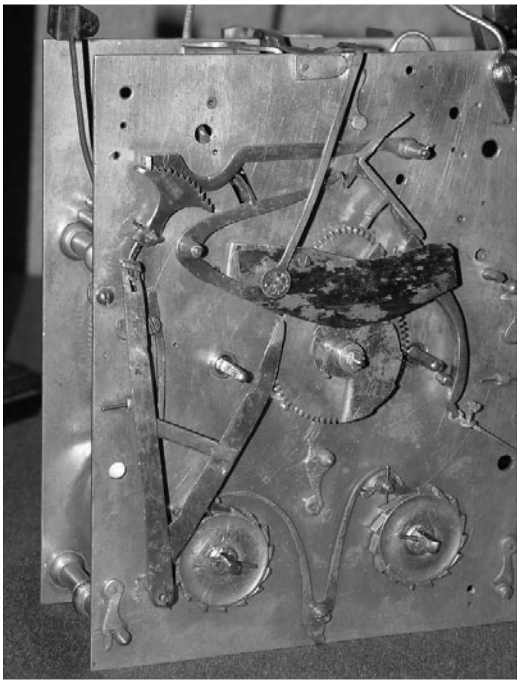

Fig. 11. Front view of the movement, showing the external rack for holding with a rack hook. One arm of the V-shaped lever falls onto the snail, while a slot in the other arm links with a pin on the external rack.

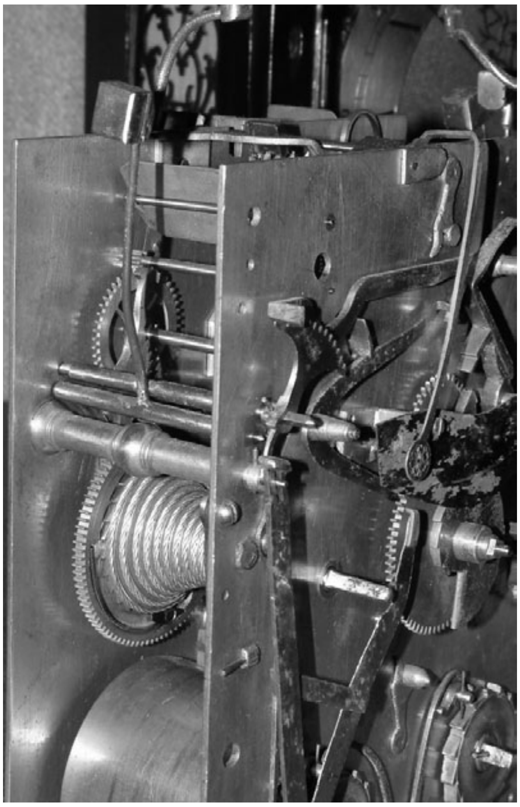

Fig. 12. Side view showing the internal gathering rack on the same arbor as the external one. When gathering is complete a flag on a vertical extension to the rack contacts a pin on the wheel and locks the train.

quarter repeating, the other without, and they must be some of the earliest examples known. Figs 10-12 show the repeating clock, probably made about 1685, but difficult to date as the dial and possibly the case are later.[26] Hour striking employs two racks, one internal for gathering and locking, the other external for counting the number of strikes and holding in conjunction with a rack hook. The use of two racks is similar to Tompion's earliest arrangement, but Knibb has arranged for both to be on the same arbor, hence they move together. Instead of a rack tail, one end of a pivoted two-arm lever falls onto the snail, while a slot in the other end engages with a pin on the external rack.

The Phase I striking clock (Figs 13-15) is probably earlier, being dated by Christie's to about 1680,[27] although other Knibb clocks with

26. Bonham's auction catalogue, New Bond Street, London, (15 December 2004), lot 173. In the illustration the slot in the link is shown disengaged from the pin on the rack.

27. Christie's auction catalogue, King Street, London, (2 July 1997), lot 119.

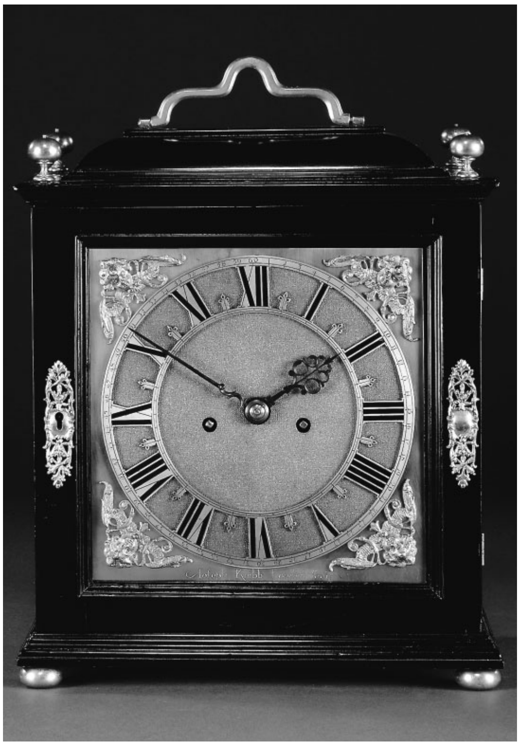

Fig. 13. Bracket clock by Joseph Knibb with a skeletonised chapter ring, in an ebony Phase I case, about 1675, © *Christie's Images Ltd*.

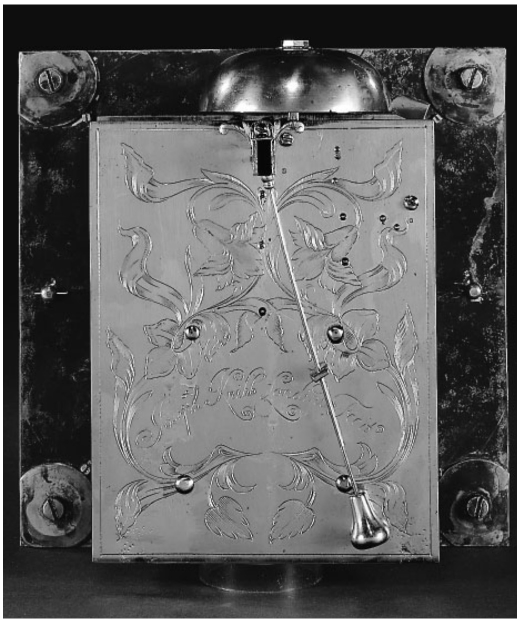

Fig. 14. Backplate of the Knibb clock, with no evidence of an earlier countwheel, © *Christie's Images Ltd*.

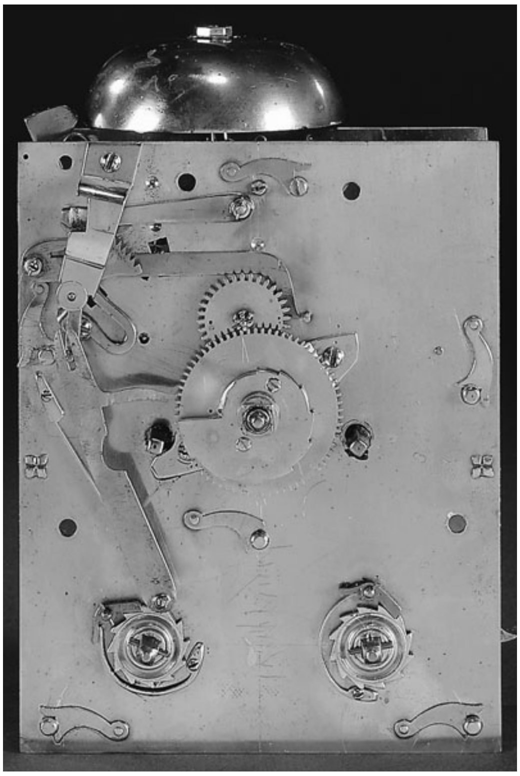

Fig. 15. Front plate of the Knibb clock with rack-and-snail striking, © *Christie's Images Ltd*.

very similar dials and cases are put at 1675-80.[28] The striking work is crammed into the top left of the front of the movement (Fig. 16), as often found with repeating work. The curved lifting piece is pivoted on a stud on the left, with a warning flag on its rear passing through a slot in the front plate. Above is the rack hook, pivoted on a stud in the centre of the plate. Again instead of a conventional tail there is a separate spring-loaded vertical lever, pivoted at its lower end, with a horizontal extension to contact the snail. The motion of this 'tail' is transmitted to the rack via a slot in its upper end and a pin on another pivoted lever. No side view of the movement is available, but as no gathering pallet is obvious (although possibly out of sight behind the cock) it is likely that gathering employed a separate internal rack, as in the repeating clock.

Joseph Knibb, like Tompion, is usually regarded as preferring countwheel striking on his non-repeating striking clocks until later in the century. His quarter-repeating clocks (rather

28. Dawson, Drover, & Parkes, *op. cit.*, pp.418-422.

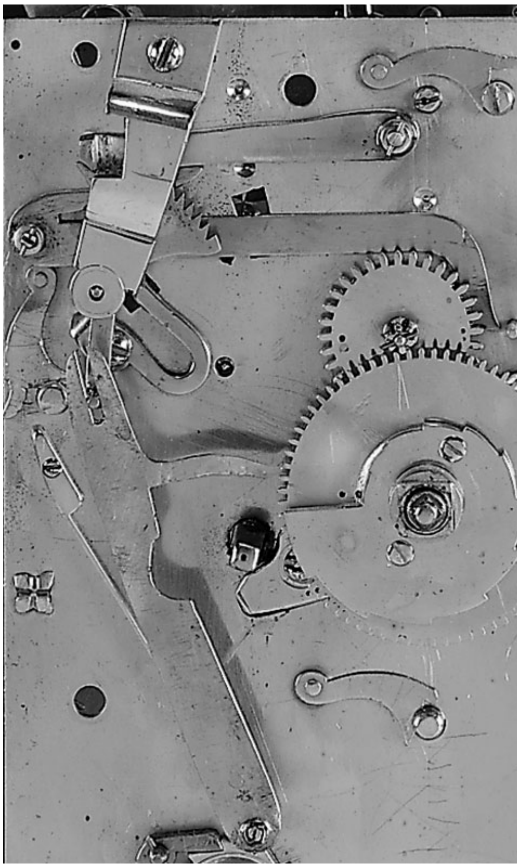

Fig. 16. Detail of the rack striking mechanism. An extension of the vertical lever falls onto the snail, its motion being transferred to the rack via a pin and slot, rather than a rack tail. The rack hook is pivoted on the right and the lifting piece is of the type used with countwheel striking, © *Christie's Images Ltd*.

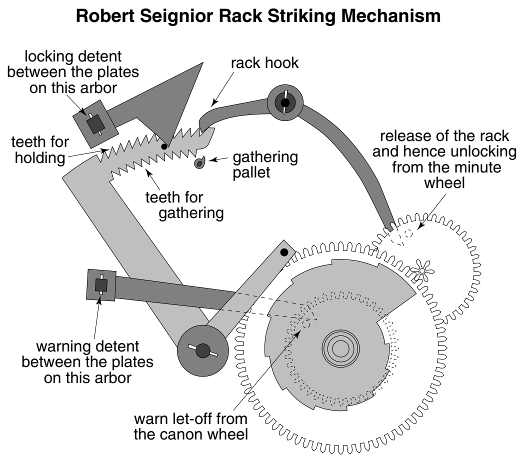

Fig. 17. Hour rack striking on a bracket clock with pull quarter repeat by Robert Seignior, about 1680. The rack, which has two sets of teeth for holding and gathering, falls towards the snail, and has a spring-loaded contact stud. When fully gathered a pin on the rack lifts the triangular shaped lever and an internal detent locks the train. There are separate lifting pieces for unlocking and warning, instead of the usual arrangement of the lifting/warning piece also raising the locking detent.

than his silent-pull timepieces), by necessity used rack striking, with the rack normally between the plates. The clocks illustrated here are evidence of an early experimental phase. As the striking clock in Figs 13-15 does not have any provision for repeating the hour, which is the main advantage of the rack system, it may well be that he was keen to try out the new method, but decided that it provided little advantage for clocks that did not need to repeat. There appears to be no attempts, based on the photographic evidence, of a later conversion from countwheel to rack striking. In any event, if this had been done, it is likely that a conventional rack tail would have been used, not the complex system shown here.

ROBERT SEIGNIOR RACK STRIKING

A pull repeat bracket clock by Robert Seignior, London, of about 1680, or possibly just before, has an early form of rack striking.[29] Like the Knibb clocks, this has a hook to hold the rack between each gather of the pallet, but the Seignior clock has one rack with two sets of teeth, one on top for holding and another set below for gathering (Fig. 17). Whenever gathering takes place on teeth below the rack it falls towards the snail (assisted here by a spring), whereas if gathering uses teeth on top of the rack it falls away from the snail, as later became standard practice. While some other clockmakers occasionally used two sets of teeth, Segnior's arrangement is unusual in having separate lifting pieces for unlocking and warning, actuated by pins on the minute wheel and cannon wheel respectively.

This movement has some features that are more advanced than the Knibb clocks, such as the conventional spring-loaded rack tail and the single rack, while others, such as the separate let-off of locking and warning, are less developed. These clocks appear to be

29. Dawson, Drover, & Parkes, *op. cit.*, pp.352, 358-9.

Fig. 18. Dial of eight-day longcase clock by Henry Young, London, about 1680-5, 10 in. square, plain matted centre, minute numbers within the minute track, bolt-and-shutter maintaining power, and large cherub head spandrels, *courtesy of A.W. Porter & Son*.

Fig. 19 (right). Case with panels of marquetry of a relatively simple floral design, an oval lenticle in the trunk door, and a lift-up hood, *courtesy of A.W. Porter & Son*.

independent developments made about the same time, each pursuing a different approach.

HENRY YOUNG RACK STRIKING

Figure 18 shows the 10 in. square dial of a longcase clock signed 'Henricus Young Londini', typical of about 1680-5. The walnut case (Fig. 19) has panels of marquetry of a relatively simple floral design, not inconsistent with the suggested date of the dial. Henry Young was apprenticed to Thomas Taylor in 1659, but not free of the Clockmakers' Company until 1672, six years later than usual. He took his first apprentice later that year, two others in 1680, and another in 1681/2. He worked 'near the Wine House in the Strand', but by 1689 he is believed to have left London for Portsmouth.[30] Illustrations are known of ebony bracket clocks of about 1685-90,[31] and an

30. Loomes, *op. cit.*, p.602.

31. *Antiquarian Horology*, (September 1965), 357 (front cover); (September 1981), 9; (Autumn 1997), 470; Phillips auction catalogue, (15 Dec 1992), lot 317.

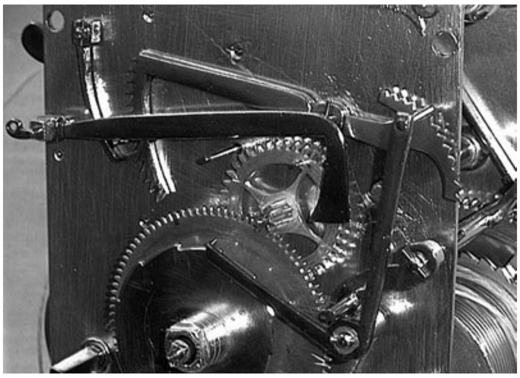

Fig. 20. Henry Young movement with unusual rack striking. The lifting piece is similar to that used on countwheel clocks. The horizontal rack falls by gravity and has a 'staircase' on its right-hand end instead of a tail. One end of the L-shaped lever runs on the snail, which is reversed compared to the conventional arrangement, the top end intercepting a step on the staircase. The arm and arbor on the right are part of the restored bolt-and-shutter mechanism, the shutters being on the back of the dial, rotating on a central boss, *courtesy of A.W. Porter & Son*.

Fig. 21 Another view of the striking mechanism, *courtesy of A.W. Porter & Son*.

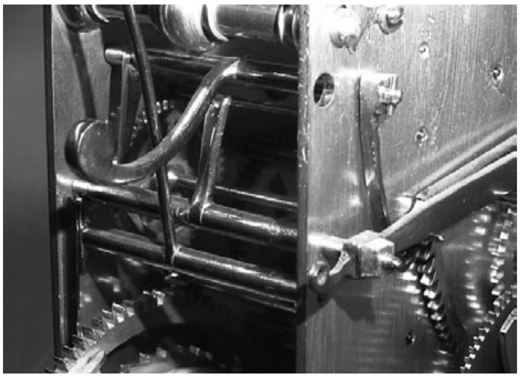

Fig. 22. The arbors of the striking work. The arbor of the lifting piece has both a link piece in the centre to help unlock the train, and the warning piece (just behind the front plate and not visible). The arbor below the top pillar carries the rack hook on its right-hand end and the locking detent at the other end. In the centre is a lever for manual repeat of the strike, *courtesy of A.W. Porter & Son*.

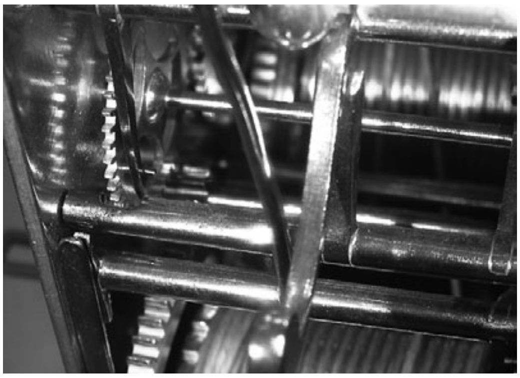

Fig. 23. Close-up of the striking arbors, with the warning detent just visible on the right, *courtesy of A.W. Porter & Son*.

olivewood parquetry longcase of about 1680 signed 'Henry Younge in ye Strand, London'.[32] An early thirty-hour longcase clock is known, while an eight-day example of about 1675, with a very unusual trompe loeil arch-topped dial with Arabic hour numerals, but outside countwheel striking, is at Lyme Park (National Trust), Disley, Cheshire.[33] One of the bracket clocks, signed just 'Henricus Young' with no placename, is reported to have internal rack strike, while another is said to have an almost circular rack, with internal and external teeth for gathering and holding respectively. He was clearly an innovative clockmaker, and his work deserves further study.

While the dial and case of the clock illustrated here are typical of London clocks of the period, the strikework of the eight-day movement is quite different to any other known clock, not only of that date, but of any period (Figs 20 & 21). There appear to be no major alterations to the mechanism, apart from the recently replaced maintaining power and shutters. The lifting piece is of the axe-head shape often found with countwheel striking, and the internal warning

32. *Antiquarian Horology*, (June 1974), 695.

33. Jonathan Betts confirms that this is the clock illustrated, but not attributed to any maker, in *Antiquarian Horology*, (Winter 1978), 153.

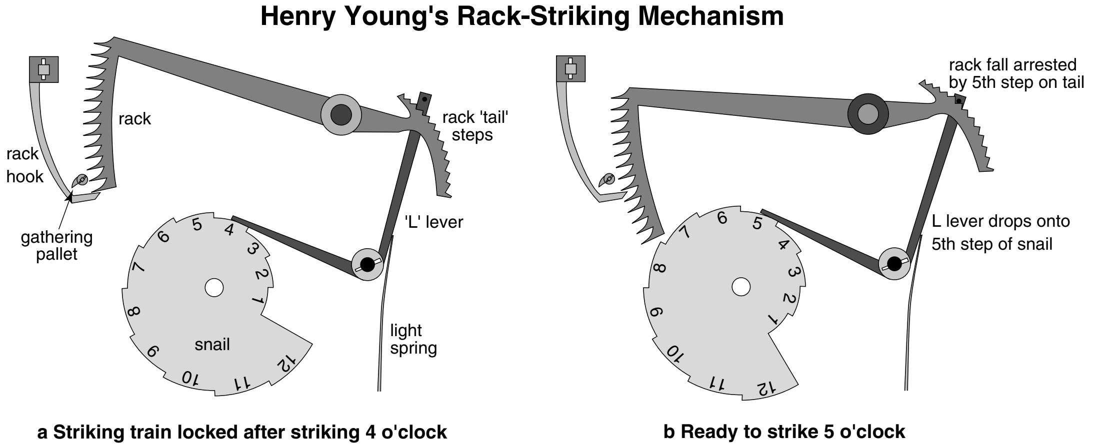

Fig. 24. Diagrams of the Henry Young striking arrangement. In a the striking train is shown locked after completing a strike on the hour (in this case 4 o'clock). One end of the L-lever sits on the snail, while the other end is free of the steps of the 'tail'. At b the snail has rotated by one hour, the train is held on warning, the rack has been released, and its fall arrested by the fifth step on the 'tail', so that five blows of the hammer will be sounded when warning is released.

detent is on the lifting-piece arbor, while the locking detent is also internal, fixed to the rack-hook arbor (Figs 22 & 23). Apart from locking on a pin rather than a hoop, lifting, locking and warning are identical to countwheel practice, rather than the lifting piece being pivoted on a post on the right-hand side, with the warning flag passing through a slot in the front plate, as later became the usual arrangement for rack striking. A similar arrangement of countwheel-type lifting/warning piece was used with early internal rack striking (later examples often positioned the lifting/warning piece on the right), and, in conjunction with an external rack, by some early-eighteenth-century Dublin clockmakers.[34]

The arm of the rack is horizontal, pivoted on the right, with the rack itself vertical and the teeth pointing to the left. The rack hook hangs vertically and locking occurs when the hook falls off the lower end of the rack (deep-tooth locking). The rack does not have the expected tail, instead there is a extension to the right with a series of steps, rather like a staircase. The snail is fixed to the hourwheel pipe as usual, but is the reverse of the normal arrangement, so that the high step counts twelve strikes rather than one. As there is no conventional rack tail to fall on to the snail, this function is carried out by an intermediate L-shaped lever, whose horizontal arm or follower rests on the snail, while its vertical arm intercepts one of the steps of the rack extension, so determining how far the rack will fall to count the number of hammer blows (Fig. 24).

In Fig. 24a the striking train is shown locked, with the horizontal arm of the intermediate lever resting on that step of the snail which determined the previous strike, in this case four o'clock. The vertical arm of the lever is free of the staircase. When the next hour is ready to strike the snail has rotated and the lever lifted onto the fifth step, so when the rack is released its fall is arrested by the lever's vertical arm contacting the fifth step of the staircase (Fig. 24b). With this arrangement the follower remains in contact with the snail at all times, and is rounded and polished to ride over the small steps, which, surprisingly, are not angled.

It is difficult to understand why Henry Young devised his complex arrangement. The only apparent advantage is that, although the follower is in constant contact with the snail and has to ride up the small steps, it falls off the large step between twelve and one, so that there is no danger of it jamming if twelve o'clock is not fully struck. In the usual later arrangement the rack tail either has a spring-loaded contact pin or the tail itself is flexible, so that the pin can ride up onto the face of the snail to avoid damage or stopping the clock. This seems an obvious solution, and was used by Robert

34. J. Robey, *The Longcase Clock Reference Book*, (2001), p.260.

Seignior and also by Henry Jones on an early rack-striking bracket clock of about 1680.[35] Had Henry Young seen or heard descriptions of rack striking, such as the early Tompion or Knibb arrangements, and was this his own interpretation of these ideas? Possibly the staircase was an attempt to give more positive sensing of the snail steps than the Knibb pin-and-slot arrangement.

Perhaps it was a deliberate attempt to avoid plagiarising the ideas of others, or maybe, as one of the '*London* Artists' who 'set their heads to work', he hoped to devise an alternative arrangement that he could patent. It may be significant that Tompion's earliest repeating system used a detent in constant contact with the snail (and the snail is reversed for the same reason as on Young's clock), Knibb's early rack striking had an intermediate lever, while the two-snail repeating system also employs an L-shaped lever in conjunction with a stepped cam, equivalent to Young's 'staircase'. Was Henry Young trying to combine all these elements into his own system for hour striking? Whatever the reason, although the geometry of the two-snail repeating work is quite simple, when combined with a rack it becomes unnecessarily complex and the steps on the staircase (which are not equally spaced) are likely to have been marked out on the components themselves, rather than from geometrical drawings. It is not surprising that these ideas were not developed further, as there were easier solutions to the problem.

THE INTERNAL RACK

Although it has been said that 'The rack was first placed inside the plates (internal rack), but commonly found mounted on the front plate by 1690',[36] there are few, if any, published illustrations to confirm this date, and the same author has also stated that the rack moved to the front of the plates about 1720.[37] Robinson illustrates an internal rack on a longcase clock by Henry Stoker, London, about 1700, and comments that: 'The internal rack is comparatively rare in longcase clocks because not many makers had adopted rack striking before the external version came in shortly after 1700 and few inside racks were made after *c.*1730'.[38] These quotations indicate a range of thirty years in the estimated dates for the introduction of the external rack, but the Knibb, Seignior and Young clocks put a fresh perspective on this.

While Tompion's and Knibb's earliest rack-striking quarter-repeating clocks have internal racks, the clocks illustrated here show that the situation is not as simple as often portrayed. It appears that both internal and external racks developed about the same time – even being used on the same clock – and were employed concurrently for a while, until eventually the external rack became standard. Some clockmakers persisted with the internal rack long after it had been abandoned by virtually everyone else, and an example attributed to Henry Hindley of York from as late as the middle of the eighteenth century, is known.[39]

CONCLUSIONS

Rack-and-snail striking was a development of early repeating mechanisms using a snail, and there were three different repeating systems that did not use a gathered rack (two of these methods became commonly used, but Tompion's earliest method of repeating was probably only used on his first three repeating clocks). They were an amalgam of ideas by Barlow, Tompion, Knibb and Hooke, but no one person can be said to have been the sole inventor of repeating. The gathered rack came later, initially on clocks by Tompion and Knibb in London, and Henry Webster in Lancashire, maybe with the assistance of Edward Barlow, but the latter cannot be said with certainty to have been *the* inventor of rack-and-snail striking.

Initially rack striking was normally confined to pull-repeat striking clocks, where the system was obligatory (hence the mis-attribution of the rack to Edward Barlow, rather than the snail), while silent-pull mechanisms (with only one known exception) used a snail but not

35. Hurst & Evans, *op. cit.*, pp.154-5.
36. E. Bruton, *The Wetherfield Collection of Clocks*, (1981), p.52.
37. E. Bruton, *The Longcase Clock*, (1977), p52.
38. T. Robinson, *The Longcase Clock*, (1981), pp.130-1.
39. Robey, *op. cit.*, pp.260-1.

a rack. Striking clocks without repeat work favoured countwheels until the reliability of the new method was fully proven, although a few clockmakers experimented with it for striking alone.

In the early phase of development a number of complex arrangements were tried until the system that we know today was finalised. Initially a separate lever was used to sense the steps of the snail and transfer this to the movement of the rack. Knibb used a slotted link, while Henry Young used a staircase arrangement. The separate lever was later simplified to the conventional rack tail. There does not seem to be a logical development of the system, as some of these presumably earlier clocks with complex alternatives to the rack tail had either two racks or a rack with just one set of teeth, whereas clocks with seemingly more embryonic racks having different sets of teeth for holding and gathering, had the more advanced and simpler system of a rack tail with a spring-loaded contact stud. It is difficult to place these developments in a chronological sequence, as they occurred over a very short period of time, possibly within about five years of each other, while dating of the clocks themselves relies mainly on stylistic features of the dials and cases alone, and is unlikely to be precise. Until there is a more accurate method of determining the age of the clocks discussed here, or documentary evidence is discovered, the full story of the development of repeating and rack striking is unlikely to be definitive.

It is remarkable that Henry Young's idiosyncratic rack striking mechanism and Joseph Knibb's unusual arrangements have survived for over three centuries and have not been replaced by more conventional systems. The Young example is the earliest rack-striking longcase clock recorded to date. It shows that there is still much to be learned about the development of this important horological feature, and it is hoped that further examples of seventeenth-century rack-striking mechanisms, both conventional and unusual, will be reported, so that more may be discovered about the chronology of their development.

ACKNOWLEDGEMENTS

The author would like to thank Mark Porter of A.W. Porter & Son, Hartley Wintney, Hampshire, for information and photographs of the Henry Young clock; Jeremy Evans of the British Museum for very useful comments and information about early Tompion clocks, the development of rack-and-snail striking and repeating; Michael Hurst for useful comments and for bringing the early Knibb rack-striking bracket clocks to my attention; Philip Spruce for information on horological patents; Alan Midleton for arranging for me to inspect and photograph the Swansea Tompion, and to M.H. Vivian for permission to publish photographs of it; James Stratton of Bonhams for assistance in examining the Knibb repeating clock; Christie's Images Ltd for photographs of the Knibb striking clock and Brian Loomes for the photograph of the Henry Webster clock. The remaining photographs and diagrams are by the author.

POSTSCRIPT

Shortly after this article had been completed an illustration in *Spring-Driven Dutch Pendulum Clocks 1657-1710* by R. Plomp (1979) was brought to my attention, showing a Hague clock by Claude Pascal. This has grande sonnerie striking using countwheels for normal hours and quarters, while after each quarter the preceding hour sounds using a rack with a pin-and-slot link instead of a rack tail. As Claude Pascal died in Paris between 1672 and 1674, and before the usual accepted date of the snail (never mind the rack, which was probably later) Plomp suggests that the rack and snail must be later modifications.

The owner of this clock confirms that despite the similarity between the decorative work on levers associated with the rack and the countwheels, the rack-and-snail striking is a careful conversion using only existing holes, probably done in the middle of the twentieth century, utilising some components from another old, but later, clock. Rack striking did not appear in Holland until about 1685, due to English influence, although a little earlier in France. Hence this clock does not affect the above conclusions.