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The Incarnation of Time

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The history of timekeeping and the history of automata have been often presented as separate narratives. The former encompasses astronomical observation and calculation, and includes the construction of monumental observatories and temples in Babylon, Mesoamerica, China, and Europe; the use of sundials, clepsydras, astrolabes, and calendars; and the invention of the mechanical escapement, the pendulum, and the oscillating quartz movement[1]. The latter begins with the mechanical devices of the Hellenistic period, dwells briefly on the elaborate automata from the Dar al-Islam and the somewhat cruder automata used in late medieval courtly pageantry, but, in the main, has been focused on the increasingly complex machines from

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1. For example, see R. Tom Zuidema, «Solar and lunar observations in the Inca calendar», in Clive Ruggles and Gary Urton, *Skywatching in the ancient World: new Perspectives in cultural Astronomy*, Boulder, University Press of Colorado, 2007; David A. King, *In Synchrony with the Heavens: Studies in astronomical timekeeping in medieval islamic Civilization*, Leiden, Brill, 2004-05; Stephen C. McCluskey, *Astronomies and Cultures in early medieval Europe*, Cambridge, Cambridge University Press, 1998; Gerhard Dohrn-Van Rossum, *The History of the Hour: Clocks and modern temporal orders*, trans. Thomas Dunlap, Chicago, University of Chicago Press, 1996; Derek J. de Solla Price, «Clockwork Before the Clock and Timekeepers Before Timekeeping», in J. T. Fraser and N. Lawrence, eds., *The study of time II: Proceedings of the second conference of the International Society for the Study of Time, Lake Yamanaka–Japan*, Berlin, Springer-Verlag, 1975, pp. 367-380; Derek J. de Solla Price, «On the Origin of Clockwork, Perpetual Motion, and the Compass», *U.S. national museum bulletin 218: Contributions from the Museum of History and Technology*, Washington, DC, 1959, 82-112.

the seventeenth and eighteenth centuries[2]. These two independent narratives coincide in accounts of late medieval Europe, as mechanical developments in clockwork technology–the mechanical escapement—enabled the construction of monumental astronomical clocks with multiple trains of automata[3].

Of these, the most famous was and is the clock in the cathedral of Notre-Dame in Strasbourg. Originally built in the mid-fourteenth century, the clock was completed in 1354, almost a hundred years before the cathedral itself was finished in 1439. It had an automated astrolabe, a perpetual calendar, a musical carillon, tables indicating auspicious times for bloodletting, and several automata. The automata comprised moving statues of the three Magi, who appeared at regular intervals to pay their respects to figures of the Virgin and infant Jesus, and a mechanical rooster that flapped its wings and crowed at noon[4]. By the sixteenth century the clock had fallen into disrepair, and was

2. For example, see Minsoo Kang, *Sublime Dreams of Living Machines: The Automaton in the European Imagination*, Cambridge, Mass., Harvard University Press, 2011; Sylvia Berryman, «The imitation of life in ancient Greek philosophy», in Jessica Riskin, ed., *Genesis redux: Essays in the History of Philosophy and artificial Life*, Chicago, University of Chicago Press, 2007; Scott Lightsey, *Mechanical Marvels in medieval Culture and Literature*, New York, Palgrave Macmillan, 2007; Jessica Riskin, «The Defecating Duck, Or, The Ambiguous Origins of Artificial Life», *Critical Inquiry* 29, 2003, p. 599-633; Karin Tybjerg, «Wonder-making and philosophical wonder in Hero of Alexandria», in *Studies in History and Philosophy of Science* 34, 2003, p. 443-466; Jessica Riskin, «Le canard, l'homme, et le robot», *La Recherche*, 350, February 2002, p. 36-40; Marc Vanden Berghe, «Technique et utopie au siècle des lumières: Les androïdes Jaquet-Droz dans l'Encyclopédie d'Yverdon», in Jürgen Söring, ed., *Androïden: zur Poetologie der Automaten*, Frankfurt, P. Lang, 1997; Susan Murphy, «Heron of Alexandria's *On automaton-making*», *History of technology* 17, 1995, p. 1-45; William Eamon, «Technology as Magic in the Late Middle Ages and the Renaissance», *Janus* 70, 1983, p. 173-212; Banu Musa, *The Book of ingenious Devices (Kitab al-Hiyal)*, Donald R. Hill, trans., Dordecht, 1979; Alfred Chapuis and Edmond Droz, *Les Automates, figures artificielles d'hommes et d'animaux*, Neuchâtel, Éditions du Griffon, 1949; A.G. Drachmann, *Ktesibios, Philon, and Heron, a Study in ancient Pneumatics*, Copenhagen, Munksgaard, 1948.

3. The phrase «monumental astronomical clock» is taken from Maurice Klaus, *Die deutsche Räderuhr: Zur Kunst und Technik des mechanischen Zeitmessers in deutschen Sprachraum*, 2 vols., Munich, Beck, 1976, vol. 1, p. 38.

4. Alfred Ungerer, *Les Horloges astronomiques et monumentales les plus remarquables de l'Antiquité jusqu'à nos jours*, Strasbourg, 1931, p. 165. There are many other examples of monumental astronomical clocks with automata. See, in addition to Ungerer, Dohrn-van Rossum, *op. cit.*, p. 108-113; Alan H. Lloyd, *Some outstanding clocks over seven hundred years, 1250-1950*, London, Leonard Hill Books, 1958.

extensively renovated between 1571 and 1574. After its completion, it was considered the most complex and advanced piece of technological engineering in Europe. The clock was again renovated in the late nineteenth century, though it remained largely unchanged from the sixteenth century, and a visitor to Strasbourg today can see the sixteenth-century clock and appreciate why it was so justly famous. The clock is almost eight meters wide at its widest point at the base, and over eighteen meters high. Highly decorated and extremely elaborate, the clock is covered with paintings of the three Fates, a portrait of Copernicus, Biblical scenes of creation, resurrection, and the Last Judgment, Urania (the muse of astronomy), and the armorial devices of Strasbourg. It displays multiple time-telling devices, including an astrolabe, a lunar dial, a calendar, a celestial sphere supported by a statue of a pelican, and a clock giving local time. There are several principle trains of automata, including a musical carillon, powered by the falling-weight drive in the clock case. Gods borne in chariots personify the days of the week, while four figures–infant, youth, adult, and old man–divide the day into quarters, each giving way to the next as the day goes on, illustrating the life cycle. Every hour, mechanical figures of Death and Christ do battle, with Death winning each hour except the last. A replica of the rooster from the original clock ruffles its feathers and crows at noon[5].

All of these worked in concert to present time in its totality: diurnal, lunar, cosmological, sacred, and eschatological. Furthermore, the roots of this marvelous machine lie in the centuries before its original construction and its renovation and are bound up with material and textual automata, as western European writers, philosophers, artisans, and artists imagined, reported, designed, and built related objects. Elaborate hydraulic clocks with moving figures came as gifts to western European courts from Byzantine and Abbasid

5. The original rooster was repaired and placed on the clock after the sixteenth-century renovation; however, it was removed in the last century and replaced by a replica. The original–the oldest extant automaton in Europe–is in the nearby Musée des Beaux Arts in the Palace de Rohan.

courts in the early medieval period. Pilgrims, soldiers, and diplomats wrote of the apparently self-propelled artificial humans and animals they saw at palaces in Byzantium, Baghdad, and Karakorum. Artists and scholars grappled with the alien, exotic origins of these objects and re-created them in literary and historical texts. And, by the late thirteenth century, artisans and engineers in Europe began to create elaborate, richly ornamented self-moving machines that incorporated human and animal figures as centerpieces for the glory of the Church. With the spread of monumental clocks, adorned with mechanical people and animals, in the fourteenth and fifteenth centuries, automata were installed in the public gaze, linked with timekeeping, and imbued with religious significance. In towns and cities throughout Europe, giant clocks revealed the movements of the cosmos, while on them mechanical Magi paid homage to the Christ-child; manufactured monks prayed; wooden and metal clock-jacks rang bells; and artificial roosters crowed, like Chanticleer, every hour.

Early Water Clocks and Automata

Water-clocks, or clepsydrae, first appeared in Europe as gifts from foreign leaders in the Dar al-Islam. The earliest example is from 807, when envoys from Harun al-Rashid, the Abbasid caliph of Baghdad, brought a magnificent gift to Charlemagne at Aachen. A Carolingian chronicler at the court described the gift in detail. It was a water clock, made of brass, and

> wondrously wrought by mechanical art, in which the course of the twelve hours was marked by a clepsydra, with the right number of little bronze balls, which would fall into a basin and make it ring. Also in this clock were the same number of horsemen, which would, through twelve windows, come forth at the end of the hours. With the force of their exit they would close the proper number of windows, which had before been open[6].

6. *Annales regni Francorum*, annum 807, MGH, Scriptores rerum Germanicarum, Hanover, 1895, p. 123: «...necnon et horologium ex auricalco arte mechanica mirifice compositum, in quo duodecim horarum cursus ad clepsidram vertebatur, cum totidem aereis pilulis, quae ad completionem horarum decidebant, et causu suo subiectum sibi cimbalum tinnire faciebant additis in eodem eiusdem numeri equitibus, qui per duodecim fenestras completis horis exiebant, et inpulsu egressionis suae totidem fenestras, quae prius erant apertae claudebant.»

In the Dar al-Islam water clocks were often built with elaborate automata, in part because there was an older Syrian tradition (before the Islamic conquest) of constructing water-clocks with automata[7]. A thirteenth-century water clock designed by Al-Jazari (1136-1206), an engineer for the Urtuq court in Diyarbekir, was «double the height of a man» and echoes the description of the earlier clepsydra from Baghdad. It contained mechanical birds that dropped balls into twelve glass bowls, marking the hours and twelve small figures of horsemen who came out of apertures at the top of the clock at regular intervals; as well as two drummers, two trumpeters, and a cymbalist who made music after the sixth, ninth, and twelfth hours; the signs of the zodiac; a golden orb to mark the position of the sun and a glass orb to denote the phases of the moon[8].

Within Europe, water clocks containing moving parts did not appear until the late tenth century. Furthermore, although any timekeeper is an indication of celestial movement, water clocks in Europe did not have astronomical complications, such as the solar and lunar indicators on Al-Jazari's clepsydra. For several centuries, water clocks were found mainly in religious communities and were often attached to bell-striking mechanisms to sound the time. This was due to the fact that accurate timekeeping was important to determine and audibly mark the correct hours for the celebration of the Divine Office, the eight «hours» for daily prayer laid out by St. Benedict of Nursia in his *Rule*[9]. They were: Matins or Lauds, Prime, Terce, Sext, Nones, Vespers, Compline, and Vigils or Nocturns. The observance of these

7. Banu Musa, *op. cit.*, p. 19; Finbarr Barry Flood, *The Great Mosque of Damascus: Studies on the Makings of an Umayyad Visual Culture*, Leiden, Brill, 2000, p. 114-38.

8. Ananda K. Coomaraswamy, *The Treatise of Al-Jazari on Automata*, Boston, Museum of Fine Arts, p. 10-12.

9. Benedict of Norcia, *Regula Sancti Benedicti*, chs. 8-11 and 16-17, [On line]. [Page consulted 24 June, 2009]. Availability and access http://www.intratext.com/X/LAT0011.HTM. In English [On line]. [Page consulted 24 June, 2009]. Availability and access http://www.ccel.org/ccel/gregory/life_rule.i.html On how these «hours» changed names and, to some extent, time of celebration, see Dohrn-van Rossum, *op. cit.*, p. 31-37.

offices relied on proper timing, as the first office, Matins, took place at dawn, and it was necessary to have a long enough interval between Vigils (in the middle of the night) and Matins. The oldest account of a western clepsydra (not a gift from an eastern court) is in a late-tenth or early-eleventh century manuscript in the Benedictine monastery of Santa Maria de Ripoll in northern Catalonia[10]. It had a hydraulic driving mechanism–the regular flow of water from one container into another–and a weight-operated striking mechanism–a hammer and flail–to sound the bells[11]. A Cistercian rule from the twelfth century attests to the link between daily time-keeping and monastic observance. It was the sacrist's duty (the monk who oversaw all aspects of daily devotion) to wake himself with the clock before Vigils, and set the clock (*horologium temperare*) and make the bell ring (*facere sonare*) in the winter before Matins.[12] Clepsydrae were also used in monasteries in northern Europe. A chronicler at the monastery at Bury St. Edmunds wrote that in 1198 a fire broke out «that same hour the clock struck before the hours of Matins,» and the monks used the water from the clock to help quench the fire[13].

By the mid-thirteenth century, water clocks were also familiar outside the cloister. The earliest visual representation of a water clock is in a French *Bible moralisée* created for the French court around 1250. The miniature illustrates the story of Hezekiah, king of Judea, for whom God, acting through Isaiah, extends the life of the terminally ill Hezekiah by fifteen years[14]. The clock in the miniature represents the importance of time in the story. The main wheel has

10. «The first mechanical clocks», Samuel Macey, ed., *The encyclopedia of time*, New York, Garland, 1994, p. 127-132.

11. F. Maddison, B. Scott, and A. Kent, «An early medieval water-clock», *Antiquarian Horology* 3, 1962, p. 348-53; C. B. Drover, «A medieval monastic water-clock», *Antiquarian horology* 1, 1954, p. 54-8.

12. Johann Beckmann, *History of Inventions, Discoveries, and Origins*, William Johnston, trans., London, H. G. Bohn, 1846, vol. 1, p. 346-48.

13. *The Chronicle of Jocelin of Brakelond*, H. E. Butler, ed. and trans., London, Thomas Nelson, 1949, p. 107: «Eadem enim hora cecidit horologium ante horas matutinas...»

14. Kings II, 20: 11; Isaiah 38: 3.

teeth, under which water flows, causing the wheel to rotate[15]. There is also a bell-striking mechanism in the lower right of the main wheel, complementing the bell-wheel (which also has teeth) at the upper left of the main wheel. A water clock similar to the one depicted in the *Bible moralisée* may have been installed at the royal palace in Paris[16].

Celestial Models and Monumental Clocks

Unlike the Islamic tradition, which conjoined automata and water-clocks as early as the ninth century, it was not until the development of the mechanical escapement–a new method of regulating the release of force in repetitive, rather than continuous, increments–and the consequent ability to build large, complex astronomical clocks in the late-thirteenth and fourteenth centuries that automata and clocks were linked in the western European tradition. The repeating bell-striking mechanism in place in many water clocks gradually led to the earliest type of mechanical escapement, called the verge, or verge-and-foliot, escapement.[17] The mechanical escapement, often coupled with a falling-weight drive, offered the possibility of creating large and heavy automata, which was unsustainable with hydraulic drives. The word «clock» comes from the Latin word for bell (*cloca*), and the audible signal that an interval of time had passed is very much tied up in the development of mechanical clocks, so much so that many early mechanical clocks had bell-striking automata, called clock-jacks or *jacquemarts*, on them[18]. These were huge wooden and metal

15. Scholars have disagreed over the exact design of this clock, and how often the main wheel rotated. To explore this further, see Dohrn-van Rossum, *op. cit.*, p. 70-71; J. D. North, «Monasticism and the First Mechanical Clocks», in *The Study of Time II*, p. 382-383; Lynn White, Jr., *Medieval technology and social change*, Oxford, Oxford University Press, 1962, p. 119-120; C. B. Drover, «A Medieval Monastic Water-Clock», p. 57-63.

16. On the *Bible moralisée* manuscript and this particular miniature and links to the French royal court see Alexandre de Laborde, *La Bible moralisée*, 5 vols., Paris, Societé française de reproductions manuscripts à peintures, 1911-27, vol. 1, pl. 183; vol. 5, p. 181; White, *op. cit.*, p. 120.

17. Dohrn-van Rossum, *op. cit.*, p. 103-05; Lynn White, *op. cit.*, p. 124-25.

18. «Horloge», which was a very common term for clocks in the medieval period, comes from the Latin word «*horologium*», and comes from the Greek «*hora*» (time)

figures, often of men, who struck the hours with a hammer. Further technological developments that allowed clocks to ring bells at shorter quarter-hour intervals allowed for the possibility of new automata in addition to the *jacquemart*.

Although it is not clear when or where the mechanical escapement was invented, there is widespread consensus that the large astronomical clocks that appeared in the last fifteen years of the thirteenth century were mechanical, rather than hydraulic. England appears to have had a large number of early mechanical astronomical clocks, all of which were located in cathedrals or religious communities[19]. In addition to the reasons mentioned above, this is due to the fact that many monasteries were centers of academic education, and so had access to texts on astronomy and physics that were necessary to design astronomical timekeepers. Additionally, monasteries often had the funds to employ skilled craftsmen to build and maintain their clocks[20].

Churches benefited from automata on their clocks, as they increased the reputation of the church, and most church clocks had religious-themed automata[21]. The earliest record of automata on a monumental astronomical clock comes from the Sacrists' Rolls of the Norwich cathedral priory, about thirty years after the first record of an astronomical clock there (c. 1321-25). The clock, which cost fifty-two pounds to build, had fifty-nine automata, including personifications of the days of the month and a procession of choir monks, in addition

and «*legein*» (to tell). This word is often used to denote a timekeeper, but does not say anything specific about the mechanism used. The word *jacquemart* appears to have been derived from the French «Jacquème» and «marteau» meaning «a man with a hammer.» This was shortened to «jacquemart» and translated into English as «clock-jack». See Silvio A. Bedini, «The role of automata in the history of technology», *Technology and Culture* 5, 1964, p. 24-42, p. 29-30.

19. C. F. C. Beeson, *English Church Clocks*, London, Phillimore, 1971, p. 6-12. Beeson notes the following early mechanical clocks: Dunstable Priory (1283), Exeter Cathedral (1284); St. Paul's Cathedral (1286); Merton College, Oxford (1288); Norwich Cathedral Priory (1290); Ely Abbey (1291); Christchurch Cathedral, Canterbury (1292).

20. J.D. North, *op. cit.*, p. 381-98.

21. Bedini, *op. cit.*, p. 29-31.

to an astronomical dial and models of the sun and moon[22]. According to a Glastonbury chronicle from the same period, an abbot installed at the church a clock with numerous automata and an organ[23].

Aside from the administrative purpose of notification and signaling the timing of services and public events, mechanical clocks were also built for modeling the solar system. The movement of the cosmos was a towering example of divine power and ingenuity, as well as a manifestation of divine order, the knowledge of which could help inform knowledge of the sublunary realm. Yet despite the fact that timekeepers and automata were not fused together in the European tradition until the invention of mechanical clocks, there is at least one well-known literary example of this pairing from several centuries before the first monumental astronomical clocks were built.

There are in the twelfth-century *chanson de geste Le Voyage de Charlemagne* two different examples of automata, both at the court of the king of Greece, powered by astrological magic and the movement of air[24]. The work is a fictional history of Carolingian emperor Charlemagne's travels to Jerusalem on pilgrimage and then to Constantinople for diplomatic purposes. Arriving in Constantinople, Charles encountered his rival for the title of Roman emperor, King Hugo, riding on a golden litter behind a giant golden plow. «In his hand [Hugo] held a sceptre of pure gold and he drove his plough so skillfully that his furrow is in a perfectly straight line. Here comes

22. This amount is roughly $500,000 in today's money. I have not seen the Sacrists' Rolls, and instead have relied on the excerpts printed in *The archaeological Journal* 12, 1855, p. 175-77; and J. D. North, *op. cit.*, p. 386.

23. *Chronica sive historia de rebus Glastoniensibus*, Thomas Hearne, ed., Oxford, 1726, cited in R. P. Howgrave-Graham, «Some clocks and jacks, with notes on the history of horology», *Archaeologia: or, miscellaneous Tracts relating to Antiquity* 77, 1928, p. 257-312, p. 288.

24. The exact date of the poem is unclear, but modern scholars place its composition in the middle of the twelfth century. Gaston Paris posited that the poem was composed immediately before the First Crusade, while others have argued that it is contemporaneous with the *chanson de Roland*, i.e., the second half or end of the eleventh century. Burgess concurs with scholars who date the poem, based on notions of courtliness found within the text, to the mid-twelfth century. See *Le Pèlerinage de Charlemagne*, Glyn S. Burgess, ed., Edinburgh, Société Rencesvals British Branch, 1998, p. xi.

Charles approaching him on an ambling mule![25]» The golden artifacts underscore Hugo's majesty, and his work at the plough is symbolic of his position as the protector of the vitality and fertility of his realm. In contrast, Charles rides up to him on a mule; he and his knights gaping like provincial rubes at the king and his wealth.

The vast differences between the Byzantine and Carolingian empires are further magnified when the group reaches Hugon's palace, an architectural marvel built with great skill and knowledge of astral science. Painted blue on the ceiling to resemble the sky and covered in paintings of birds, beasts, serpents, and other animals, the main hall was a model of the earth, under heavenly skies and teeming with natural bounty. The entire palace rotated around a central point, a silver pillar in the center of the hall. The palace itself is an automaton and a model of the world and the heavens: the grand salon is blue with images of all the animals in the world, and it rotates, like the spheres, on its *axis mundi*, the central silver pillar. On top of the hall are two statues; figures of children cast in copper, each holding an ivory horn to its lips. «One regards the other as if they were smiling, so that you would have sworn they were actually alive[26].» When wind strikes the palace, it turns like the shaft of a mill[27] and causing the statues «to blow their horns and smile at one another so that you would have sworn they were actually alive. One blew loud, the other clear[28].» The author stressed the life-like appearance of the automata twice in similar language, drawing attention to Hugon's ability (or the ability of his astrologers or artisans–we are not told who is responsible for creating the automata, only that that they are fluent in *cumpas*) to mimic nature to an astonishing and unusual degree[29]. *Cumpas* refers

25. *Ibid.*, lines 283-298, p. 18-20: «Si a cundut sun arêt tant adreceement, / Si fait dreite sa rei cum line que tent. / Atant est vus Carlun sur un mul amblant!»

26. *Ibid.*, lines 352-361, p. 22: «De quivre e de metal tregeté douz enfanz; / Cascun tient en sa buche un corn d'ivorie blanc [...] Li uns esgardet le altre ensement cum en riant, / Que ço vus fust viarie que tut fussent vivant.»

27. *Ibid.*, line 372, p. 24: «Cum arbre de mulin.»

28. *Ibid.*, lines 373-377, p. 24: «E celes imagines cornent, l'une a l'altre surrist, / Que ceo vus fust viarie que il fussent tuz vis. / L'un halt, li altre cler [...].»

29. The language stressing the life-like attributes appears in line 361, p. 22 («Que ço vus fust viarie que tut fussent vivant») and line 374, p. 24 («Que ceo vus fust viarie que il fussent tuz vis»). See Patricia Trannoy, «De la technique à la magie : enjeux des automates dans *Le Voyage de Charlemagne à Jérusalem et à Constantinople*», in Gérard Chandès (ed.), *Le Merveilleux et la Magie dans la littérature*, Amsterdam, Rodopoi, 1992, p. 227-252, p. 239.

specifically to the astral knowledge needed to predict the lunar cycle and eclipses, and to determine the liturgical calendar[30].

Despite the wind outside the palace that causes it to turn and the automata to play, inside the palace all is tranquil and calm[31]. The palace rotates by the motions of the heavens and also the wind, which Hugo can harness; although a violent storm rages outside, he has used the wind to rotate his palace and animate the automata. Hugo is the Cosmocrator, in the center of the cosmos, his palace, as it turns on its axis[32]. The automata serve as a reminder of Hugo's divinely anointed status as emperor, as he has animated the inanimate, thereby displaying his status as a thaumaturgical ruler, able to perform miracles.

In this twelfth-century text, the author compared the technology that powers the automata to technology familiar to his audience, when he compared the rotation of the palace to the movement of a chariot wheel and a mill wheel[33]. These metaphors signal the opacity of the technology to western eyes and perhaps an attempt by the author to relate the marvels of the palace and the automata to technology his western audience would be able to understand. Yet less than two centuries later, astronomical models (albeit as astronomical clocks,

30. *Le Pèlerinage de Charlemagne*, *op. cit.*, line 348, p. 22: «E fu fait par cumpas e serét noblement.» The definition of «*cumpas*» is found in the *Dictionnaire historique de la langue Française*, Alain Rey (dir.), 2 vols., Paris, Robert, 1992, s. v. «cumpas».

31. *Ibid.*, lines 384-389, p. 24: «Mult fut grés li orages e hidus e costis. / Karles vit le paleis turner e fremir; Il ne sout que ceo fud, ne l'out de luign apris. / Ne pout ester sur pez, sur le marbre s'asist. / Franceis sunt tuz versét, ne se poent tenir, / E coverirent lur chés e adenz e suvin [...].»

32. The Byzantine emperor, according to Byzantine political theology, was God's anointed viceroy on earth. As such he had authority over the entire universe, regardless of any interlopers who contested or denied his lordship. See Karl Leyser, «*Theophanu divina gratia imperatrix augusta:* Western and Eastern emperorship in the later tenth century» in Adelbert Davids (ed.), *The Empress Theophano: Byzantium and the West at the Turn of the first Millennium*, Cambridge, Cambridge University Press, 1995, p. 1-27.

33. See *Le Pèlerinage de Charlemagne*, *op. cit.*, line 357, p. 22; line 372, p. 24. See also Trannoy, *op. cit.*, p. 230.

rather than rotating palaces) and human automata were common enough in Europe that in 1324, the treasurer of Lincoln Cathedral offered a donation toward a new clock, because «the cathedral was destitute of what other cathedrals, churches, and convents almost everywhere in the world are generally known to possess[34].»

Monumental astronomical clocks not only contained automata, they were automata. Like Hugon's rotating palace, astronomical clocks were majestic, elaborate self-moving models of the cosmos and of celestial motion. The contemplation of the heavens was not, to the medieval intellectual, contemplation of the unknown, the void, or the mysterious. Instead it was as if looking upward was the same as looking inward; to look up to the heavens was to look at a perfectly organized system, created by God, and which was also repeated in a smaller scale on earth[35]. The cathedral clock at Notre-Dame de Strasbourg, nicknamed the «Horloge des Trois Mages / Die Dreikönigsuhr» because of its automata, was a symbol of the macrocosm–celestial bodies and motion–and the microcosm–the human body. It both demonstrated the glory of God's creations–the universe and living things–and dramatized the sacred timeline of human salvation. The perpetual calendar and mechanical astrolabe on the clock of Notre-Dame de Strasbourg reflected the orderly movements of the cosmos, which had been ordained and created by God. The tables for bloodletting displayed the link between the macro and micro.

The automata–the Virgin, Jesus, the three Magi, and the rooster–embodied and enacted Christian allegory and proclaimed Gospel truth. The Magi enacted the recognition of the divinity of Jesus, while the rooster symbolized Peter's denial of Christ's divinity and sacrifice and his ultimate repentance. Furthermore, because Peter later became the head of the Church, the rooster also stood for papal vigilance. The rooster's crow each morning recalled Christian readiness to accept the sudden second coming of Christ, the resurrection of the

34. Beeson, *op. cit.*, p. 18.

35. C.S. Lewis, *The Discarded Image*, Cambridge, Cambridge University Press, 1964.

dead, and Christ's final judgment[36]. The rooster and the clock appear to have played a part in religious pageantry, as the clock was also known as the Leidensuhr (the Clock of the Passion), and Passion plays given in the cathedral were coordinated with the movements of the automata[37]. Conrad Dasypodius, the architect of the renovated and re-invented Strasbourg clock in the sixteenth century, made sure that the rooster, which had by then fallen into disrepair, was cleaned and restored to the clock, saying, «This poultry cock itself was skillfully made two hundred years ago and placed on the old clock, and since at that time it was customary to commemorate the Passion of the Christ in the Christian church, this cock by its crowing warned men of the denial of Peter[38].»

The original clock broke around 1500 and plans to build a new one arose around 1547. Due to conflicts arising from the Reformation, work was abandoned and re-started again in 1571. Dasypodius, professor of mathematics at the Strasbourg Academy, was appointed by the Senate of Strasbourg to build a magnificent work. He designed the new clock and made the large celestial globe on it, but skilled craftsmen were responsible for the rest of the horological and artistic work. The stated purpose of the clock and all the automata and other decoration was to illustrate the meaning of both secular and sacred time in a Christian context. The pelican supporting the celestial globe signified Christ's death and his sacrifice for humankind[39]. Dasypodius wrote, after the clock was completed, «But we have attached this Pelican so that it should be in the place of Atlas and represent a symbol of eternity, or

36. Matthew 26: 34-75; Mark 13:32; Mark 13:35-36; Mark 14:30-72; Luke 22:34-61; John 13:38-18:27.

37. Théodore Ungerer and l'Abbé André Glory, «L'astrologue au cadran solaire de la cathédrale de Strasbourg (1493)», *Archives alsaciennes d'Histoire de l'art*, 12, 1933, p. 73-108; Joseph Walter, «Le mystère Stella des trois mages joué à la cathédrale de Strasbourg au XII[e] siècle», in *Archives alsaciennes d'Histoire de l'art*, 8, 1929, p. 39-50.

38. Conrad Dasypodius, *Heron mechanicus: Seu de mechanicis ejusdem horologii astronomici*, Strasbourg, 1580, cited in F.C. Haber, «The Cathedral Clock and the Cosmological Clock Metaphor», in *The Study of Time II*, p. 400.

39. The pelican tears the flesh from its breast to feed its young; this was seen as a symbol of Jesus' sacrifice to save humankind.

even of our Redeemer and Saviour[40].» The celestial orb, lunar dial, and moving astrolabe pointed to the magnificence of God's universe. The human automata have allegorical functions: the figures of Christ and Death show that Death is triumphant in the short-term, but that he will be vanquished at the Second Coming of Christ, and the four stages of humankind dramatize the linear nature of time during a single lifespan, and the cyclical nature of the life cycle. Conrad wrote:

> And on this clock we exhibit eternity, the century, the orbits of the planets, the yearly and monthly revolutions of the sun and moon, the divisions of the week, days, hours, parts of hours, minutes; all these I say, we exhibit to be seen. We have added also, for the sake of adornment, splendor, admiration, various contrivances, pneumatic, sphaeropoetic, and automatic, everything from history and the tales of the poets, and also from sacred and profane writings in which there is or can be some delineation of time[41].

This magnificent mechanical clock was a moving model of the world and the heavens, representing the micro and macro of divine ingenuity. Indeed, as the Strasbourg clock makes vividly clear, they were in the late medieval and early modern periods used to celebrate the grandeur and glory of divine creation and human salvation. Together, astronomical clocks and their automata yoked sacred and secular time; measuring out the minutes and hours of human lives while also showing the power of divine creation and the mercy of divine salvation.

40. Conrad Dasypodius, *op. cit.*, p. 404.
41. *Ibid.*

Merveilles, machines et mécanique au XVII^e siècle. La relecture de Héron d'Alexandrie par Grégoire de Saint-Vincent

Patricia Radelet-de Grave*

Grégoire de Saint-Vincent (fig. 16) est né à Bruges le 8 septembre 1584, un an avant les premières publications de son concitoyen Simon Stevin, et en particulier du *Weeghconst* ou « art pondéraire »[1]. Grégoire est mort à Gand le 27 janvier 1667. Il est surtout connu pour son *Opus Geometricum* (fig. 17) parce que ce travail a influencé Leibniz dans l'invention du calcul différentiel et intégral, et ce aux dires de Leibniz lui-même.

Pourtant Grégoire est un savant aux multiples facettes dont je ne dévoilerai qu'une très petite partie. D'autant plus qu'il s'agit de montrer chez lui la persistance d'une idée erronée. Mais une erreur chez un personnage de cette envergure mérite notre attention. L'idée provient de l'Antiquité et probablement des automates de Héron d'Alexandrie et sa persistance est intéressante car elle est le signe d'un certain bon sens. On en retrouve encore des traces après l'époque de Grégoire. Luca Antonius Portius (Porzio) reprend encore cette théorie en 1704 dans son *De motu corporum non nulla*, tout comme Guido Grandi en 1711 dans ses *Epistola mathematica*[2].

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1. Simon Stevin, *Van de Beghinselen der Weeghconst,* Leiden, Plantin, 1586.
2. Lucantonio Porzio, Lucae Antonii Portii, *De motu corporum nonnulla, et De nonnullis fontibus naturalibus,* Neapoli, impensis Bernardini Gessari, 1704 ; Guido Grandi, *Epistola mathematica de momento gravium in planis inclinatis deque directione fulcri in mechanicis attenda [...]*, Luca, Peregrini Frediani, 1711.

L'Automate

MODÈLE MÉTAPHORE MACHINE MERVEILLE

Actes du colloque international de Grenoble
(19-21 mars 2009)

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