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The role of the mechanical clock in medieval science

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The invention and spread of the mechanical clock is a complex and multifaceted historical phenomenon. Some of these facets, such as its social impact, have been widely studied, but their scientific dimensions have often been dismissed. The mechanical clock was probably born as a scientific instrument for driving a model of the universe, and not only natural philosophers but also kings, nobles and other members of the social elites showed an interest in clocks as scientific instruments. Public clocks later spread a new way of telling time based on equal hours, laying the foundations for changes in time consciousness that would accelerate scientific thinking.

What is a mechanical clock? The answer to this question depends on whom you ask. Today, most people consider it a time-telling instrument. Actually, it is a pillar of Western society; we unconsciously use it numerous times every day, but we usually do not reflect on the fact that if all clocks were to simultaneously fail, Western society would collapse. Many historians, influenced by contemporary culture, have explained the origin of the mechanical clock through the assumed birth of a new necessity of time consciousness in 13th and 14th century Europe. Werner Sombart and Lewis Mumford, for example, found this new necessity's origin in strictly organized monastic life. Mumford asserted that the monastery was the natural context for the invention of the mechanical clock.[1] Other historians have considered the advent of the clock to be a secular phenomenon that was linked to a change in urban time consciousness. Jacques Le Goff developed the oft- referred to notion of a struggle between 'church time', the old religious time told by the bells, and 'merchant's time', a new secular time measured by the newly invented mechanical clock, which the rising merchant class demanded.[2] Social history perspectives such as these have been widely accepted and frequently used by historians.

Many of these ideas originate from misconceptions about what the mechanical clock was in the 14th and 15th centuries. Its birth and diffusion is a very complex phenomenon involving many factors; telling time is just one and perhaps not even the most relevant factor. A complete explanation of this phenomenon would exceed this paper's aim, so we will focus on the mechanical clock's scientific links before the invention of the pendulum in the context of the so-called Scientific Revolution.

From the point of view of the history of technology, a mechanical clock is a device with at least three elements. First, a clock requires a driving force to run the clockwork. Hanging weights have been used for this purpose from the earliest history of the clock; but beginning in the first third of the 15th century, the spring was also used to drive small domestic clocks.[3] The second required element is an indicator showing the time information generated by the clock. Bells and dials have been the most common clock indicators from the outset. The third essential feature is the escapement, a mechanical device that stops the fall of the weight at intervals and makes the clock run regularly. The escapement transforms the rotary motion of the wheels into an oscillating motion. Weight driven devices and time indicators existed from late antiquity, but the escapement only appeared in the last third of the 13th century and is the key technological novelty that allowed for the construction of the first mechanical clock. The escapement is the key element that distinguishes the mechanical clock from other devices such as the clepsydra, another time telling instrument in which water is both the driving force and the escapement.

Limitations on the measurement of time in the natural sciences

From a history of science perspective, when the clock is considered a time device, it is linked with two elements: the 'modern time concept' and 'modern time reckoning'. The latter could be defined in opposition to 'old time reckoning', characterized by the separation of day and night with two series of unequal hours for each. Various systems of modern time reckoning have been used across the centuries, but all of them use equal or equinoctial hours that a mechanical clock can easily measure. The oldest known modern system is Italian reckoning, which counted twenty-four hours from one sunset to the next. (Fig. 1) Another

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[1] G. Dohrn-Van Rossum, *History of the hour. Clocks and modern temporal orders*, Chicago, The University of Chicago Press, 1996, p. 10.

[2] J. Le Goff, *Time, work and culture in the Middle Ages*, Chicago, University of Chicago Press, 1980, p. 51–52.

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[3] E. Morpurgo, *L'origine dell'orologio tascabile*, Roma, Edizioni La Clessidra, 1954, p. 24.

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Fig. 1. 'Italian clock' in the Rialto Place, Venice, Italy. The reckoning of the twenty-four hour day begins at the sunset.
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Fig. 2. Richard of Wallingford, abbot and scientific instrument maker, 14th century. British Library, MS Cotton Claudius E. IV, f. 201r. © The British Library Board, UK.

method is the half clock, which counted two twelve-hour series that began at midday and at midnight, no matter the length of day and night. Midday was the most common reference for adjusting clocks in Western Europe.[4]

The modern time concept can be defined as abstract, mathematical and independent from nature; time is a magnitude that can be measured with the appropriate instrument. In the Middle Ages, the modern time concept took a prototypical form that was more theoretical than practical; it existed only in science and was told with astronomical instruments, such as astrolabes or quadrants. In 1484, Bernhard Walther was probably the first known person to use a clock to measure modern time accurately for scientific purposes. He used the clock during an observation of a Mercury transit across the sun, but he was forced to count the teeth of the hour wheel to know the time in minutes. Three years after this event, he used the clock again during an eclipse.[5] Despite its mechanical limitations, his clock was acceptably accurate, though he used it only twice, as far as we know.

Walther's effective use of the clock was exceptional for his day. 15th century clocks were generally bad timekeepers, and they could not show minutes on their faces because of their inaccuracy. From the second half of the 16th century, there was a search for a reliably accurate clock, for astronomy and for finding longitude at sea, that promoted progress in horological technology. Subsequently, the cross-beat escapement, spiral spring, pendulum and marine chronometer appeared, all great technical inventions that changed mechanical clock history. Before these inventions, especially the pendulum, the mechanical clock was generally not suitable for scientific time measurement. The case of Bernhard Walther is the exception that confirms the rule.

These limitations did not mean that the mechanical clock was scientifically useless during this period or that it had no connection with science. Some historians have hypothesized that astronomy encouraged the invention of the mechanical clock.[6] An important support for this hypothesis is a commentary on the *Sphere* of Sacrobosco by Robertus Anglicus published in 1941 by Lynn Thorndike.[7] In this well-known text, Anglicus expressed his desire to have a self-moving mechanical machine to drive a model of the universe, and he stated that scientific instrument makers were searching for a way to make such a machine. The commentary dates back to 1271, and it is been assumed that the mechanical clock was invented after this date; however, no certain information or concrete facts now substantiate that claim. Non-scientific motives, such the construction of monastic alarms, could have also encouraged the invention of the mechanical clock.[8] We actually do not know exactly where, when and why the mechanical clock was invented, but the hypothesis that it was invented to satisfy the scientific requirements of an exclusive scholarly group is feasible.[9]

Some of the earliest clockmakers were also natural philosophers or passed through a university. Richard of

[4] G. Dohrn-Van Rossum, *History of the hour. Clocks and modern temporal orders*, Chicago, The University of Chicago Press, 1996, p. 113–117.

[5] D.B. Beaver, 'Bernard Walther: Innovator in astronomical observation', in *Journal for the History of Astronomy*, 1 (1970), p. 40–41.

[6] Derek J. De Solla Price, *On the Origin of Clockwork, perpetual motion devices and compass*, Washington, Smithsonian Institution, United States National Museum, 1959, p. 86.

[7] L. Thorndike, 'Invention of the mechanical clock about Ad 1271', in *Speculum*, 16 (1941), p. 242–243.

[8] L. Mumford, *Technics and civilization*, New York, Harcourt, Brace and Company, 1934, p. 13.

[9] J.D. North, *God's Clockmaker. Richard of Wallingford and the invention of time*, London-New York, Hambledon and London, 2005, p. 160–166.