"A Certain Motion": Automata and Mechanism in Early Modern Europe

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Abstract

This article explores early modern hopes and fears that texts about automata, machines that imitate organic life, could transform the reader from curious layman into a superhuman engineer. Katherine Park and Lorraine Daston's seminal work, *Wonder and the Order of Nature (1150-1750)* (1998), argues that displays of automata aim to stimulate emotion, but it does not explore the transformative possibilities for the reader encountering these machines. This article contends that written accounts of automata in early modern Europe reflect growing uncertainty about the relationship between body and mind, which would later be expressed in the mechanical philosophy of René Descartes. This uncertainty is illustrated by literary texts, particularly Thomas Nash's innovative prose work *The Unfortunate Traveller* (1594); historical chronicles that recall the inventions of the Spanish clockmaker Juanelo Turriano; and the technical manuals of the automaton-makers themselves. This article argues that the early modern automaton's potential to change the organic human body is both a threat to contemporary understanding of human nature, and a fantastical hope for humanity's future evolution.

Keywords: automaton, Descartes, mechanical, early modern, wonder.

Introduction

In his dictionary, the *Bibliotheca Eliotae* (1542), Thomas Elyot includes an addendum to his definition of automata: "it is also taken generally for al thynges which happen without any notable cause."[1] The automaton is best known as the central metaphor of seventeenth-century Cartesian mechanical philosophy, which posits that the organic body can be explained by its resemblance to a complex machine. For Elyot, the automaton is instead synonymous with the inexplicable. Yet Elyot's definition also suggests some technical understanding that automata, "thynges without lyfe, whiche seme to moue by them selfes", are in fact moved by the internal operations of clockwork mechanisms or "vyces".[2] Wonder and technical understanding co-exist, and Elyot implies that familiarity with the workings of the machine does not prevent the suspicion that there is some miraculous element to its movement. There may be some other "notable cause", within the clockwork or hydraulic systems, which reveals why the automaton mimics life so closely.

Automata have captivated audiences since antiquity, and by the early modern period could take forms as diverse as a giant dolphin and a player-less organ, but Elyot's explanation suggests that they are nonetheless somehow mysterious.[3] The automaton is conventionally defined by its illusion of self-motivated movement, placing it in defiance of Aristotelian philosophy, which classifies matter as natural or artificial dependent on its ability to move of its own accord.[4] They engender wonder in the viewer not because of their movements, which are usually quite mundane (such as bending to drink from a water source), but because of their accurate imitation of mundanity, and the suspicion

[1] Thomas Elyot, *Bibliotheca Eliotae* (London, 1542), Early English Books Online, Bodleian Library, [sig. Eviiir].

[2] Ibid.

[3] For discussion of the enormous, hydraulic dolphin at Kenilworth during Elizabeth I's visit in 1575, see Kara Reilly, *Automata and Mimesis on the Stage of Theatre History* (Basingstoke: Palgrave Macmillan, 2011), 30-32. For discussion of the musical automata of Achilles Langenbucher, see Derek J. De Solla Price, "Automata and the Origins of Mechanism and Mechanistic Philosophy", *Technology and Culture* 5, no. 1 (1964): 20, accessed 9th March 2019, doi:10.2307/3101119.

[4] Zakiya Hanafi, *The Monster in the Machine Magic, Medicine, and the Marvelous in the Time of the Scientific Revolution* (Durham, NC: Duke University Press, 2000), 88.

that they may not be artificial at all.[5]

René Descartes famously voices an alternative side to the automaton's resemblance to natural life in his *Meditations on First Philosophy* (1641), in which passers-by transform into automata as he watches: "But then if I look out of the window and see men crossing the square, as I just happen to have done, I normally say that I see the men themselves, just as I say that I see the wax. Yet do I see any more than hats and coats which could conceal automatons? I *judge* that they are men."[6] While Descartes examines whether man is indistinguishable from machine, Elyot's earlier definition conjures a different response to mechanical bodies, a form of wonder that Wendy Beth Hyman has called "the most magical, and yet the most engineered."[7] This article will examine technical manuals of automata, as well as their literary counterparts to suggest that the relationship between organic and mechanical bodies in early modern Europe was defined by more than the unsettling difficulty of distinguishing between them. In the technical descriptions of automata, a technological kind of wonder emerges, which holds its own transformative possibilities for the human body.

Modes of Reading Automata

Automata in fiction tend to be distinguished from their non-fictional counterparts because of their lack of technical limitations in perfectly mimicking the natural world. The motion of the early modern automaton was characteristically jerky, and would occasionally require carefully-timed adjustment from the automaton-maker while his audience was occupied.[8] In his study of the sixteenth-century Spanish engineer and clockmaker Juanelo Turriano, José A. García-Diego catalogued the movements of a friar automaton (see Figure 1) of unknown craftsmanship (but popularly attributed to Turriano); its limbs, head, eyes and mouth make a series of choreographed gestures which can be timed and listed in order of their occurrence in the sequence without

[5]Lorraine Daston and Katharine Park, *Wonders and the Order of Nature, 1150-1750* (Cambridge, MA: Zone Books, 1998), 287.

[6]John Cottingham, ed., *René Descartes: Meditations on First Philosophy: With Selections from the Objections and Replies* (Cambridge: Cambridge University Press, 2013), 43-45, accessed 8th March 2019, Cambridge Core.

[7]Wendy Beth Hyman, "The Early Modern Figure of the Mechanical Bird", in *The Automaton in English Renaissance Literature*, ed. by Wendy Beth Hyman (Farnham, Surrey: Ashgate, 2011), 152.

[8]Hanafi, *Monster in the Machine*, 77.

difficulty.[9] Its wind-up mechanism is hidden in its side, and may have been completely concealed from sight by a monastic cassock when in motion, but an operator would have been required to use its key.

Figure 1

Comparatively, the mechanical servants of the god Vulcan in Homer's *Iliad* provide a classical example of unconstrained and divinely inspired automata:

> Handmaids of gold, attending him; resembling in all worth,
> Liuing yong damzels; fild with minds, and wisedome, and

[9] José A. García-Diego, *Juanelo Turriano, Charles V's Clockmaker: The Man and His Legend*, trans. by Charles David Ley (Wadhurst: Antiquarian Horological Society, 1986), 98-100.

> were train'd In all immortall ministrie; virtue, and voice contain'd, And mou'd with voluntarie powers.[10]

George Chapman's 1616 English translation anatomises the mechanical maidservants to reveal not the pulleys of the Smithsonian's friar but independent minds. Crucially, the maidservants move under their own will, and Chapman implies that they achieve not only an aesthetic resemblance to living women but a degree of interiority that makes them closer to human than any real automaton can be.

Thomas Nash's *The Unfortunate Traveller* (1594), the innovative literary text that satirises the travels of wealthy aristocrats, would seem an exception to the tradition of the idealised literary automata exemplified in the *Iliad*. Its mechanical birds encountered in an Italianate garden are described minutely in technical terminology, not dissimilarly from the manuals drawing upon classical sources which had begun to circulate in the period. Nash satirises aesthetic excess in the passage, and though he immediately denies that the birds are natural creatures, the technological description returns to that possibility:

> Though there were bodies without soules, sweete resembled substances without sense, yet by the mathemeticall experimentes of long siluer pipes secretly inrinded in the intrailes of the boughs whereon they sate, and vndiscerneablie conuaid vnder their bellies into their small throats sloaping, they whistled and freely carold theyr naturall field note.[11]

The mechanical birds are contrived by "mathematicall experimentes", which encompass the technical and artisanal expertise needed to engineer the complex design. Nash emphasises that the pipes which enable the birds to produce sound should be hidden secretly and "undiscernably" so that the birds appear to imitate organic life. Yet he does not hide the mechanism from the reader, who is drawn into the elaborate imagery of the internal workings of the pipes rather than the birdsong itself.[12] The passage concludes that the mechanical elements of the birds were so well-hidden "that euerie man there present renounst

[10]George Chapman, *The whole works of Homer* (London, 1616), Early English Books Online, Harvard University Library, 262.

[11]Thomas Nash, *The vnfortunate traveller* (London, 1594), Early English Books Online, Huntington Library, sig. Kr.

[12]Hyman, "Mechanical Bird", 153.

coniectures of art, and sayd it was done by inchantment."[13] Nash, in revealing the mechanical construction of the bird, dispels the enchantment that preoccupies visitors to the garden, but creates another kind of spell in writing of the machine which forges these non-organic bodies. The reader's discovery of the hidden mechanism is another form of enchantment.

Nash's attention to the pneumatic mechanism of the singing birds typifies an early modern phenomenon in which technological description heightens rather than dispels the reader's amazement. Alexander Marr has suggested that wonder at automata is often spoken of in terms of "ravishment" of the spirits, which he attributes to the skill of the mechanician in "manufacturing minutely detailed simulacra of nature."[14] Yet Nash's readers, as well as those of other technical descriptions of the period, are struck not by the mimicry of the natural but by the intricacies of the artificial. The sixteenth-century historian Ambrosio de Morales describes the Spanish clockmaker Juanelo Turriano's watches in terms of wonder and amazement in his chronicle *Las antigüedades* (1575): "Y aunque este ingenio ensalzado sobre todos los que hemos visto y leemos habia hecho ántes tales maravillas en los dos relaxes que fabricó para el Emperador Don Carlos Quinto" (And although this invention is exalted above all others that we have seen and read about, he had made such wonders before in both the watches that he made for the Emperor Charles V).[15] Turriano was a fixture at the court of Charles V, and was later employed by his son, Philip II of Spain. The exalted invention referenced by Morales above is the device known as the Artificio de Juanelo, which served a practical and political purpose of fetching water to the Alcázar in Toledo, and which was his most famous commission. Yet Turriano also built a mechanical dancing lady which Morales similarly praises for its craftsmanship: "Though it is a toy and fit for mirth, it is nevertheless a great proof of his high intelligence."[16] The dancing lady's movement is trivial, divorced from Turri-

[13]Nash, *The vnfortunate traveller*, sig. Kr.

[14]Alexander Marr, "Gentille curiosité: Wonder-working and the culture of automata in the late Renaissance", in *Curiosity and Wonder from the Renaissance to the Enlightenment*, ed. by R. J. W. Evans and Alexander Marr (Aldershot: Ashgate, 2006), 161.

[15]Ambrosio de Morales, *Las antigüedades de las ciudades de España* (Madrid, 1792), Biblioteca Digital de Castilla y León, 330. Translations are my own unless otherwise indicated.

[16]Quoted in translation from García-Diego, *Juanelo Turriano*, 101.

ano's service to the state, but its manufacture is to be remembered, and Morales ends his description of Turriano's life with a hope that his text will be a memorial to the "artífice" (inventor) (341), not the magic of his devices.[17]

Wonder and Physiological Reactions

In both Nash's text and Morales' account of Turriano, there is an underlying sense of the physiological effect of automata on their human counterparts. Nash's use of the term "enchantment" recalls the disruption of both bodily humours and mental faculties by witchcraft in the early modern period, as described in the *Malleus Maleficarum* (1486) of Heinrich Kramer and James Sprenger: "Therefore the Devil can, by moving the inner perceptions and humours, effect changes in the actions and faculties, physical, mental, and emotional, working by means of any physical organ soever."[18] This physiological change causes the victim to believe they are transformed into an animal, or forget their loved ones; it can even induce disease. Yet witches, too, are "infected by witchcraft" (113) in the *Malleus Maleficarum*, which implies that it is a subtle distortion of their physical make-up that allows them to perform their magic.[19] The Devil's influence alters the human body of both enchanter and victim on a physiological level, and Nash's connection of his mechanical birds with enchantment implies that automata wreak the same disruption in both their makers and those who encounter them, even in textual form.

The automaton's association with the demonic, as well as its resistance to the Aristotelian categories of natural and artificial, makes encounters with the mechanical in the early modern period both troubling and astounding. Morales' description of the effect of Turriano's devices suggests that they cause not only wonder but terrified amazement: "que habia puesto espanto" (which could cause terror).[20] Turriano is even described in the Italian painter Antonio Campi's account of his automata as "superhuman", more alike to Vulcan than humanity.[21] Lorraine Daston and Katherine Park have effectively argued that

[17]Ibid., 340.
[18]Heinrich Kramer and James Sprenger, *Malleus Maleficarum*, trans. by Montague Summers (London: John Rodker, 1928), 135.
[19]Ibid., 113.
[20]García-Diego, *Juanelo Turriano*, 330.
[21]Ibid., 102.

wonder and curiosity were gradually changing during the sixteenth and seventeenth centuries alongside the development of the scientific method. Wonder, once a sign of willingness to learn, becomes a mark of risible ignorance, whereas curiosity is no longer a dangerous loss of self-control but an avaricious need to discover more about the world, which can be put to investigative use.[22] Morales, like Campi, distances the reader from Turriano, "raro y extremadamente insigne artifice" (an unusual and extremely illustrious inventor), whose mechanical ability has altered him much like an enchantment.[23] It is a discouragement of curiosity for its own sake, outside of Turriano's sanctioned patronage relationships. Nash, comparatively, models curiosity for the reader, uncovering the path of the pipes and the source of the sound of the mechanical birds "if anie demand how the wind was breathed."[24] The reader of these texts about automata is not yet curious in the manner of a scientific investigator, but both Morales and Nash suggest that they may come to possess a knowledge which will elevate them beyond the limits of the ordinary human.

Technical Manuals of Automata and Their Readers

The technical manuals of the late sixteenth and early seventeenth centuries, written by the automaton-makers themselves, also depend on written descriptions as well as elaborate illustrations to explain their devices. Dennis des Chene has described early modern technical manuals as requiring "back and forth reading" between diagrams, images and written accounts.[25] Agostino Ramelli's popular treatise *Le diverse et artificiose machine del Capitano Agostino Ramelli* (The various and ingenious machines of Captain Agostino Ramelli) (1588) was published in a bilingual vernacular edition, in Italian and French, highlighting the importance of the written commentary to the schematics. Images were not consistently included next to the description of the device they depict, even when the author directs the reader to examine a particular pulley or string for further information. Isaac de Caus' *New and rare inventions of water-works* (1659), an English adaptation and expansion of his brother Salomon's 1615 manual on hydraulics and automata, in-

[22]Daston and Park, *Wonder and the Order of Nature*, 305.
[23]Morales, *Las antigüedades de las ciudades de España*, 34.
[24]Nash, *The vnfortunate traveller*, sig. Kr.
[25]Dennis Des Chene, *Spirits and Clocks: Machine and Organism in Descartes* (Ithaca, NY: Cornell University Press, 2001), 74.

cludes an illustration and description of mechanical birds designed to turn away from an owl in apparent fear which is entirely borrowed from Salomon's earlier book. Isaac explains that the artificer can also introduce "a certain motion to the Tayls and Beacks of the Birds", and directs the reader to the corresponding diagram, which is located in a selection of plates at the back of the book and is unlabelled.[26] The "certain motion" is not described further. The reader of the technical manual is, like the reader of literary automata, expected to be curious enough to discover more without direction.

The genre of the early modern technical manual is almost misleading for modern readers, because the texts do not restrict themselves to mechanical schematics. Salomon de Caus produced *Les raisons des forces mouvantes* (1615) while his designs were implemented in the magnificent formal garden of the Hortus Palatinus at Heidelberg, commissioned by the Elector Palatine, Frederick V. The book is lavishly illustrated and would have been an expensive production; Isaac appropriated many of the images for his much later work printed in England. It also does not consistently anatomise its automata in either text or image. De Caus' garden grottoes, which were to be influential in their design throughout Europe, are illustrated as if they are scenic paintings, with a mechanical schematic adjacent to the artistic interpretation. One depiction of Neptune surrounded by nymphs, set on slowly turning platform, is detached from the workings of the mechanism, which is included in a separate image entirely.[27] Only one bird is drawn separately with its mechanical movements clearly mapped, and all of the humanoid automata in the book are drawn as human figures, without discernible joints or simplified features. De Caus, rather than introduce meticulous detail into the book, instead appeals to his reader's "gentile curiosité" (noble curiosity), displacing curiosity from the realms of the demonic and sinful into a suggested mode of reading.[28] The frontispiece reflects the experience of reading the book, with a stone monument displaying De Caus' name and his employment at Heidelberg, as well as the name of the printer, half-opened to reveal the world beyond. Though the technical manual gives schematic descriptions, it

[26]Isaac de Caus, *New and rare inventions of water-works* (London, 1659), British Library, sig. Iv.

[27]This format is preserved in Isaac de Caus' *New and rare inventions of water-works*.

[28]Marr, "Gentille curiosité", 151.

always suggests there is more to be uncovered, and more wonders to be found.

Both Salomon and Isaac de Caus address their technical manuals to "you", the reader, whose identity is complicated by the style of reading encouraged by the text. The technical manual deliberately and rhetorically figures the reader as craftsmen, although those who perused these expensive editions were likely potential patrons or employers as well as contemporaries. The reader of *New and rare inventions of water-works* is expected to be familiar enough with Des Chene's back-and-forth approach that lengthy written complements to schematics are considered unnecessary: "The Ingenious Reader may easily see the effect of these Sluces, without more words, and making other description then that which is described in the Figure".[29] Isaac's narrative on the construction of a hydraulically-powered dial extends this expectation to artisanal expertise: "and then you may make a Pignon to the Arbor of the said wheel having six Teeth [...] and when the said Dyal shall be well justned, it shall continue a long time without alteration. You must also note that it is necessary that the water of the Vessel B be as high as the Pipe P".[30] Isaac gestures, then, not only towards an imagined possibility that the reader may reconstruct his machines, but also at the incremental narrative mode of his technical writing, of which the final product is the impressive plate at the end of the book. It is a wondrous, textual form of engineering, in which the reader is a precocious novice.

The de Caus brothers and Agostino Ramelli draw from the classical example of Hero of Alexandria, an engineer and mathematician of the 1st century AD whose manuals on automata and pneumatic devices had been circulating in Europe in printed form since the late sixteenth century. Hero is depicted on Salomon de Caus' frontispiece, looking up towards de Caus' name on the opening stone door in acknowledgement of the debt owed to his own technological treatises. Like those of de Caus, the aesthetics of Hero's automata are carefully considered and are complemented by his written descriptions, such as one example of an animal that "shall drink with a loud noise so as to present the appearance of thirst."[31] Hero's treatise concerns two kinds of automata: a static theatre wherein figures could be presented to an audience, and a

[29] De Caus, *New and rare inventions of water-works*, sig. Lv.

[30] Ibid., sig. G2v.

[31] Hero, *The Pneumatics of Hero of Alexandria*, ed. trans. by Bennet Woodcroft (London: Taylor Walton and Maberly, 1851), 46.

moving version of the same device. It is impossible to reconstruct his machines from the descriptions given, however, since he excludes crucial information such as the connection of pulleys and the workings of moving internal parts. Susan Murphy suggests that his text is aimed at fellow craftsmen and therefore lacks the need for specific detail to be understood, but the example seems to have been adapted in the early modern period into the paradoxical secrecy of the technical manual.[32]

Hero begins his work with a defence of making automata: "The study of automaton-making has been considered by our predecessors worthy of acceptance, both because of the complexity of the craftsmanship involved and because of the striking nature of the spectacle."[33] The duality of the technical manual is in its showcase of the skill of the artificer while omitting enough information to maintain an illusion, not only of the automata but also of the superhuman craftsman.

Mechanical Transmutations

The technical manual's implication that secrets lie within mechanisms explains Robert Burton's association of automata with alchemy in his compendious *Anatomy of Melancholy* (1628). Burton advises the melancholic reader, unless they have identified excess study as the cause of their illness, to investigate treatises on automata and other mechanical creations, and blends them with alchemical texts to suggest that the reader may discover "to walk on the water by art, and to fly in the ayre, to make several Cranes and pullies, *quibus homo trahat ad se mille homines* [by which a man may draw a thousand men toward himself], lift up and remove great weights."[34] The mechanical is seamlessly blended with the supernatural, recalling the magical enchantment of Thomas Nash's literary machinery. Allusions to Hero of Alexandria and his *"machinâ se movente"* (self-moving machine) are included within a passage on "strange miracles" (2:93), and Burton's recommendations to the reader are based upon texts as well as experimentation.[35] He re-

[32]Susan Murphy, 'Heron of Alexandria's "On Automaton-Making"', *History of Technology*, 17 (1995): 5-6.

[33]Ibid., 16.

[34]Robert Burton, *The Anatomy of Melancholy*, ed. by Nicolas K. Kiessling, Thomas C. Faulkner, and Rhonda L. Blair, 6 vols (Oxford: Clarendon Press, 1990), 2:93. Translations are my own unless otherwise indicated.

[35]Ibid.

quests that the melancholy reader "peruse and practice".[36] Mary Ann Lund has argued that the *Anatomy* itself enacts a kind of therapeutic reading, particularly in this section, where most of the cures suggested are almost impossible for all but the wealthiest readers to access, or exist only in the poetic imagination, such as the description of Menelaus' palace.[37] The *Anatomy* stands in as a synecdoche for the other texts it cites, just as written descriptions of automata simulate the wonder of Hero's "spectacle".[38] The enchantment of the books of automata, in Burton's text, is positive, and the curiosity they engender is as noble as de Caus imagines.

When Burton concludes his account of automata, he has given a long list of works, including alchemical treatises and mathematical textbooks, with which the reader may occupy themselves and thwart their ill health. A dedicated search for knowledge is as much a tonic for the melancholic mind as it is a pleasing diversion. His final recommendation is that the melancholy reader may find themselves confronting tales of these machines in "pleasure and delight, or crabbednesse".[39] The term "crabbed" appears elsewhere in the *Anatomy*, mostly in a context familiar to modern readers (as in "perverse" or "ill-tempered"), but the noun form is applied only in this instance to the act of studying a text. The *Oxford English Dictionary* offers an alternative contemporary definition: "Ruggedly or perversely intricate; difficult to unravel, construe, deal with, or make sense of."[40] Burton implies that technical manuals and stories of automata may ultimately contain only deeper secrets. Curiosity in itself acts upon the reader, even if the truth of the automaton's powers remains out of reach.

The *Anatomy* maintains the older image of the extraordinary artificer, however, and casts the technological as transformative in those who are able, finally, to fully understand it. In the short Latin quotation from Roger Bacon in this section of the *Anatomy*, it is the engineer rather than the automaton who is centred and makes effective use of

[36]Ibid., 2:92.

[37]Mary Ann Lund, *Melancholy, Medicine and Religion in Early Modern England: Reading 'The Anatomy of Melancholy'* (Cambridge: Cambridge University Press, 2010), 105.

[38]Susan Murphy, 'Heron of Alexandria's "On Automaton-Making"', 16.

[39]Burton, *The Anatomy of Melancholy*, 2:93.

[40]"crabbed, adj.", *Oxford English Dictionary*. Online, Oxford University Press, http://www.oed.com/view/Entry/43592?rskey=DV6pq6result=4 (accessed March 14, 2019).

pulleys and cranes to gain the physical strength to overcome a thousand others.[41] Burton also alludes to Bacon's famous description of flight in the alchemical text *De Mirabili*, in which he imagines an early ornithopter, or wings which could be harnessed to a man to allow him to fly.[42] The intermingling of the pulleys familiar to mechanicians and those who knew of the inner workings of automata with the more fantastical images of flight and impossible strength does allow, as Lund suggests, a mode of therapeutic reading, but it also connects Burton's image of the artificer back to the "superhuman" Juanelo Turriano.[43] Not only can encounters with the enchantment of automata implicitly alter the humoural balance of the body, but the body itself can be altered to mimic the machine. It is the same scenario that Descartes acknowledges when he doubts his own sensory perception in the *Meditations* and wonders whether the men he sees are truly automata, but in the *Anatomy of Melancholy*, the technological wonder and its possibilities are a hope worth pursuing rather than a fear realised.

Conclusion

Dennis des Chene writes of Descartes that he adopts the metaphor of the machine "because it is familiar, a glass or grid through which to grasp the less familiar [...] [For example] a spring-powered clock may illustrate the storage of power whether one can explain springiness mechanistically or not."[44] The late sixteenth century and early seventeenth century witnessed a changing relationship to the mechanical schematics of automata, but even Descartes does not embrace the familiarity of the machine with as much enthusiasm as des Chene implies. His vision of the human automaton reflects both its mimicry of the natural world, and the older, persisting mystery inherent in its design. The association of the mechanical with the magical and the hidden, in even the most technical early modern accounts of automata, leads the reader to suspect that close encounters with these self-moving machines might subtly alter the organic body. Those drawn to this mechanical magic, and its potential transgression of ordinary human limits, have strayed far beyond the familiar. The automaton-makers, and automaton-readers, are early modern technology's most curious pio-

[41] Burton, *The Anatomy of Melancholy*, 2:93.
[42] Lund, *Melancholy, Medicine and Religion*, 105.
[43] García-Diego, *Juanelo Turriano*, 102.
[44] Des Chene, *Spirits and Clocks*, 14.

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Bibliography

Primary Sources

Burton, Robert. *The Anatomy of Melancholy.* Edited by Nicolas K. Kiessling, Thomas C. Faulkner, and Rhonda L. Blair. 6 vols. Oxford: Clarendon Press, 1990.

Caus, Isaac de. *New and rare inventions of water-works.* London, 1659. British Library.

Caus, Salomon de. *Les raisons des forces mouuantes.* Frankfurt, 1615. British Library.

Chapman, George. *The whole works of Homer.* London, 1616. Early English Books Online. Harvard University Library.

Cottingham, John, ed. *René Descartes: Meditations on First Philosophy: With Selections from the Objections and Replies.* Cambridge: Cambridge University Press, 2013.

Elyot, Thomas. *Bibliotheca Eliotae.* London, 1542. Early English Books Online. Bodleian Library.

Hero. *The Pneumatics of Hero of Alexandria.* Edited and translated by Bennet Woodcroft. London: Taylor Walton and Maberly, 1851.

Kramer, Heinrich and James Sprenger. *Malleus Maleficarum.* Translated by Montague Summers. London: John Rodker, 1928.

Morales, Ambrosio de. *Las antigüedades de las ciudades de España.* Madrid, 1792. Biblioteca Digital de Castilla y León.

Nash, Thomas. *The vnfortunate traveller.* London, 1594. Early English Books Online. Huntington Library.

Reference Works

"crabbed, adj." *The Oxford English Dictionary*. Online. March 2019. Oxford University Press. http://www.oed.com/view/Entry/43592?rskey=DV6pq6&result=4 (accessed March 14, 2019).

Secondary Sources

Benedict, Barbara M. *Curiosity: A Cultural History of Early Modern Inquiry.* Chicago: University of Chicago Press, 2001.

Butterworth, Philip, and Katie Normington, eds. *Medieval Theatre Performance: Actors, Dancers, Automata and Their Audiences.* Cambridge: D. S. Brewer, 2017.

Daston, Lorraine, and Katharine Park. *Wonders and the Order of Nature, 1150-1750.* Cambridge, MA: Zone Books, 1998.

Des Chene, Dennis. *Spirits and Clocks: Machine and Organism in Descartes.* Ithaca, NY: Cornell University Press, 2001.

Evans, Robert John Weston, and Alexander Marr, eds. *Curiosity and Wonder from the Renaissance to the Enlightenment.* Aldershot: Ashgate, 2006.

García-Diego, José A. *Juanelo Turriano, Charles V's Clockmaker: The Man and His Legend.* Translated by Charles David Ley. Wadhurst: Antiquarian Horological Society, 1986.

Glennan, Stuart, and Phyllis McKay Illari, eds. *The Routledge Handbook of Mechanisms and Mechanical Philosophy.* Routledge Handbooks in Philosophy. New York: Routledge, 2017.

Gnudi, Martha Teach, and Eugene S. Ferguson, eds. *The Various and Ingenious Machines of Agostino Ramelli.* Baltimore: Johns Hopkins University Press, 1976

Hanafi, Zakiya. *The Monster in the Machine Magic, Medicine, and the Marvelous in the Time of the Scientific Revolution.* Durham, NC: Duke University Press, 2000.

Hyman, Wendy Beth, ed. *The Automaton in English Renaissance Literature.* Farnham: Ashgate, 2011.

LaGrandeur, Kevin. *Androids and Intelligent Networks in Early Modern Literature and Culture: Artificial Slaves.* London: Routledge, 2012.

Lund, Mary Ann. *Melancholy, Medicine and Religion in Early Modern England: Reading 'The Anatomy of Melancholy'.* Cambridge: Cambridge University Press, 2010.

Murphy, Susan. "Heron of Alexandria's 'On Automaton-Making'". *History of Technology* 17 (1995): 1–46.

Price, Derek J. De Solla. "Automata and the Origins of Mechanism and Mechanistic Philosophy". *Technology and Culture* 5, no. 1 (1964): 9-23. doi:10.2307/3101119.

Reilly, Kara. *Automata and Mimesis on the Stage of Theatre History.* Basingstoke: Palgrave Macmillan, 2011.

Sawday, Jonathan. *Engines of the Imagination: Renaissance Culture and the Rise of the Machine.* Abingdon: Routledge, 2007.

Wolfe, Jessica. *Humanism, Machinery, and Renaissance Literature.* Cambridge: Cambridge University Press, 2004.

Legend to Figures

Figure 1: Automaton of a friar, 16 in x 5 in x 6 in. 1977.1191. Division of Work and Industry, National Museum of American History, Smithsonian Institution. Photo reproduced with permission of the National Museum of American History.