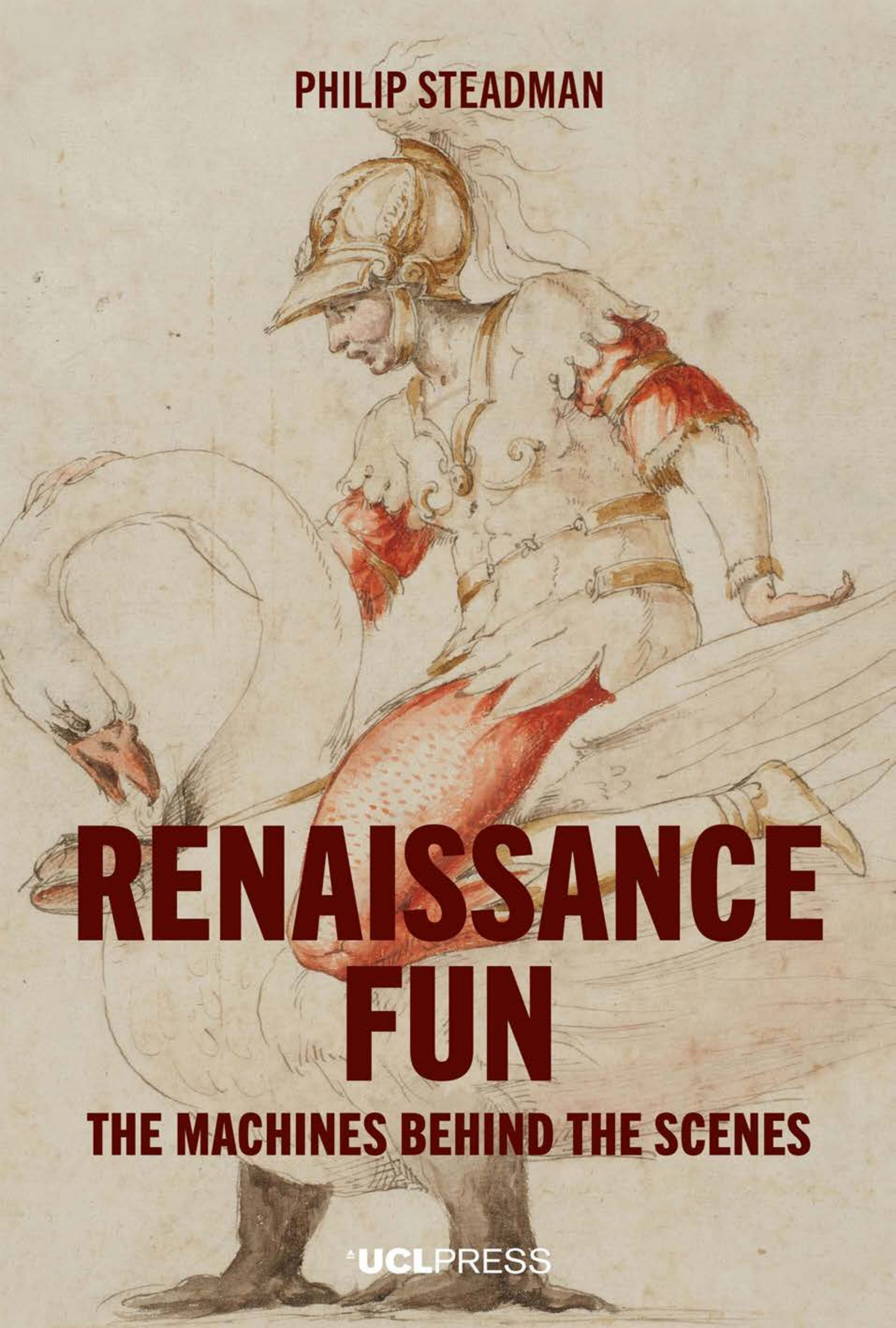

PHILIP STEADMAN

RENAISSANCE FUN

THE MACHINES BEHIND THE SCENES

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Renaissance Fun

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The machines behind the scenes

Philip Steadman

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Introduction

John Evelyn's Grand Tour

In November 1643 John Evelyn set out from England on a series of journeys around the Low Countries, France and Italy in an early and unusually extensive version of the Grand Tour.[1] Evelyn was an amiable 23-year-old with an Oxford education, a moderately deep purse, and some useful contacts and introductions. He knew Latin and acquired other languages as he travelled. He also had an intrepid spirit that served him well in some tricky moments, from altercations with customs officers to ambushes by bandits. He was endlessly curious, talked to everybody and on his return wrote up his experiences in the *Diary* that remains his greatest claim to fame.

Evelyn's travels were spread out over eight years, with some short trips back home. He visited cathedrals, palaces, monasteries and universities. He saw the classical ruins of Rome and southern Italy. He climbed Mount Vesuvius and journeyed across the Alps in winter on horseback. And he saw many of the paintings, sculptures and works of architecture produced in the Renaissance of the visual arts of the previous two centuries.

But Evelyn also saw and enjoyed a great variety of other entertainments and amusements, some serious and refined, others vulgar and trivial. Indeed, to judge by the space he devotes to them in the *Diary*, and the enthusiasm of his descriptions, these often drew more of his attention than the art collections, which he tends to cover dutifully with bare lists of artists and titles of works.[2]

In November 1644 Evelyn paid a visit to the Collegio Romano, the Jesuit college in Rome, where the polymath Athanasius Kircher entertained him and his friends with 'many singular courtesies'. Kircher had scholarly interests and unreliable opinions across a bewildering range of subjects – he is one of those individuals who have been described as 'The last man who knew everything'. But for Evelyn's party he brought out, 'with Dutch patience', his 'perpetual motions, Catoptrics, Magnetical experiments, Modells, and a thousand other crotchets & devises'.[3] 'Catoptrics' was the study of mirrors and the reflection of light. Kircher devised several optical entertainments making use of mirrors and lenses, including camera obscuras and magic lanterns.

Evelyn visited many of the great Renaissance and Baroque gardens of Italy and France, and admired their walks, parterres, groves and statuary both ancient and modern. He was entranced by the 'jettos' of water that made patterns of spray in the air in the shapes of glasses, cups, crosses, crowns or fleurs de lys. Other fountains imitated the sound of thunder or produced artificial rainbows. In May 1645 at the Villa Aldobrandini he saw 'a copper ball that continualy daunces about 3 foote above the pavement, by virtue of a wind conveyed seacretly to a hole beneath it'.[4]

In the same month Evelyn visited the gardens of the Villa d'Este in Tivoli, where he enjoyed the scale model of the city of Rome with its stream representing the Tiber:[5]

> In another garden a noble Aviarie, the birds artificial, & singing, til the presence of an Owle appeares, on which the[y] suddainly chang their notes, to the admiration of the Spectators: Neere this is the Fountaine of Dragons belching large streames of water, with horrid noises: In another Grotto, called the *Grotta di Natura*, is an hydraulic Organ …[6]

This was not the only water-powered organ that Evelyn saw. He mentions hearing 'artificial music' in several places on his travels.

One more type of entertainment about which Evelyn was greatly enthusiastic was the theatre: he attended many performances on his travels. Arriving in Venice in June 1645, he went to the opera accompanied by 'my Lord Bruce' to see a performance of *Hercules in Lydia*. The music and singing were 'excellent', 'with variety of Seeanes painted & contrived with no lesse art of Perspective, and Machines, for flying in the aire, & other wonderfull motions. So taken together it is doubtlesse one of the most magnificent & expensfull diversions the Wit of Men can invent.'[7] In *Hercules* the scenes were changed 13 times.

Evelyn will be our occasional guide, reappearing throughout the book with descriptions and reactions – as will the French essayist and philosopher Michel de Montaigne, who wrote of his travels in Italy a few years later, and enjoyed many of the same experiences.

The common factor in all this variety of entertainments was that they depended on *machines*, or, to use an anachronistic term, technologies. The fountains relied on elaborate systems of water control: aqueducts, reservoirs, pipes and nozzles. Animal and human automata were worked by concealed hydraulic, pneumatic and mechanical apparatus. The machinery of the Renaissance theatre brought celestial personages down from the clouds ('gods from machines') and brought characters from the Underworld up from below. Scenery was rotated, slid, rolled and replaced using yet more mechanical devices. Sets were built and painted to create realistic illusions of depth using the 'technology' of perspective.

How did these machines work? How exactly were chariots filled with singers let down onto the stage? How were flaming dragons made to fly across the sky? How were seas created on stage? How did mechanical birds imitate real birdsong? What was 'artificial music', three centuries before Edison and the phonograph? How could pipe organs be driven and made to play themselves by waterpower alone? And who were the architects, engineers and craftsmen who created these wonders?

Giovanni Battista Aleòtti and Bernardo Buontalenti

Many of the shows described here were designed and mounted by Renaissance artists better known for their paintings, sculptures and buildings, but who saw no sharp boundaries with those more prestigious arts, and were prepared – when required – to devote their great talents to events lasting only a few days or hours. Filippo Brunelleschi, architect of the dome of Florence Cathedral, built machinery to allow an actor playing the archangel Gabriel to fly the length of the church of the Annunziata in Florence. Leonardo da Vinci built a golden rotating dome representing Paradise for a play in Milan, and designed mobile robot lions to greet the Kings of France. The sculptor Gian Lorenzo Bernini, besides designing some of Rome's finest Baroque fountains and putting on performances of his own plays, was also an expert in pyrotechnics.

As Roy Strong, the historian of seventeenth-century English drama and garden design, puts it, 'The Renaissance engineer was an artist and an artisan, a military man, an organizer of court festivities, a man whose mind was of such complexity and genius that no effect was beyond his powers.'[8]

Strong was perhaps thinking about such multitalented experts as Carlo Fontana, Giulio Parigi or Salomon de Caus, all of whom make appearances here. Above all, he could have been writing specifically about two men who worked in the late sixteenth century, Giovanni Battista Aleòtti and Bernardo Buontalenti. Aleòtti was an architect employed by the d'Este family in Ferrara who devoted much of his professional life to hydraulic engineering. He designed the magnificent Teatro Farnese in Parma – which we will visit at the end of the book – and devised much of its elaborate stage machinery. He also designed little theatres of automata to be incorporated in gardens.

Buontalenti was chief designer and engineer to the court of the Medici in Florence. As an architect, Buontalenti was not in the first rank: his real genius was for entertainment. He was given the nickname 'delle Girandole', which seems to refer to a model with figures and revolving lights that he made, but also alludes to his skill with fireworks. The word *girandola* is a protean term that recurs with several meanings throughout the history of pyrotechnics.[9] Even professional fireworks people complain about its slipperiness. Generally, however, the reference is to rotating pieces, such as Catherine wheels. I like to think that Buontalenti might have been so called because he was always spinning about, throwing off showers of creative sparks. Buontalenti and Aleòtti are the chief protagonists of this book. It was in the design of gardens and theatrical effects that they both specially excelled.

Elsewhere these histories touch on the technical writings of some Renaissance scholars who worked on mechanics, hydraulics and other engineering subjects – Giovanni Fontana, Robert Fludd, Giovanni Battista Della Porta and Cornelis Drebbel, as well as Athanasius Kircher – who have tended to play small parts in histories of science and technology, because they made few contributions to mainstream developments in their subjects. They have been categorised as eccentrics or discussed under the history of magic – although this has been changing more recently – in part because their technical illustrations, before the introduction of formal methods of engineering drawing, can sometimes appear amateurish or impractical. However, I have thought it worthwhile taking these writings and drawings at face value, at least in the first instance, since they can be more coherent and informative than is immediately apparent.

Scope of the book

I have taken as my rough chronological definition of 'Renaissance' the period 1400 to 1700. Geographically the focus is on Italy, with occasional excursions into Northern Europe. The subject matter is confined to the direct application of machines or mechanical devices to the purposes of entertainment.

Scientific instruments are omitted, despite the fact that many amateurs derived much intellectual pleasure from contemplating and being allowed to use them, and elaborately decorated instruments found their ways into the collections of courts and museums. I have decided arbitrarily to exclude clocks, because of their complexity, even though in many cases their time-keeping function was secondary to their value as *objets d'art* or conversation pieces. Clockwork automata are mentioned, but only in passing. Food and sex are only included in a few cases where technology is involved. I have reluctantly abandoned an early plan to cover fireworks in depth – although they will still burst in from time to time – on the dubious rationale that gunpowder was unknown to the ancient world, and there was thus no Renaissance in pyrotechnics.

In recent decades there has been a growing interest among historians in Renaissance festivals across Europe, originally given momentum by a major conference, Les Fêtes de la Renaissance, held in 1955.[10] This literature covers many forms of celebration: pageants on land and water, entries of dignitaries and military heroes into cities, royal progresses, firework shows, banquets, dancing, equestrian displays and tournaments. Most of these festivals are outside the scope of this book since – apart from the decorated boats and 'pageant cars' that made up the processions – there was little or no machinery involved (and because I have excluded fireworks). There are, however, two large areas of overlap: the theatrical productions that accompanied many of these festivals and the animated mechanical figures that took part in entertainments – both of which feature prominently here.

A great part of the existing literature is concentrated on the experiences of the audiences of Renaissance entertainments and the impressions gained by visitors to the great Renaissance gardens.[11] This book differs by revealing the view from 'round the back': by explaining what was involved in conceiving, producing and putting on these productions and displays, and showing what the technical crews were doing. Many of their designers were architects, as am I, and perhaps in that capacity I have some qualifications.

If many of these events and works have faded from historical memory, it is because they were by their nature ephemeral and fragile. Gardens are always precarious and vulnerable. Fireworks are gone in an instant. Automata wear out and stop working. Theatrical performances are only remembered from scripts, drawings for sets and the occasional testimony of audience members. Many Renaissance theatres burned down. Even so, enough documentary evidence remains to attempt at least partial reconstructions. I have given special attention to those rare cases in which artefacts, and annual festivals with their origins in the Renaissance, have survived to the present day.

The book is offered primarily as an entertainment, like its subject matter. But there are some secondary ambitions. There is a strangeness and remoteness to this world of pleasures and diversions and its frameworks of cultural reference. At the same time there are the beginnings of several modern entertainment technologies: robotic simulacra of animals and humans, recorded music, cinematography, special stage effects in musicals and concerts, even the amusement park, water park and theme park. The book hints at these connections.

It might seem on first sight that these various types of machinery found their places in quite separate forms of entertainment. In fact they overlapped and made reference to each other at many points. Perspective pictures were placed in gardens to create illusory spaces and false extensions to real vistas. Animated figures representing mythological characters and wild animals appeared on stage, and were set around fountains and by pools in garden grottoes. Theatrical performances were staged in gardens, and gardens were recreated in theatrical sets. Again, the book explores these interrelationships. By putting the subjects together it is possible to make links that are not always visible in separate histories of science, art, mechanics, music, theatre and gardening.

There are other connections at a more abstract and conceptual level. In automata, in gardens and in the theatre, Renaissance designers sought to recreate the phenomena of nature through art. Nature itself was conceived as a theatre or spectacle, and Renaissance audiences were pleased to see imitations and illusions of nature that could simultaneously be appreciated as products of human ingenuity. Conversely, works of art such as gardens, grottoes and fountains could be constructed from materials and elements that seemed to keep their natural character, albeit cunningly arranged to achieve the desired poetic and sculptural effects. In the Mannerism of the seventeenth century, this artificiality came to be specially appreciated.[12]

Technologies of all these kinds were brought together in the great court theatricals and villa gardens of the late Renaissance. The book culminates with accounts of two of these occasions and places, seen both ‘from the front’ as experienced by their visitors and audiences, and ‘from the back’ as planned and executed by their designers, builders, stage crews, actors and ‘fountaineers’. We tour Buontalenti’s lost masterpiece of garden design at Pratolino near Florence, with its grottoes, fountains, automata and many fabled ‘marvels’. Finally, we attend the production of *Mercury and Mars* at the Teatro Farnese in 1628, for which Aleòtti designed some of the most impressive stage effects ever seen. This was a strange hybrid form of entertainment combining tournament and drama, with music by Claudio Monteverdi – one of the birthplaces of the art of opera.

The improbable influence of Hero of Alexandria

The designers of Renaissance entertainments looked back to the work of their predecessors in the ancient world. They studied such archaeological evidence as remained: the fountains, theatres and ruined villas of Rome and the Empire. Above all they read those few texts on machines that survived from Rome, Greece and Alexandria, in some cases through their being copied and preserved by scholars in the Islamic world. These were translated into Latin and Italian in the fifteenth and sixteenth centuries and were studied intently by Renaissance engineers in an attempt to recover and recreate some of that lost world of knowledge and expertise.

First among these ancient writers was Vitruvius, a Roman military engineer and architect who lived in the first century BC, about whose life we have only a little information.[13] He may have been responsible for war machines under Julius Caesar, and perhaps also worked on aqueducts in Rome. Vitruvius’s *On Architecture*, in ten books, is the only text on the design of buildings to have survived from antiquity. The first printed version was published in Rome in 1486–7.[14]

On Architecture describes construction technique, building materials and the needs of different building types. One book is devoted to fresco painting and pigments; another to machines, many of which have nothing to do with architecture, such as clocks and catapults. Several chapters in Book V cover the design of theatres and the scenic decoration of the ancient drama. Vitruvius also devotes just a few sentences to painting in perspective, and its use in the design of stage scenery.

The impact of Vitruvius's writings on Renaissance theatre design from the fifteenth century was very great, and has been much studied. The high point was reached in Andrea Palladio's Teatro Olimpico in Vicenza of 1585, which faithfully followed ancient Roman precedent. After this, however, Vitruvius's influence waned, with a move in theatrical taste away from classical drama towards modern comedies and musical entertainments that demanded a very different kind of theatre building, with much more elaborate scenic machinery, as we shall see.

Interest among designers, and in particular Buontalenti and Aleòtti, turned to a second ancient writer, who like Vitruvius could also be described as a 'technologist'. This is Hero of Alexandria (in Greek: Heron), who will play a central part in what follows. Even less is known about Hero than about Vitruvius. He lived in the first century AD and worked in Alexandria, where he probably taught and studied in that city's far-famed Museum and Library, the ancient equivalent of today's advanced research centres. His best-known work is the *Pneumatics*, which despite the title is largely devoted to ingenious and entertaining devices, some of which operated automatically. These provided models for the automaton figures of humans and animals that populated the garden grottoes designed by Buontalenti and Aleòtti. Both men had translations of the *Pneumatics* made into Italian.

Hero wrote another book, much less well known, *On Automata-Making*. There was no English translation until the 1990s. The contents of both the *Pneumatics* and *On Automata-Making* are summarised here in Chapter 3. The automaton book describes the construction of two miniature theatres that put on elaborate performances without human intervention. One theatre was mobile and propelled itself along on wheels. The other was fixed in place, and was more complex. It had a proscenium arch with doors that opened onto a series of scenes, in which figures of men and gods moved in front of mobile scenery. It was thus quite unlike the classical open-air theatre; but it does bear close similarities to both the form and the machinery of the new Italian theatres of the late sixteenth century. I make the argument that Aleòtti and Buontalenti must have read *On Automata-Making*, and that Hero's importance for Baroque theatrical machinery – which has previously been little appreciated – was crucial.

Notes

1 *The Diary of John Evelyn*, ed. E. S. De Beer, 6 vols (Oxford: Clarendon Press, 1955), see vol. 2, p. 29. Besides the *Diary*, more biographical details are given in Gillian Darley, *John Evelyn: Living for Ingenuity* (New Haven, CT, and London: Yale University Press, 2006), and Geoffrey Keynes, *John Evelyn: A Study in Bibliophily* (Cambridge: Cambridge University Press, 1937), pp. 4–8.

2 Esmond de Beer, editor of the *Diary*, explains how Evelyn actually wrote up his experiences some decades afterwards, using notes, almanac entries and letters. De Beer also discovered that for his accounts of sights, buildings and works of art Evelyn drew heavily in many places on guides by other authors. This would account for their often summary nature. We can imagine that for the reminiscences of popular entertainments, however, he would have relied on his own more vivid memories. In some cases, for instance theatrical performances, details given in the *Diary* can be checked from other sources, as noted below.

3 Evelyn, *Diary*, vol. 2, p. 230. 'Dutch' could mean German, referring to Kircher. De Beer questions whether Evelyn is conflating accounts of two buildings here: the Casa Professa of the Jesuits, and the Collegio Romano.

4 Evelyn, *Diary*, vol. 2, p. 392, 5 May 1645.

5 Evelyn, *Diary,* vol. 2, p. 396. The model was designed by Pirro Ligorio.

6 Evelyn, *Diary*, vol. 2, p. 396.

7 Evelyn, *Diary*, vol. 2, pp. 449–50. 'My Lord Bruce' was Robert Bruce, second Earl of Elgin. *Hercules in Lydia* had a libretto by M. Bisaccioni and music by G. Rovetta, and was staged at the Teatro Novissimo, possibly with sets by Giacomo Torelli: see Per Bjurström, *Giacomo Torelli and Baroque Stage Design* (Stockholm: Almqvist and Wiksell, 1961), pp. 96–7. Evelyn counted the appearance of flying machines as 'scene changes'. Evelyn also saw Palladio's Teatro Olimpico in Vicenza, 'being of that kind the most perfect now standing'.

8 Roy C. Strong, *The Renaissance Garden in England* (London: Thames and Hudson, 1979), p. 75.

9 Alan St H. Brock, *A History of Fireworks* (London: George H. Harrap, 1949), pp. 218–19. On the other hand, according to Florio's 1611 Italian–English *Dictionary*, *girandola* means 'a long tedious flim flam story, an idle discourse'.

10 Jean Jacquot (ed.), *Les Fêtes de la Renaissance*, 3 vols (Paris: Editions du Centre Nationale de la Recherche Scientifique, 1973–5). See also J. R. Mulryne and E. Goldring (eds), *Court Festivals of the European Renaissance: Art, Politics and Performance* (Aldershot: Ashgate, 2002).

11 Roy Strong, *Art and Power*, 2nd edn (Woodbridge: Boydell and Brewer, 1984) gives a panoramic overview of Renaissance festivals as seen by their audiences, including the Medici entertainments in Florence. Claudia Lazzaro does the same for *The Italian Renaissance Garden* (New Haven, CT: Yale University Press, 1990). More of the 'audience-side' literature is cited below.

12 See John Shearman, *Mannerism* (Harmondsworth: Penguin Books, 1967). Eugenio Battisti also explores the spirit of Mannerism in the context of what he calls the 'Anti-Renaissance' in *L'Antirinascimento* (Milan: Feltrinelli, 1962), an eccentric and controversial book that among many other subjects covers automata and the gardens at Pratolino. Battisti focuses on the Gothic, grotesque, alchemical and 'non-classical' strands in sixteenth-century Italian art.

13 Vitruvius, *De Architectura* [*The Ten Books on Architecture*], probably written c.20 BC, trans. Ingrid D. Rowland (Cambridge: Cambridge University Press, 1999). Rowland (pp. 2–7) gives a brief biography of Vitruvius, sometimes known as Marcus Vitruvius Pollo, although there is doubt about the first and last names.

14 G. Sulpizio, *L. Victruvii* [*sic.*] *Pollionis ad Cesarem Augustum de Architectura* (Rome: 1486–7). The first Italian edition was C. Cesariano, *Di Lucio Vitruvio Pollione de architectura libri dece traducti de latino in vulgare affigurati* (Como: G. Da Ponte, 1521). In the sixteenth and seventeenth centuries many more editions of the *Ten Books* were published in several languages and countries: see Philip Stinson, 'Vitruvius', in Christine Walde (ed.), *Die Rezeption der antiken Literatur; Kulturhistorisches Werklexicon* (Stuttgart: J. B. Metzler, 2010), pp. 1132–8.

Part I
The machine in the theatre

1 Changing the scenes

A medieval tradition of religious plays, performed out of doors or in churches, continued into the Renaissance. At the same time there was a revival in Italy of classical drama, and a recreation and adaptation of the ancient theatre building, as understood above all from the writings of Vitruvius. These two then gave way in the sixteenth century to a wholly new kind of entertainment, the *intermezzi*, offered between the acts of conventional comedies: extraordinarily lavish productions put on in princely courts for weddings and other great occasions of state.[1] These were the places where modern stage machinery was developed.

The revival of ancient plays

In the mid-fifteenth century humanist scholars began to print the comedies of the old Roman playwrights Plautus and Terence, and the tragedies of the ancient Greek theatre. Learned academies were formed to study the texts and put on performances. At first the venues were typically large rooms or temporary structures.[2] Later, ancient theatres were faithfully reconstructed.

There were many developments in the design of theatres in the five centuries between the emergence of classical Greek drama in the great days of Aeschylus, Sophocles and Euripides, and the time of Vitruvius.[3] Certain generic features remained essentially unaltered, however. The auditorium or *theatron* consisted of raked seating, generally in a semi-circular or horseshoe arrangement. At the centre of the seats was the *orchestra*, a flat, usually circular floor where members of the *chorus* played, sang and danced. Behind the *orchestra* was the *skene* building.

There were doors in the *skene* through which actors entered and left the stage. Both actors and audience could also enter around the ends of the building.

The *skene* was the part of the theatre that changed most over time. In the fifth century it was a temporary one-storey structure. From the fourth century it was built of stone on two storeys, and an open single-storey arcade was added in front, the *proskenion*. This may have served on occasion to present interior scenes. The action moved from the *orchestra* to the area immediately in front of the *skene*, with the flat roof of the *proskenion* providing a second raised stage. Actors playing the parts of gods and goddesses appeared on this upper level. In later Roman theatres the *skene* (the *frons scenae* in Latin) became architecturally yet more elaborate, on two or more storeys, decorated with niches, thin columns and pediments, providing a decorative backdrop to the action.

Medieval religious plays were performed in front of fixed scenic backgrounds. If several settings were needed, these could be all presented in schematic form at once, side by side, and the audience moved from scene to scene. Otherwise specific locations could be conjured up with a few portable properties – an altar, a painted cut-out rock, maybe a tree in a pot. Revived classical dramas also had fixed sets. From the beginning of the sixteenth century, scenes were depicted in perspective, using the techniques introduced into painting a hundred years earlier by the architect Filippo Brunelleschi and several painters, and first described in writing by Leon Battista Alberti.[4] (Vitruvius's remarks on the use of perspective in the scenery of the ancient theatre are extremely brief and cryptic,[5] and he explains no method of geometrical construction; so the mathematical techniques had to be rediscovered or reinvented in the Renaissance.)

Stage scenery in perspective

It is difficult to know just from verbal descriptions or even drawings quite what role perspective first played in set design. In 1508 the designer Pellegrino da San Daniele painted a set in Ferrara for a comedy *La Cassaria* by the poet Ariosto. A member of the audience wrote that it showed a view of a town 'with houses, churches, belfries and gardens, such that one could never tire of looking at it'.[6] However, it seems this was just a flat picture in perspective used as a backdrop, perhaps with painted wings at the sides.

It was only gradually that perspective sets came to be built in three dimensions, like their modern counterparts, so as to create not just backdrops, but enclosed spaces within which the action unfolded. A scurrilous comedy called *La Calandria* by Bernardo Dovizi (soon to become Cardinal Bibbiena) was presented at the court of Urbino in 1513. This had what appears to have been one of the first three-dimensional sets, designed by the painter Girolamo Genga. Baldassare Castiglione, author of the famous guide to manners *The Book of the Courtier*, directed the performance and wrote a description. Like *La Cassaria*, the play had an urban setting, in this case a view of Rome. However, Castiglione is explicit that the palaces, churches and streets were now 'all in relief, but still assisted by excellent painting and very good perspective'.[7] A triumphal arch and an octagonal temple were built out solid in the centre of the stage.

La Calandria was given again in the Vatican in 1514 in front of Pope Leo X, and yet again in 1520 with scenery designed by the architect and painter Baldassare Peruzzi. The artist and biographer Giorgio Vasari describes this set in his *Life* of Peruzzi. 'It cannot be imagined how he, in such a narrow place, made room for so many streets, palaces and various temples, balconies and cornices, so well made that they seemed not imitations but very real and the piazza not painted and little but real and very large.'[8] Peruzzi lit the scene from inside. The effect, in Vasari's words, surpassed any previous production in 'magnificence and sumptuousness'.

Figure 1.1 reproduces what some historians believe to be a design by Peruzzi for *La Calandria*, a view of Rome with a medley of recognisable monuments clustered in the background (but with little respect for their real locations): part of the Colosseum, Trajan's Column, the obelisk now in St Peter's Square and the Castel Sant'Angelo.[9] The repetition of references in written accounts to 'streets', 'towers' and 'houses' suggest that this design for *La Calandria* echoes earlier scenery, and that all resembled the conventional architectural settings of some fifteenth-century paintings. Both paintings and sets had buildings at the sides, central squares and in some cases streets leading into the distance, closed with arches or opening onto the countryside.

In a painting, the central space is where the action of what Alberti calls an *istoria* – a harmonious composition telling a mythological, historical or Christian story – is depicted. On the stage it is of course where the main action of the drama is played out. Actors can enter and leave between the houses at the sides. The theatre historian Elena Povoledo suggests that the nearest buildings in the scene for *La Calandria*

Figure 1.1 Set design, possibly for a production of the comedy *La Calandria* in Rome in 1520, believed by some historians to be by Baldassare Peruzzi. Gabinetto Disegni e Stampe, Gallerie degli Uffizi, Florence.

of Figure 1.1 would have been 'practicable': that is to say, they would have been built with real openings and solid columns and upper floors, so that actors could appear on the balconies and indoors.[10]

'Accelerated perspective' sets by Sebastiano Serlio and Baldassare Peruzzi

The first written description of how to set up perspective scenery on stage is to be found in the second of the architect Sebastiano Serlio's multi-volume work *On Architecture*.[11] From what he says, Serlio was in a hurry writing his sections on the theatre: 'So many things come to my mind, that I could have made a much larger book.' But he still gives a full account, with drawings, of a design for a wooden theatre similar to one that he had built in Vicenza, 'the largest of our times'. This was a temporary construction in the courtyard of the Porto Palace for a production in 1539 featuring 'chariots, elephants, and diverse morris dances'.[12] Figure 1.2 shows a cross-section and plan of the building.[13] The layout follows the design of the ancient theatre, with raked seating in an arc, surrounding a flat semicircular *orchestra*. The stage is raised. The front part of the stage is flat, but the rear part slopes upwards to the back wall.

On the sloping stage we see a tapered grid of floor tiles, with heavy black lines marking the bases of scenic flats representing buildings. Some of these flats face front. Others recede towards the back of the stage. Each building is constructed from two flats, joined at an angle. Seen from the auditorium, the flats could make up a setting such as the 'Comic Scene', also reproduced by Serlio in his book (Figure 1.3).[14] This is Serlio's imagining of a type of set described in words (but not illustrated) by Vitruvius, suitable for the comedies of the ancient theatre.

Figure 1.4 shows a model that was built by Gregorio Astengo and myself from cut-out pieces of Serlio's engraving of the Comic Scene, erected on his Vicenza stage.[15] The stage was shallow, as we see from his plan, but the visual effect created by the scenery is of a deeper space. This is a type of optical illusion known as accelerated perspective, produced by the fact that the stage slopes upward, and the buildings are compressed in depth and tapered as they recede.

Serlio was not the inventor of this illusion. It was first introduced – probably for *La Calandria* in 1520 – by Baldassare Peruzzi, for whom Serlio worked in Rome in the 1510s and 1520s.[16] Two working drawings by Peruzzi survive for a performance of a play called *Le Bacchidi* by the Roman author Plautus, put on in Rome in 1531.[17] These are the earliest known designs for a set constructed in accelerated perspective. Once again there is a central piazza surrounded by buildings, from which a narrow street leads into the distance, all set out on a sloping stage. Figure 1.5 is a view, as from the centre of the auditorium, of a model made from Peruzzi's drawings by Gregorio Astengo. There is no elevation by Peruzzi of the buildings on the left, so we have improvised here, guided by the plan and by Peruzzi's annotations. He mentions a 'Temple of Apollo', so Astengo has built a schematic temple, the feet of whose columns appear in the plan as thin ellipses.

As with Serlio's Comic Scene, we are deceived into thinking that the fictive space is much deeper than the actual stage. The buildings do not look compressed in depth. The columns of the temple seem to be truly cylindrical. One can imagine that the visual impact would

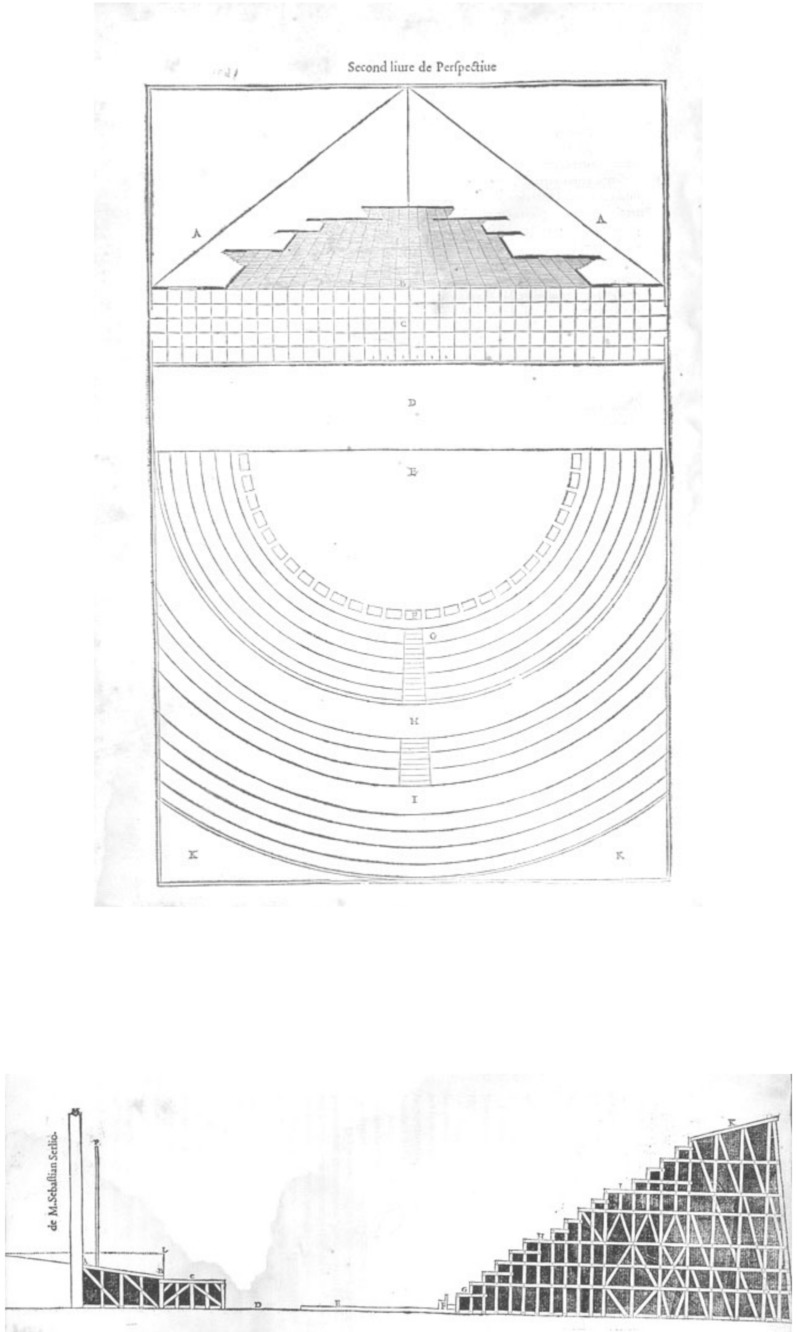

Figure 1.2 Plan and cross-section of Sebastiano Serlio's temporary wooden theatre in Vicenza of 1539. From *The Second Book of Perspective*, Paris, 1545.

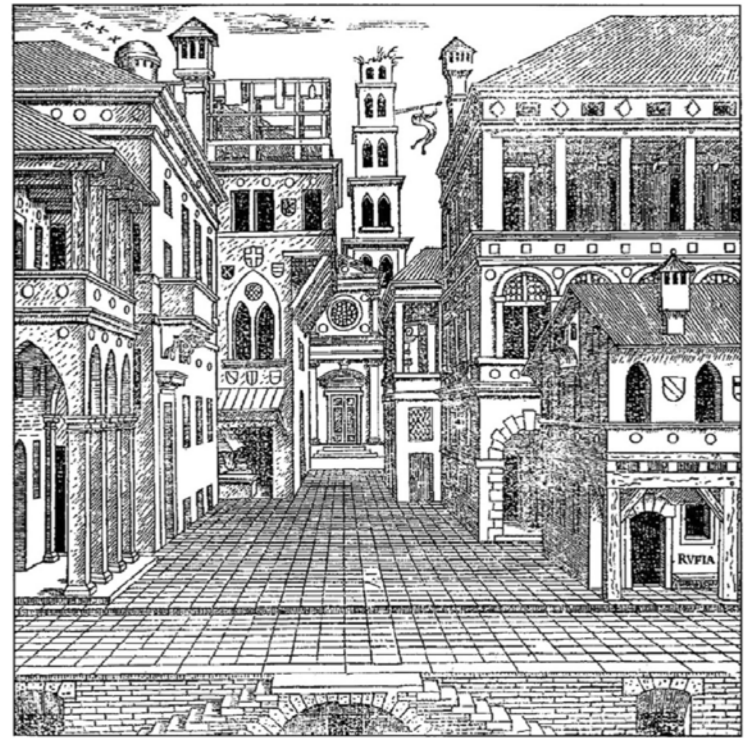

Figure 1.3 Serlio's version of Vitruvius's Comic Scene. From *The Second Book of Perspective*, Paris, 1545.

be further enhanced by painting the set, perhaps depicting a faraway landscape on the back shutter and introducing painted shadows.

A member of the audience for *Le Bacchidi* on 4 June 1531, Marco Cadamosto da Lodi, recorded his reactions. The scene was set in Athens:

> beautiful and more splendid than anything I ever saw, made with such great artifice that the eyes of the spectators were almost deceived. Here was a temple supported by columns, all rounded and without other walls, with a roof which being flat, appeared all in relief, and this temple looked as far away as a strong man might throw a stone.[18]

Notice how Cadamosto refers to the temple as 'rounded', perhaps alluding to the appearance of the columns despite the fact that these are in reality flattened; and how he praises the highly convincing nature of

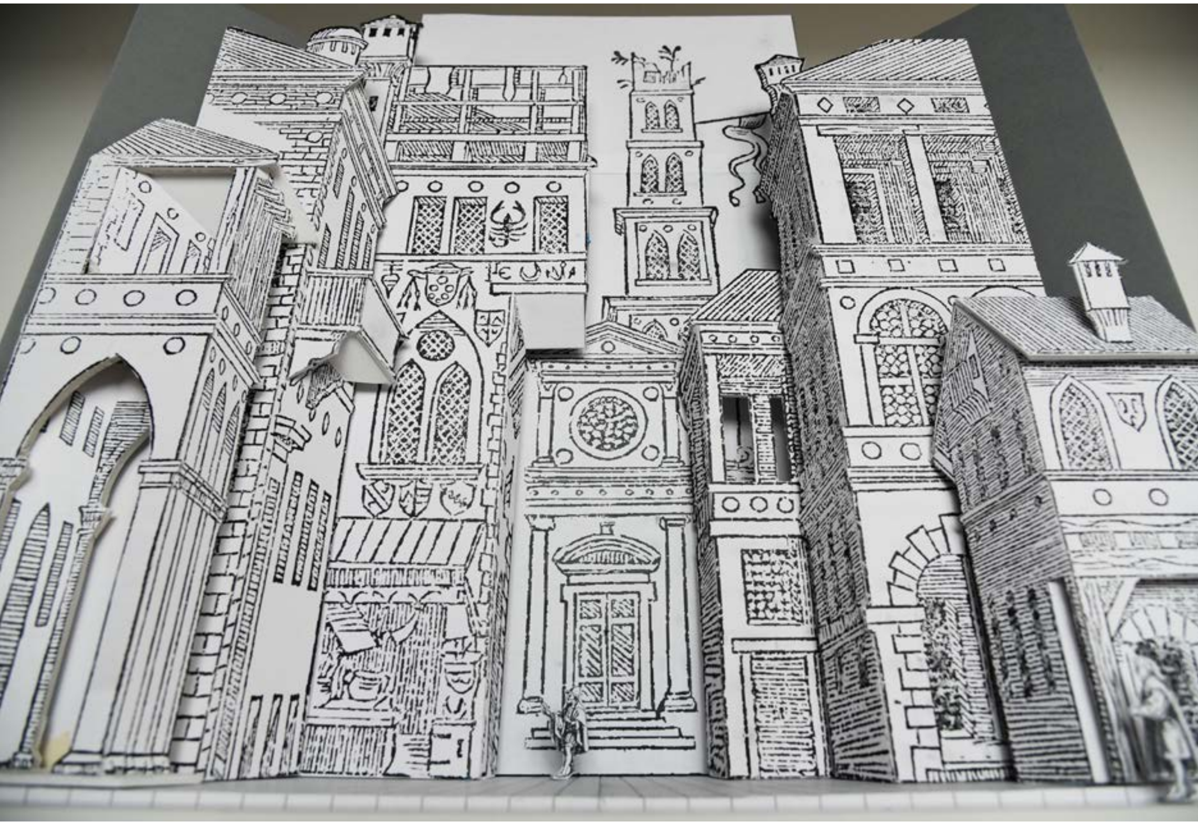

Figure 1.4 Model built by Gregorio Astengo and the author, of Serlio's Comic Scene on the stage of his Vicenza theatre. This photo approximates the view obtained by the most honoured guests, at the centre of the auditorium. Photo: Gregorio Astengo.

the perspective effects, while repeating his appreciation that the illusion is all achieved by 'artifice'.

Because of the wide circulation and influence of his book, this kind of perspective set has become known as 'the Serlian scene'. Peruzzi, so far as we know, wrote nothing on the subject; but there is arguably a much stronger case for using the word 'Peruzzian'. Whether Serlian or Peruzzian, scenery in accelerated perspective became general in the Italian and European theatre over the following two centuries. The best-known example still standing is that most accomplished of all Renaissance theatres, Andrea Palladio's Teatro Olimpico in Vicenza, completed in 1585.[19] Here there are seven miniature streets leading away from the stage in different directions, all built in

Figure 1.5 Model of Baldassare Peruzzi's set for *Le Bacchidi*, built by Gregorio Astengo. The buildings on the left are conjectural, since no elevation drawing by Peruzzi survives. However, Peruzzi's plan mentions a Temple of Apollo and shows the bases of its columns. The model is seen frontally, from a position in the centre of the auditorium, to illustrate the illusion of depth created by the accelerated perspective. V marks the position of the vanishing point of the picture that would have been painted on the backdrop. Photo: Gregorio Astengo.

accelerated perspective, with floors that slope up and buildings that are compressed in depth. These were probably designed by Palladio's pupil Vincenzo Scamozzi, who took over when Palladio died in 1580.

Scamozzi went on to build a theatre himself in the small town of Sabbioneta near Parma, finished in 1588. This also survives. Figure 1.6 shows Scamozzi's plan and side view of the building, which like the Teatro Olimpico follows classical precedent in its sloped seating and flat *orchestra*. The set with its houses was demolished in the seventeenth century but re-erected – although left unpainted – in the twentieth century. The audience looks down a single street.

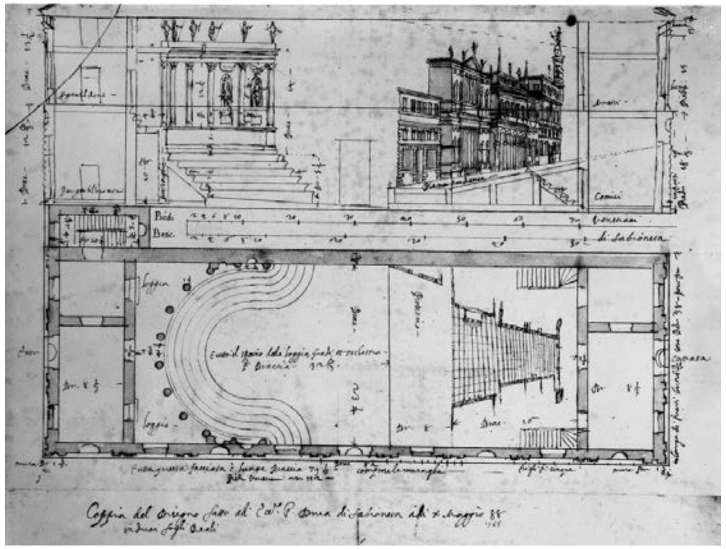

Figure 1.6 Plan and side view of the theatre and fixed scenery at Sabbioneta designed by Vincenzo Scamozzi and completed in 1588. The set represents a receding street, filling the whole stage. Gabinetto Disegni e Stampe, Gallerie degli Uffizi, Florence.

Detailed instructions for building Serlian/Peruzzian sets are given in manuals of stagecraft and theatre design published in the seventeenth century.[20] For all their beauty and ingenuity, however, they had one fatal weakness. They were inflexible, almost impossible to change between scenes (although methods were attempted, as we shall see), so that they had to stand unaltered throughout entire performances. Meanwhile the new comedies of the sixteenth century, and especially the *intermezzi* associated with these plays, called for many changes of realistic or fantastic location. These in turn required machinery for replacing entire scenes smoothly and at speed. This is a book about machines, so here is where we embark in earnest on the history of mobile sets and stage machinery.

The Florentine *intermezzi*

Intermedi or *intermezzi* were first introduced in Ferrara and Urbino in around 1500 and were taken up with the most enthusiasm at the court of the Medici in Florence from the late 1530s. Musical interludes with singing and dancing were inserted between the acts of conventional comedies. These entertainments became ever more spectacular and began to take over the evening.[21] Audiences sat impatiently through the dramas waiting for the entr'actes. The eyewitness *Descriptions* that were always published afterwards lavished all their attention on the *intermezzi* and barely mentioned the plays.[22] The form was also popular at the Gonzaga court at Mantua and the Farnese court at Parma, and the *intermezzi* became an opportunity for artistic rivalry, designed to impress important guests and visiting delegations. The Florentine shows were generally the most magnificent: at their peak, they reached levels of extravagance and splendour that have rarely been equalled in theatrical history.

Such entertainments were mounted only every few years, to celebrate dynastic weddings or the visits of foreign monarchs, along with pageants, jousts, fireworks and banquets. A play with its *intermezzi* would be performed just once or twice. Despite this, preparations went on for months or even years in advance, and prodigious amounts of money were spent. In 1585 Grand Duke Francesco I of Florence lavished 25,000 scudi on a production of the comedy *L'Amico Fido* [*The Faithful Friend*] and its *intermezzi*, at a time when the average income of Italians was around 15 scudi a year.[23] Four hundred craftsmen were employed on this occasion. Typically the actors and stagehands were also numbered in the hundreds.

This production marked the inauguration of the Uffizi Theatre in Florence, designed by Giorgio Vasari, chief architect to the Medici court. (The theatre was created inside the Palazzo Uffizi but no longer exists.) Figure 1.7 reproduces an engraving by Jacques Callot of a production in 1617 in the same space, as remodelled by Bernardo Buontalenti.[24] The stepped seating was arranged around three sides of a large flat open floor, like a rectangular version of the ancient *orchestra*. There was space for some three thousand spectators. In many of the *intermezzi* – as here – performers descended periodically from the stage and were joined in the dancing by the Grand Duke and his guests.

Bernardo Buontalenti, who followed Vasari as the Medici court's architect and engineer, was orphaned as a boy and was adopted into the household of Francesco's father, Duke Cosimo I.[25] He worked for the family all his life, becoming Francesco's tutor and in due course his close friend. He studied painting and architecture under Vasari, who included an account of Buontalenti's early years in his *Lives of the Artists*.[26] One intriguing detail mentioned by Vasari, foreshadowing some of his later theatrical activities, is that Buontalenti devised 'ingenious fantasies of his own of cords for descending weights, of windlasses, and of lines'.

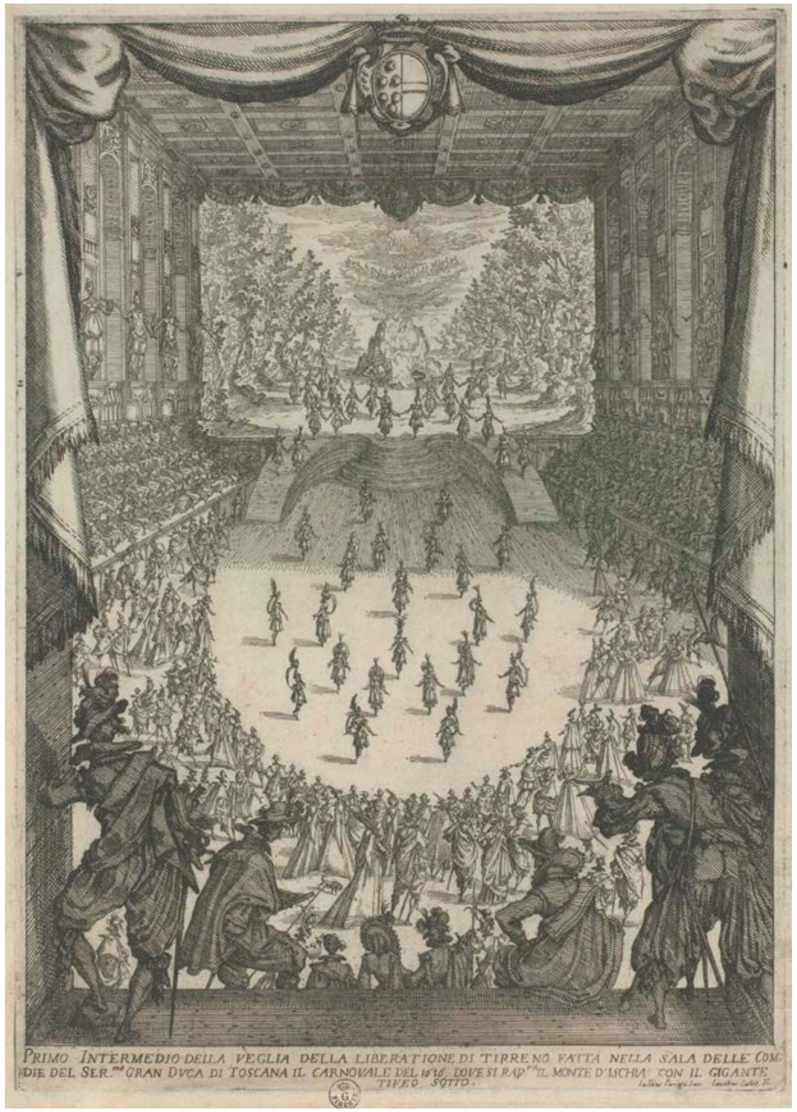

Figure 1.7 The Uffizi Theatre in Florence designed by Giorgio Vasari and Bernardo Buontalenti, opened in 1586. This engraving by Jacques Callot shows a performance in 1617 for the wedding of Ferdinando Gonzaga, Duke of Mantua, to Caterina de' Medici. Gabinetto Disegni e Stampe, Gallerie degli Uffizi, Florence.

He worked on fortifications. He built villas and laid out the gardens at Pratolino, completed in the late 1580s, for Francesco and his mistress Bianca Cappello. At the same time he was designing sets, machines and costumes for the *intermezzi* at the Uffizi Theatre. Oreste Trabucco describes Buontalenti as a 'personification of the combination of science with caprice'.[27]

The early Florentine *intermezzi* consisted of separate sketches or playlets and lacked anything so coherent as an overall plot. In 1589, however, Count Giovanni Bardi provided for the first time a unified theme – the place of music in the lives of gods and men – for the *intermezzi* that accompanied *La Pellegrina* [*The Woman Pilgrim*], designed by Buontalenti.[28] On other occasions subjects were drawn from classical myths and the poetry of Dante and Ariosto. One favourite source was the Latin poet Ovid's collection of mythological stories, the *Metamorphoses*, in which immortals, men and animals are transformed one into another. Characters might include the Olympian gods; personifications of rivers, cities, the weather or the four seasons; figures representing virtues and vices; and choruses of nymphs, satyrs, angels, devils, bacchantes, shepherds and shepherdesses.

The modern 'superheroes' of comic books and films are many of them based explicitly on characters from ancient mythology. In turn, we can see the classical gods who appeared in the *intermezzi* as anticipating today's superheroes. They too had their distinctive costumes and carried their characteristic identifying equipment and weapons. They had bands of followers. Many possessed supernatural powers. They travelled in their own vehicles on land, through the sea and above all through the sky. They were perpetually warring or getting involved in erotic entanglements. Most would have been instantly recognisable to Renaissance audiences.

A number of settings featured repeatedly. Heavenly scenes were played out on clouds above the stage (Figure 1.8), and there was much coming and going in airborne chariots. The nine Muses could be found playing their instruments on either Mount Helicon or Mount Parnassus (their twin homes), often in the company of Apollo, Dionysus and the winged horse Pegasus. In gardens or countryside scenes, bare plants and trees might come into leaf and blossom in full view. Neptune would appear in the sea in his horse-drawn seashell boat accompanied by Tritons (mermen), sea nymphs and perhaps dolphins and whales. The City of Dis, which occupied the sixth to the ninth circles of Hell in Dante's *Divine Comedy*, was represented with ruined buildings inhabited by demons, from which smoke and fire poured, surrounded

Figure 1.8 Set design by Buontalenti for the first *intermezzo* for *La Pellegrina*, 1589; engraving by Agostino Caracci from Buontalenti's original drawing. Wikimedia Commons: La pellegrina 1589 – Intermedio 1 – L'armonia delle sfere.

by muddy rivers and gloomy swamps. Volcanoes provided more opportunities for incendiary effects.

The conventional drama was played typically in front of just one or two settings, including realistic perspective views of Florence, Pisa or Rome of the kind illustrated in Figure 1.1. Meanwhile the *intermezzi* had many changes of wholly imaginary and exotic scene. Figure 1.9 is an engraving by Epifanio d'Alfiano after Buontalenti's set design for the fourth *intermezzo* of *La Pellegrina*.[29] This is not a 'snapshot'. As was often the practice with such commemorative images, d'Alfiano has combined several dramatic moments into one picture. A sorceress descends from the sky in a richly jewelled car drawn by flying dragons. Later the scene is 'in an instant … covered with rocks, chasms and caves filled with fire'. A city burns in the distance. The floor of the stage opens revealing Hell, from which bands of Furies and frightful devils emerge.

Figure 1.9 Set design by Buontalenti for the fourth *intermezzo* for *La Pellegrina*, 1589; engraving by Epifanio d'Alfiano, showing several dramatic moments in a composite view. Ministero per I Beni e le Attività Culturali e per il Turismo/Biblioteca Marucelliana di Firenze.

Figure 1.10 is another composite image, an engraving by Remigio Cantagallina showing the set for the fourth *intermezzo* of *Il Giudizio di Paride* [*The Judgement of Paris*].[30] This production was mounted in Florence in 1608 and was designed by Giulio Parigi, Buontalenti's successor as Medici stage designer. The explorer Amerigo Vespucci was a Florentine. His ship – behind the rocks at the right – is just arriving off the new continent of America, whose shores are covered with unknown vegetation, mostly palm trees it appears, inhabited by exotic animals. The female figure on the central rock is La Tranquillità (Lady Calm) accompanied by a swan. Several whales are in evidence, although Cantagallina has missed out the parrots that flew across the scene. Again there were Immortals observing from their clouds, not shown by Cantagallina.

Much time and expense were devoted to the preparation of costumes. The cultural historian Aby Warburg made a special study of the costume designs for the Florence *intermezzi* of 1589, when

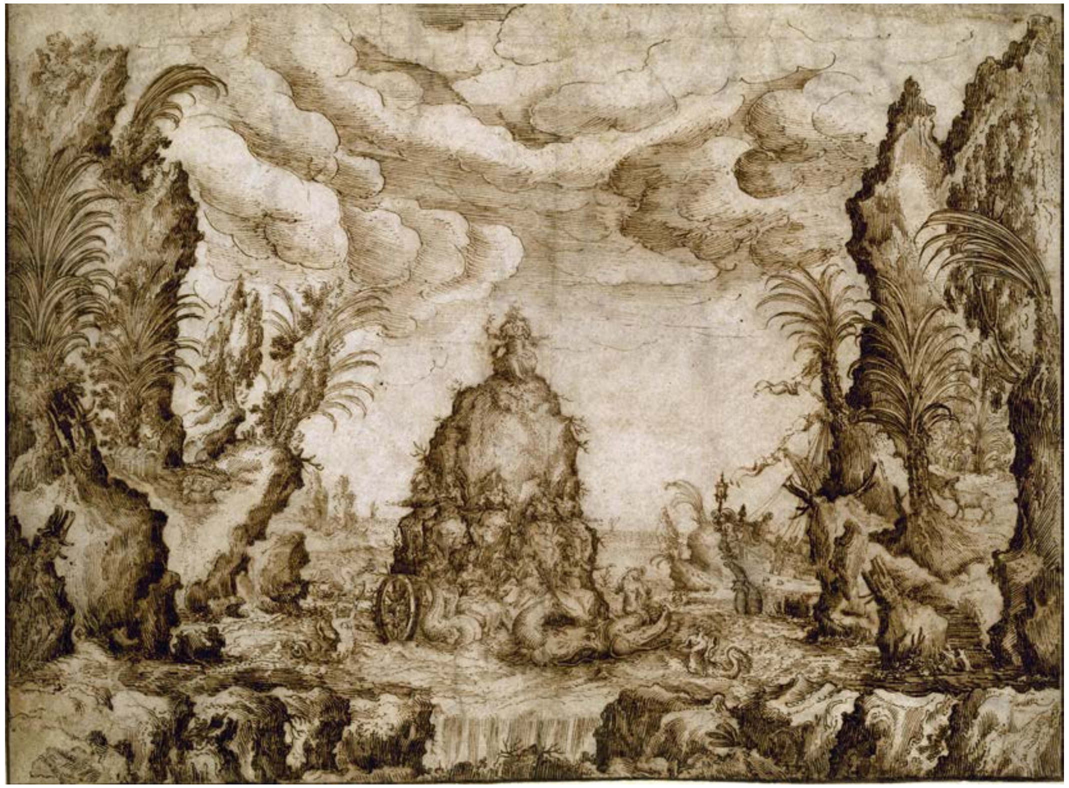

Figure 1.10 Set design by Giulio Parigi for the fourth *intermezzo* for *Il Giudizio di Paride* in 1608; engraving by Remigio Cantagallina. The setting is the coast of America. The Florentine explorer Amerigo Vespucci has arrived in the ship at the right. By kind permission of the National Art Library, Victoria and Albert Museum, London.

La Pellegrina was presented, and two master tailors supervised the work of 50 assistants.[31] Warburg published many of Buontalenti's drawings for the first time. The costumes illustrated in Figure 1.11 were for the first *intermezzo*, whose theme was the Harmony of the Spheres. From left to right, the four figures are the gods and goddesses Diana, Venus, Mars and Saturn. Diana the huntress has her bow and arrow, Mars his armour and thunderbolts, Saturn his scythe, while Venus carries a miniature Cupid. At their feet are animals of the Zodiac: crab, bull, scorpion and ram.

The 'celestial siren' of Figure 1.12 featured in this same *intermezzo*. Her deep blue outfit, trimmed with feathers, and her halo of stars signal the fact that her home is in the skies. The half-submerged sea nymph of Figure 1.13 appeared in the fifth *intermezzo*: her clothes are assembled

Figure 1.11 Costume designs for gods and goddesses by Buontalenti for the first *intermezzo* for *La Pellegrina*, 1589: from left to right, Diana, Venus, Mars and Saturn. By kind permission of the Biblioteca Nazionale Centrale, Firenze.

from seashells and coral. Buontalenti has added notes about materials, ornaments and colours. There was also much female and some male nudity in the *intermezzi*. Venus is dressed in Figure 1.11; but in other productions she and her retinue appeared either in tightly fitting flesh-tinted clothing or wholly naked, as did Cupid and his *amoretti* (the latter played by children).

Other characters besides the Olympian gods were in theory identifiable by their costumes and the props they carried. In many cases this was unproblematic. An actress playing Fame in 1608 had a dress covered in eyes, ears and tongues, and carried her traditional trumpet. In 1539 Aurora, the Goddess of Dawn, wore a 'transparent and luminous costume of red flowered silk with gold and silver stripes'.[32]

The representation of abstract concepts or human emotions such as Fear, Joy or Hope could on the other hand cause bewilderment in the audience. One character wore a hippopotamus head to represent Ingratitude in an *intermezzo* of 1586. An actor playing Thought in a production in 1565, for which Giorgio Vasari was the designer, wore a headband of peach stones 'serrated by intersecting canals' (did these perhaps signify headaches?) and a suit worked with thorns, their points facing inwards. These were to be understood as thoughts tormenting

Figure 1.12 Costume design by Buontalenti for a celestial siren who appeared in the first *intermezzo* for *La Pellegrina*, 1589. By kind permission of the Biblioteca Nazionale Centrale, Firenze.

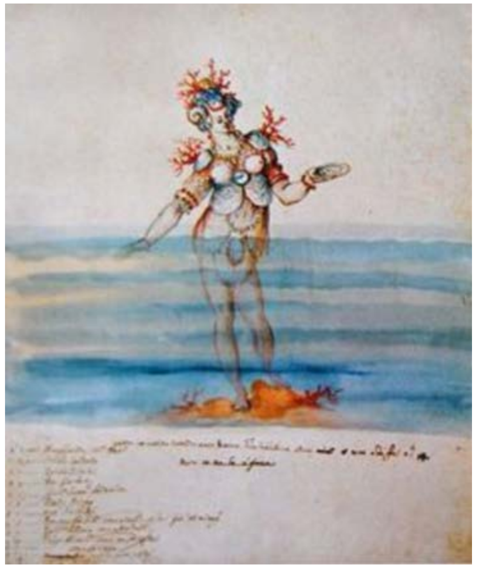

Figure 1.13 Costume design by Buontalenti for a sea nymph, who appeared in the fifth *intermezzo* for *La Pellegrina*, 1589. Her costume is made of seashells and coral. By kind permission of the Biblioteca Nazionale Centrale, Firenze.

the wearer.[33] Many such costume designs – not just for plays, but for processions and other court festivals – were derived from illustrated catalogues of emblems, myths and symbols, of which several were published from the mid-sixteenth century.[34]

Other costumes transformed themselves in full view of the audience. In one of the *intermezzi* for *La Vedova* [*The Widow*] in 1569, Zeus turned a number of peasants into frogs. It was Buontalenti who devised the costumes in question, working at this point as assistant to the set designer Baldassare Lanci. The frogs 'hopped into the water, croaking and gurgling a song which transported the spectators to their spiritual homeland somewhere between Ovid and Aristophanes'.[35] (In Aristophanes' play the chorus of *Frogs* sing 'Brekekekex-koax-koax'.) Buontalenti achieved a similar Ovidian metamorphosis in 1589 when the Pierides – nine mythical daughters of King Pieros of Macedonia famed for their singing – were changed into magpies.[36]

There is a wealth of surviving graphical material for the Florentine *intermezzi* relating to the costumes and sets – as they appeared to the audience – of which the examples here are just a small selection. On the other hand, up until 2020 it had been thought that there were no drawings from the sixteenth century of the backstage arrangements of the various theatres in question, nor of their machinery. (This situation has now changed, and some drawings have been found, but not made public: see the note following the Reprise at the end of the book.) We are therefore dependent for our understanding of the technology involved on a memorandum written by an engineer Girolamo Ser Jacopi who worked on the *intermezzi* of 1589, on the verbal testimony of a few audience members and on backwards inferences from technical books published in the following century. One thing that audiences of the *intermezzi* remarked on several occasions was the speed and smoothness with which the scenes were changed.

The renaissance of the *periaktos*

It appears that this was done, at least in the early *intermezzi*, with machinery borrowed from the classical Greek theatre. There was some scenic decoration on the ancient stage, although evidence as to its character is sparse. *Katablemata* were pictures painted on cloth that were thrown over frames and could be changed rapidly. They could be attached to freestanding wooden structures called *periaktoi* at either end of the *skene* building.[37] The *periaktos* was a triangular prism

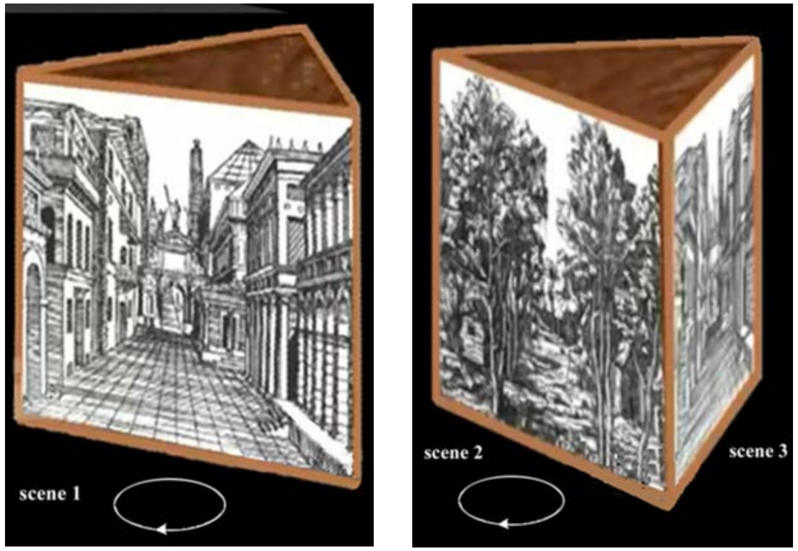

Figure 1.14 The *periaktos*: a triangular prism that can be rotated on its post. Three scenic pictures painted on cloth (*katablemata*) are attached to the three sides and can be displayed in turn. Drawing by Esther M. Zimmer Lederberg from the estherlederberg.com website. (For illustration Lederberg has shown Serlio's three Vitruvian scenes, Comic, Tragic and Satyric, on the three faces – although these were designs for complete sets, and the three scenes would not all be presented in the same drama.)

standing on end that could be turned on a vertical post (Figure 1.14). It had three painted cloths, one on each face, which could be rotated towards the audience as required. In some ancient theatres it is still possible to see the holes in the stonework for the posts. Vitruvius refers in passing to *periaktoi*: 'when there is going to be a change of setting in a play, or the epiphany of a god in a clap of thunder, then these are rotated to change the appearance of the decoration on the exterior'.[38] It is possible that they might have been turned using ropes wound around their posts.

Another writer who provides more information is the Greek grammarian Julius Pollux, who lived in the second century AD, and compiled a dictionary called the *Onomasticon*.[39] The book is organised by themes, with one chapter on the theatre. There were, Pollux says, two *periaktoi*, one at either end of the stage: turning one signalled a move to a nearby place in the same city, while changing both indicated a complete change of locality. This suggests that they served more as pictorial symbols or 'graphical captions' than as parts of some overall illusionistic 'set'.

The *Onomasticon* was published in Greek in Venice in 1502 and several Italian translations followed. Because both Pollux and Vitruvius mentioned *periaktoi*, they were adapted to the Renaissance stage and used in many theatres. Entire sets were made from enlarged and elaborated versions of the device. Among the first indications of an interest among designers is an enigmatic sketch dating to around 1520 by Antonio da Sangallo the Younger, one of a large and distinguished family of Florentine architects.[40]

Sangallo mentions 'triangular machines' in notes and includes an enlarged view of a decorated triangular prism on a pivot. Another detail of a complete scene seems to show two *periaktoi* installed in 'houses' at each side of the stage, visible through windows or above the roofs. Although these may have presented pictures appropriate to the various settings of the drama, in the ancient manner, the prisms were clearly not integrated into the central part of the scene. What is unclear is whether Sangallo is sketching his understanding of classical scenery or is recording designs for some modern show.

On the other hand, there are written accounts of Italian productions of the mid-sixteenth century in which *periaktoi* were definitely used in practice. One key witness is Egnazio Danti, co-author with the architect Giacomo Barozzi da Vignola of *The Two Rules of Perspective Practice.*[41] In his short section on stage design, Danti reminisces about plays that he has seen, in which *periaktoi* were employed.

The first was a performance in the town of Castro in 1543. The design was by Aristotile da Sangallo, one of Antonio's uncles, and the scenery, Danti says, was 'changed twice'.[42] We might take this to imply that there were three scenes painted on the three sides of the prisms.[43] On the strength of these reports Aristotile has been credited with the re-creation of *periaktoi* on the Renaissance stage.[44] But the sources do not give much more away. How could the devices have been adapted to the new kind of stage? Renaissance architects including Palladio believed that in the Roman theatre *periaktoi* were placed behind the three entrance doors of the *scenae frons*. But in a perspective scene without such doors, where would the prisms have been placed? Were they set either side of the stage, as in Sangallo's sketch?

Baldassare Lanci designed scenes for a play called *I Fabii* presented in Florence in 1567. This was a Medici production with *intermezzi*, put on in a temporary theatre in the Palazzo Vecchio. The main set for the play depicted the Via Vacchereccia in the centre of Florence itself. The setting was changed for the fifth act to the straw weavers' quarter of the city. The official *Description* of the event says 'the scenic elements

Figure 1.15 Set design by Baldassare Lanci for the first scene of *La Vedova*, put on in Florence in 1569. According to Egnazio Danti and others, this scene was painted on *periaktoi*. Gabinetto Disegni e Stampe, Gallerie degli Uffizi, Florence.

were mounted on pivots and balanced so that a small child would have had no difficulty turning them around'.[45] The process of changing the scene was concealed momentarily behind a cloud that conveniently descended from the Heavens and then rose again. Nevertheless, it was agreed that this was a 'marvellous trick'.

Lanci painted something very similar for a performance of *La Vedova* two years later, put on in the same hall as *I Fabii*. The occasion was a state visit to Florence by Archduke Karl of Austria.[46] The play had two scenes. Figure 1.15 reproduces Lanci's drawing for the first scene. It shows another view of the city, including at the right the Palazzo Vecchio with Michelangelo's statue of David in front, and the cathedral with Brunelleschi's great dome rising in the background. After three acts, the scene changed to a rural landscape in Arcetri, just outside the city, with vineyards and country houses. Two other members of the audience besides Egnazio Danti describe the scenery as 'rotating' at this point.[47]

In *The Two Rules of Perspective*, Danti offers his idea as to how a stage set of this kind might have been constructed. He has a drawing

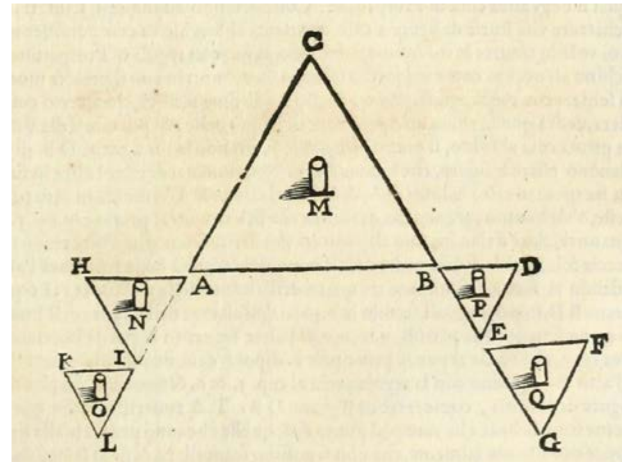

Figure 1.16 Diagram by Egnazio Danti from *The Two Rules of Perspective*, indicating how a complete set could be constructed from five *periaktoi*, one at the centre carrying the backdrops and four others at the sides serving as wings.

(Figure 1.16) showing the plan of an entire scenic background made up from five *periaktoi*.[48] These are built from wooden frames with canvas stretched over them. One large prism is used to provide the backdrops and other smaller prisms line the two sides of the stage. Danti shows four of these but says that there could be more. When all are rotated at once, an entire picture – for instance a city street – can be transformed instantly into another – say a country garden.

I see several drawbacks to this arrangement. The rear *periaktos* would have had to be very wide and would have taken up an excessive amount of space at the back of the stage. The American historian of stagecraft Orville Larson makes this point.[49] He takes the example of a production of *La Cofanaria* in Florence in 1565, for which each backdrop measured 9 metres by 13 metres. A triangular structure of this size would have been extraordinarily bulky and awkward to manoeuvre.

Another problem with Danti's scheme is there are no spaces between the prisms for actors to enter from the sides of the stage; and if there were, the audience would be able to catch glimpses, through the gaps, of backstage areas behind the scenes. Even if the prisms were touching when at rest, gaps would open up briefly between them as they were turned. By the early seventeenth century, when *periaktoi* are first described in manuals of stage design, all these difficulties have been taken care of. The scene is closed at the rear with a flat backdrop. And the *periaktoi* are given new shapes in plan.[50]

How rotating scenery worked

In 1638 the architect and stage designer Nicola Sabbattini published a *Manual for Constructing Theatrical Scenes and Machines*.[51] This gives technical instructions for building the various parts of the 'Serlian/ Peruzzian' scene: the sloped stage, the houses and the details of doors, windows, arches and balconies. It also explains the workings of revolving Renaissance scenery. Sabbattini's text is badly written and repetitive. The diagrams are crude and inconsistent. But the book goes into considerable detail about the methods actually employed in the late sixteenth and early seventeenth centuries. As the theatre historian John McDowell says, introducing his translation:

> The machines described in the *Pratica* [the *Manual*] were well-known and had long been used; in fact some were already out-of-date. The *Pratica* is a … handbook of Italian stage practice in the form of directions to an architect whose assignment is to turn a hall of state into a theatre, with auditorium and stage, along with scenery, machines, lighting and other effects. The study takes the reader backstage and reveals the secrets of the elaborate effects required for shows at the Italian ducal courts.[52]

Sabbattini's *periaktoi* are triangular in plan, like their ancient prototypes. But his triangles are isosceles: they have two long sides and one short side.[53] Only the two long sides would be shown to the audience. Sabbattini explains the mechanism by which each prism is turned (Figure 1.17). The *periaktos* sits on the stage: its pivot passes through a hole in the stage floor and rests in a socket. A rope is wound round the pivot, and the two ends are attached to windlasses, manned by two stagehands. The diameters of the axles are calculated such that a half turn of the first windlass spins the *periaktos* around, and a half turn on the other spins it back again.

As Sabbattini says, 'In this operation great care must be taken to have worthy and sincere men, since there is a danger of the many cords getting entangled and interfering with the smooth action.'[54] One general problem with mobile stage machinery in the days before radio headsets was timing: how to get many stagehands to act simultaneously at the precise moment. Sabbattini recommends that men be recruited who are able to take their cues from the music and dialogue.

A German architect Joseph Furttenbach wrote several treatises in which he too discussed stage design in detail, the first being

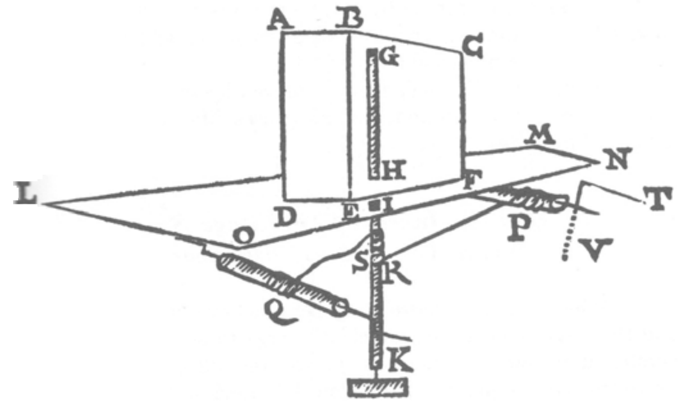

Figure 1.17 Nicola Sabbattini's design for a *periaktos* from his *Manual for Constructing Theatrical Scenes*. The prism itself *ABCDEF* has the shape of an isosceles triangle in plan, with two long sides and one short side. It is supported and turned on the rod *GK*, which passes through a hole in the stage floor *LMNO*. Two windlasses *P* and *Q* are used to turn the rod with ropes.

Civil Architecture of 1628. Later he repeated and elaborated similar material in *Recreational Architecture* of 1640, and again in a compilation of peculiar designs of many kinds, the *Noble Mirror of Art* of 1663.[55] From Furttenbach we learn the rationale for Sabbattini's elongated *periaktoi* – which Sabbattini does not explain – and how they were set out on stage.

Furttenbach spent ten years in Italy from 1610 and wrote a journal of his travels.[56] He saw several shows and became a protégé and pupil of Giulio Parigi, designer of the later Florentine *intermezzi*. From Parigi he must have learned many secrets of the trade. He took this knowledge of Italian methods back to Ulm in Germany, where he designed sets for a small number of productions, including a play put on in 1640 about Jonah and the Whale. There is nevertheless a wistful tone to Furttenbach's accounts of his own efforts, which – without comparable sponsors – could come nowhere near the magnificence of their Italian models.[57]

Figure 1.18 shows stage plans by Furttenbach for a comedy that seems, from his account of the action, to be similar to the production of *The Judgement of Paris* in Florence in 1608, designed by Parigi.[58] The back of the scene is closed with a flat shutter. The scenery at the sides is made with *periaktoi* whose shapes in plan are now right-angled triangles. We can see from the two plans how these triangles are all repositioned between the first two scenes: a 'street built of stately

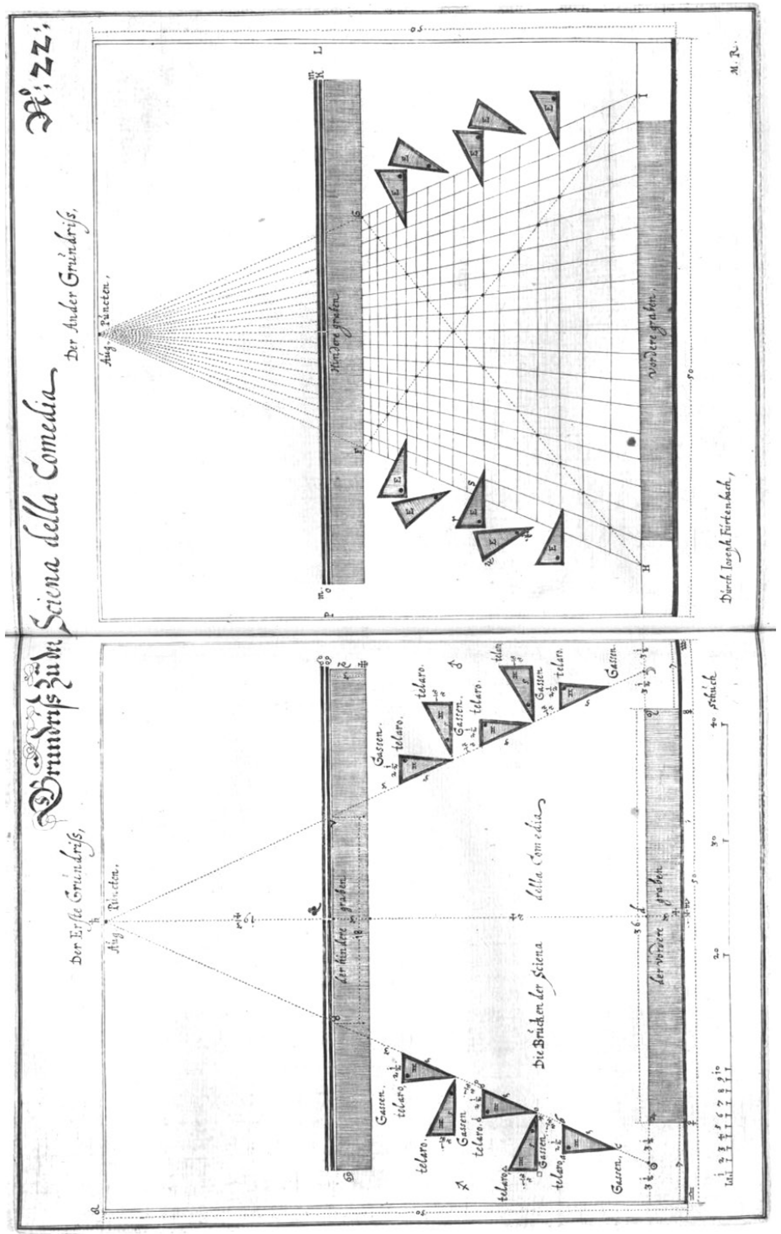

Figure 1.18 Joseph Furttenbach's plans for two successive scenes in a comedy, from *Recreational Architecture*. The wings are created from elongated triangular *periaktoi*, rather like Sabbattini's, each with two painted faces. The *periaktoi* are all turned at once to present the second scene. Notice the gaps through which actors can enter.

Figure 1.19 Furttenbach's drawing of his second scene, 'The Pleasure Garden', from the comedy described in *Recreational Architecture*: three *periaktoi* on each side of the stage are clearly distinguishable (compare the plan of Figure 1.18).

houses' and 'the garden of Calypso'.[59] Appropriate parts of each scene are painted on the two longer sides of each prism. Furttenbach's garden scene would have appeared to the spectators as in Figure 1.19. Once one knows what one is looking at, the tall individual *periaktoi* are clearly identifiable.

Notice that there are now spaces between the prisms – unlike in Egnazio Danti's scheme – through which actors can enter, and machines such as triumphal cars or monsters can be wheeled on stage. The arrangement and shape of the triangles is such, however, that the audience cannot see down these entrances; nor can the backstage areas be seen as the *periaktoi* turn. Furttenbach says that his *periaktoi* are rotated from below stage, like Sabbattini's, but with bars or handles rather than windlasses. The stagehands are coordinated by means of blasts on a whistle. 'The corners separate and suddenly and furiously the buildings disappear and the garden presents itself.' This suddenness 'astounds and delights the spectators'.[60]

Periaktoi with two usable sides would seem to be limited to presenting just two scenes. Furttenbach explains that this limit can be broken by having other loose painted cloths ready, showing further settings – perhaps 'mountains or the sea or the like'. During the second scene of a play, stagehands out of sight remove the cloths for the first scene from the hidden back faces of the *periaktoi*, and fit new cloths for the third scene into 'specially contrived grooves'. In Furttenbach's comedy this method was used for a third setting of 'great ranges of hills, with monstrous animals' representing the West Indies, no doubt modelled after Parigi's American scenery of 1608 (Figure 1.10). More scenes could be provided for, using more cloths. The parts of the sky visible on the painted surfaces of the *periaktoi* above the buildings, trees or hills were painted to blend in with the 'borders', the fixed sections of sky suspended over the stage.

Sabbattini describes two other possibilities for changeable scenery. The first involves pulling cloths over the houses in a Serlian/Peruzzian set, painted to represent some other setting. The second method is to have pairs of flats joined at oblique angles that slide in grooves in front of the houses. Sabbattini concludes, however, that neither method is entirely satisfactory, and that *periaktoi* 'seem to be better' than both. The goal is to make scene changes so fast that the audience hardly notice and are bemused. But this is 'difficult to accomplish', and Sabbattini suggests various schemes to divert the spectators' attention:

> For example, some confidential person is sent to the rear of the hall, who, watching for the time when the scene should be changed, feigns to make a noise with another person also in the know, or else (although, this might occasion much disturbance) pretends that some of the beams supporting the seats are in danger of breaking, or with the sounding of a trumpet, a drum, or some other instrument draws attention from the stage. At that very moment the change of scene is made without anyone seeing it.[61]

How were the scenes changed in the *intermezzi*?

We have seen that *periaktoi* were used in the Medici *intermezzi*, for *I Fabii* in 1567 and *La Vedova* in 1569. There are scattered mentions by audience members of scenes 'revolving' or 'rotating', continuing right up to the first decade of the seventeenth century, when Giulio Parigi and his son Alfonso were in charge of stage design in Florence. It seems very likely that Furttenbach derived his German system of *periaktoi* from what he saw when studying under Parigi.

As I said, there are no surviving contemporary drawings of the stage machinery for the *intermezzi*. But there have been suggestions that Bernardo Buontalenti in particular might have been experimenting in the 1580s with a new type of scenery, consisting of flat pieces moved in and out laterally from the stage wings. Since many flats of this type can be stacked tightly one behind another, the technique can allow for more than three changes of scene. It was for this reason that they were to become standard in European theatres for the next three hundred years.

Besides the *periaktos*, a second type of mobile scenic element seems also to have been in use on the ancient stage, the *scena ductilis*. This was a type of sliding flat. A French author Guillaume Philandrier published an edition of Vitruvius in 1544 in which he mentions the *scena ductilis* (which Vitruvius does not).[62] Philandrier quotes from a commentary on the Latin poet Virgil, referring to the theatre and describing how 'by means of panels drawn to the side, this scene or that was revealed'.[63] When one flat was moved, another behind came into view. Philandrier's edition was widely read, and this reference would have introduced the idea to Renaissance stage designers.

Buontalenti's sets for *La Pellegrina* in 1589 were certainly transformed at speed. The *intermezzi* on this occasion required seven different settings that changed 'with rapidity and ease, without the slightest incident, so that the spectators had the feeling that it was all taking place in a dream'.[64] Clearly, however this was done, Buontalenti had no need for Sabbattini's desperate ruses for distracting the audience. The theatre historians Elena Povoledo and Charles Niemeyer have both speculated that Buontalenti might have used the *scena ductilis*.[65] However, the evidence points to this step being first taken by Giovanni Battista Aleòtti in the early seventeenth century.

Giovanni Battista Aleòtti and flat wings

Aleòtti got his nickname Argenta from the town near Ferrara where he was born in 1546. He studied mathematics and architecture, including the works of Vitruvius, Alberti, Serlio and Palladio, and entered the service of Duke Alfonso II in Ferrara in the 1570s. He designed buildings and fortifications but was mainly occupied with hydraulic engineering: designing and building canals, flood defences and drainage systems in the Po delta. For 40 years he worked on a manuscript called the *Hydrology*, one chapter of which discusses water-powered automata.

Our interests are in two of Aleòtti's activities. He laid out gardens for Duke Alfonso and others. The gardens are gone, but there are drawings for the automata that Aleòtti planned to install. Most important, he designed a series of theatres, culminating in his greatest work, the Teatro Farnese in Parma, completed in 1618, for which he also devised the elaborate stage machinery. The historian of science A. G. Keller describes Aleòtti as 'a practitioner to his fingertips, with that taste for the elaborate and ingeniously cunning in which his age so much delighted'.[66]

The Teatro Farnese was inaugurated in 1628, after a decade's delay, with an opera of a kind called *Mercury and Mars*. The author of the *Description*, Marcello Buttigli, says that there were four groups of flat wings on each side of the stage. Aleòtti's surviving architectural drawings do not show these. However, there is a plan showing the stage of a second very large temporary theatre, built as part of the same 1628 celebrations in Parma, for a production of Torquato Tasso's drama *Aminta*. The designer of this structure was Aleòtti's assistant designer Francesco Guitti. There was seating in a seven-sided U-shape, a proscenium and a tapered stage, again with four banks of flat wings, plus backdrops (Figure 1.20).[67] This seems to be one of the earliest known drawings of scenery of this type.

In 1606 Aleòtti had completed a permanent theatre in Ferrara for the Accademia degli Intrepidi, the Academy of the Undaunted, a society of scholars and enthusiasts with special interests in drama. A plan drawing by Aleòtti exists but again fails to show the scenery. However, in 1625 Guitti renovated the theatre, and some rough sketches, apparently of this conversion, were rediscovered in the 1990s. These drawings are by a colleague of Guitti's, a military engineer called Pietro Paolo Floriani. The stage in Floriani's sketch plan closely resembles Guitti's stage for *Aminta* in Parma.[68]

Flat wings of this type were certainly changed with extreme speed, by a method that I will explain when we get to the performance of *Mercury and Mars* in Chapter 8. In brief, they ran on wheels and were pulled by ropes. The theatre historian Per Bjurström describes their effect as 'one of the most attractive attributes of the baroque stage – a moment's suspense while the clarity of the set dissolves, and then the sudden appearance of a new conception'.[69]

It seems possible that Aleòtti evolved the technology from a method used to move backdrops in the theatres of the sixteenth

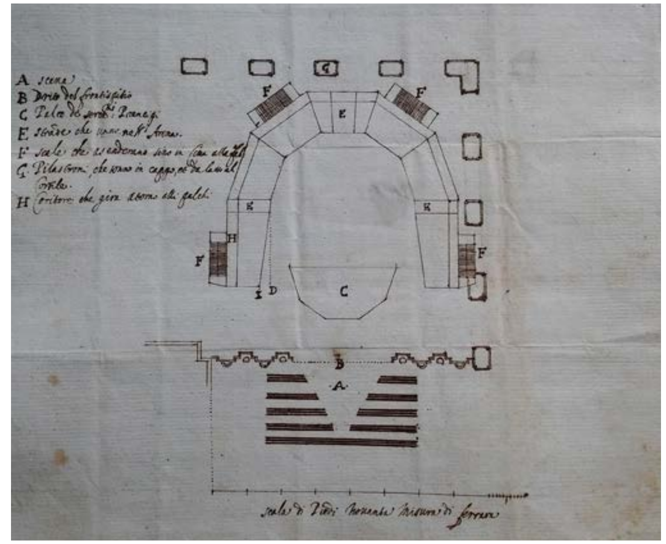

Figure 1.20 Plan of a temporary theatre designed by Francesco Guitti for a performance of Torquato Tasso's *Aminta* in Parma in 1628. This is one of the earliest known drawings of a flat wing stage. The drawing is by Francesco Mazzi. By kind permission of Biblioteca Comunale Ariostea, Ferrara.

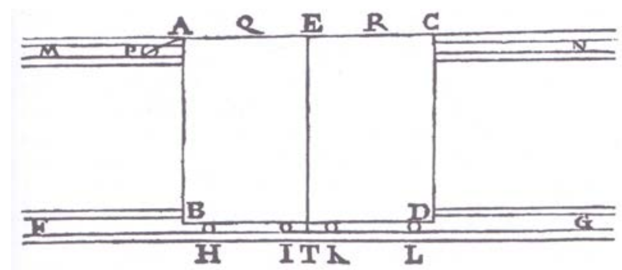

Figure 1.21 A back shutter made in two halves, running on wheels in grooves, from Sabbattini's *Manual*. These could be opened to reveal either a second backdrop, or the backstage beyond.

century, including Buontalenti and Parigi's productions. A backdrop of this type was made in two halves that were pulled aside to reveal the next picture behind. Sabbattini describes a method for opening and closing such a shutter 'during the *intermezzi*'.[70] The two sections run in tracks on hardwood wheels (Figure 1.21). Furttenbach saw dividing backdrops of this kind in Florence and took the idea back to Germany. The English architect Inigo Jones visited Florence in the 1610s and may also have met Parigi. Jones took Italian stage design to London in his court masques with the playwright Ben Jonson, and built stages in which fixed Serlian/Peruzzian houses were combined with these mobile dividing backdrops. It is easy to imagine how Aleòtti could have thought of extending the principle on which such rolling back shutters worked to flat wings at the sides of the stage.

The stage arch or frame, and the front curtain

In the ancient theatre the *proskenion*, as mentioned, was a one-storey extension to the *skene* building. Actors appeared in front of or inside the *proskenion*, or in the case of gods, on its roof. The modern word 'proscenium' means of course an archway or frame at the very front of the stage, through which the audience sees the action. It was during the second half of the sixteenth century that this transformation of *proskenion* to proscenium happened, from stage background to framing arch.[71]

Medieval religious plays and revived classical dramas were performed on open stages in front of their vestigial scenery. Scamozzi's drawings for his theatre at Sabbioneta show no scenic arch, nor do Serlio's designs – although it has been suggested that Serlio might have had a valance above the stage to conceal overhead lamps. There are nevertheless pictures of perspective stages of the Serlian/Peruzzian type from the mid-sixteenth century, which show solid architectural frames surrounding the opening of the stage.[72] It seems that actors might on occasion have moved out through the frame. They could have come down steps onto the floor of the auditorium.

Several competing theories have been advanced about the origins of the modern proscenium.[73] (To my mind these are not incompatible.) In the 1940s the theatre historian George Kernodle argued at length that the proscenium was borrowed from the framing of works in other arts.[74] T. E. Lawrenson suggested that the inspiration was the triumphal arch.[75] Sheldon Cheney proposed in the 1920s that the modern proscenium was descended directly from the archway framing the central street in Palladio's *frons scenae* at the Teatro Olimpico.[76] However, there were proscenium stages well before the 1580s when the Olimpico was completed. Figure 1.22 shows the proscenium at Aleòtti's Teatro Farnese in Parma of 1618. Here Aleòtti has retained much of the Roman *scenae frons* with its columns and niches but has punctured this with a large rectangular stage opening.

It seems likely that – whatever the formal precedents – there were two overriding practical reasons for designers in the mid-sixteenth century to want to surround the opening of the stage with a frame. The first reason, especially with the *intermezzi*, was to conceal the ever-growing quantity of apparatus and backstage storage needed for their special effects and multiple scenes: not only the mobile flat wings, but also the heavy machinery that allowed clouds and flying chariots to be suspended above the stage, more vehicles and creatures to be brought in from the sides, and all kinds of scenic elements to be raised from below stage, to be described in Chapter 2.[77]

The second purpose of the proscenium arch was to focus the attention of the audience onto the perspective set, bringing more of the seats closer to the central axis along which the illusion was at its most powerful. In this process of change, the wide auditorium and shallow stage

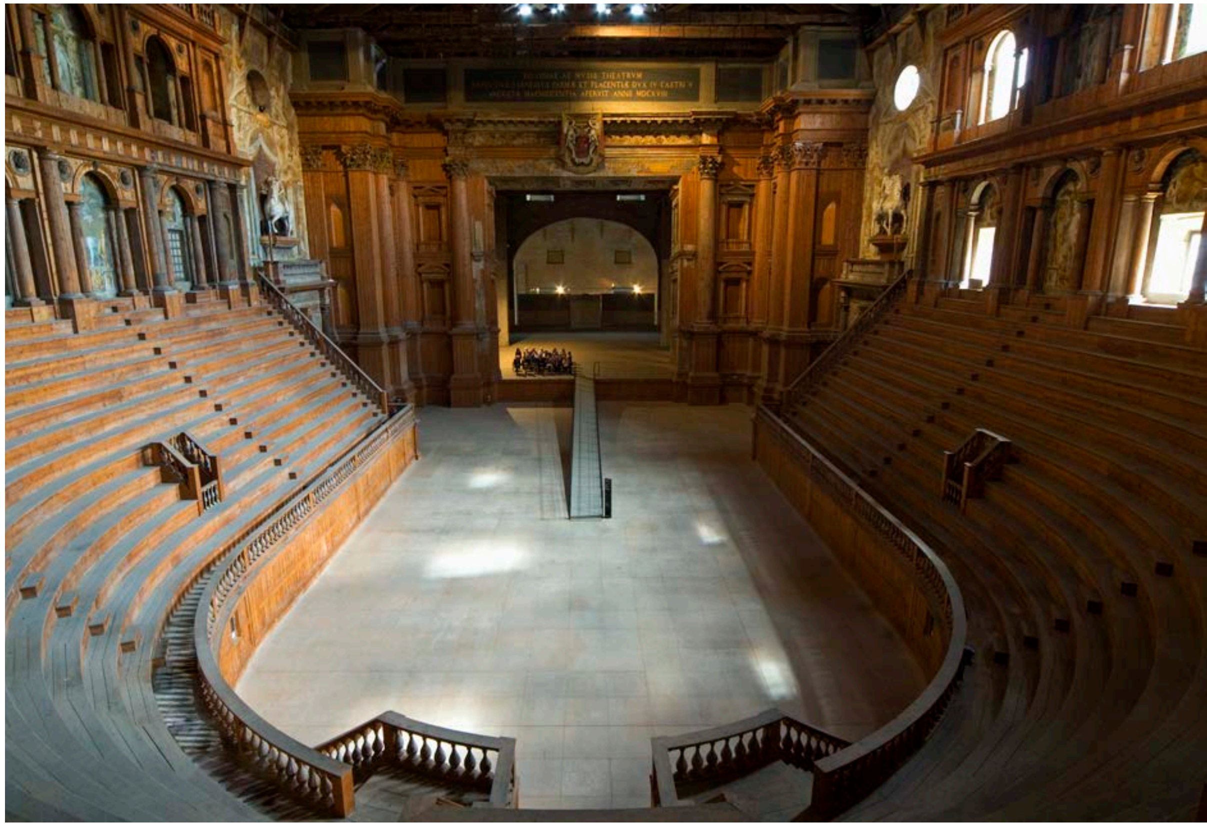

Figure 1.22 Proscenium arch surrounded by a Roman style *frons scenae* at the Teatro Farnese in Parma, designed by Giovanni Battista Aleòtti and completed in 1618. (The theatre was bombed in the Second World War and has been restored but for the most part left unpainted.) Photo: Robert Harding.

of the ancient theatre and the Teatro Olimpico were transformed into the much narrower, deeper plans of Sabbioneta and the Uffizi Theatre.

But the introduction of a frame separating stage from auditorium had a further significance, I believe, in relation to the way in which the perspective was appreciated. It created a sharp division between two worlds, the everyday world of the audience and the fantastic imagined world of the dramatic scene. It meant that the real architecture of the auditorium and the fictive architecture of the stage were held apart, and the illusion could not be spoiled by any visual inconsistency or breakage between the two. And the framing is likely to have amplified the spatial perspective illusion, I suggest, in other ways that have not generally been recognised.

The frame of the theatre proscenium is *not* like the frame of a painting in several important respects. First, obviously, it surrounds not a two-dimensional image but a view into a large box. With a perspective picture in a frame – however skilfully executed – we know where the painted surface really lies: just in front of the wall on which the picture hangs. With perspective scenery behind a frame this is not true. We do not see the outer edges of the houses or the flat pieces, so we cannot locate them precisely in depth and we can be more effectively deceived. The scenery is at a sufficient distance that – unlike a panel painting or a mural – we cannot make out the textured surface of the supporting material or the individual brushmarks. One way in which we gauge the distance of objects in normal vision is through the effects of motion parallax. If we shift sideways, objects near to us appear to move across those that are further away. This effect does not happen in a flat perspective picture. But if nothing in a painted theatrical scene is very close, the lack of parallax effects is less obvious.

All these factors were cleverly manipulated in some of the most popular and, by all accounts, impressive visual entertainments of the nineteenth century, the panoramas and the dioramas.[78] These consisted of very large paintings in perspective, viewed from a distance, sometimes modified by varying the natural and artificial lighting. But the viewing arrangements were ingeniously arranged such that the edges of the paintings were not visible and could not therefore be located in depth; the surface handling of the paint was too far away to be detectable and the effects of parallax were minimised. Viewers really did believe for a moment that they were seeing the real cities or battle scenes depicted. Leading landscape artists were glowing in their praise.[79]

Here, I suggest, are some of the reasons why Renaissance audiences – who after all would have been quite familiar with flat paintings in perspective – were so beguiled and carried away by perspective stage sets, in the form that these had reached towards the end of the sixteenth century. They would have been like three-dimensional layered versions of the dioramas and panoramas, inside brightly lit boxes.

Once the front of the stage was framed, it was possible to fill the opening with a curtain. However, it was not the practice at this period to lower and raise the curtain between scenes or acts – hence the fact that audiences witnessed the changes of scenery. The curtain was in place as the spectators entered the auditorium, and once they were in their seats it was removed to reveal the wonders of the perspective scene. This front curtain might itself be richly decorated. The vigorous hunting scene of Figure 1.23 is a painted cartoon by Federico Zuccari of the curtain for a performance of *La Cofonaria* in 1565.[80] The city in the distance is Florence.

The birth of stage lighting

Medieval religious dramas and revived classical plays were performed outdoors or in churches or halls during the hours of daylight. It was the rise of the permanent theatre and the perspective set that prompted an increasing use of artificial lighting in both the auditorium and on the stage. Towards the end of the sixteenth century, plays with *intermezzi* began typically at around seven or eight o'clock in the evening and went on into the night.[81]

Three sources of illumination were used. Flaming torches might be carried by actors or stagehands, but for strictly dramatic purposes – for instance to depict the fires of Hell. The directed light sources were candles and oil lamps. Candles were set in chandeliers and wall brackets and were generally used for lighting the auditorium. The stage and scenery were mostly lit with oil lamps. Serlio, Sabbattini and Furttenbach all give details.

The standard design of lamp was similar to a type used in churches, with the oil in a glass container in which the wick was floated. The light could be focused and intensified with the use of a reflector. Serlio recommends the kind of brass basin used by barbers, given a high polish.[82] Furttenbach describes several types of reflector, illustrated in Figure 1.24, with gold tinsel supported on metal backing plates, scored in diamond patterns.[83] The tinsel could be covered with sheets of translucent mica to further increase the reflectivity and give a 'strong splendour'. Mirrors were also used to direct the

Figure 1.23 Preparatory design by Federico Zuccari for the front curtain for a performance of *La Cofonaria* in Florence, 1565. Gabinetto Disegni e Stampe, Gallerie degli Uffizi, Florence.

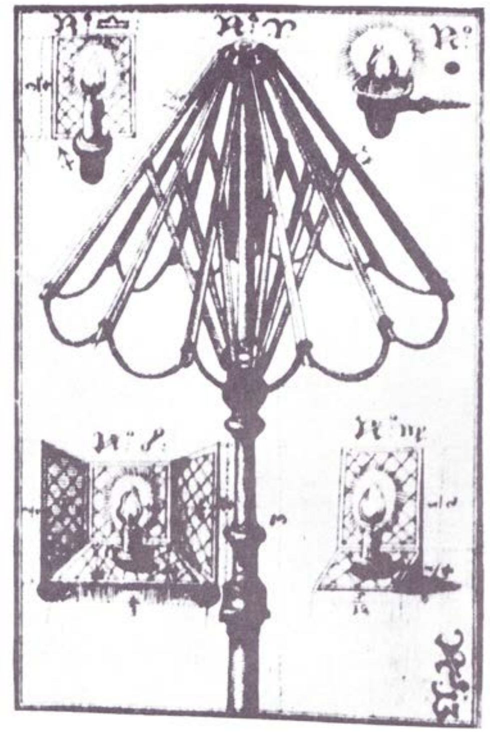

Figure 1.24 Oil lamps and candles to be used on stage, with reflectors made from gold tinsel scored in diamond patterns, on metal backing sheets. From Furttenbach, *The Noble Mirror of Art.* (The device at the centre is for creating a burning bush in a play about Moses.)

illumination, and glass globes filled with clear water served as magnifying lenses.[84]

Serlio describes how lamps can be set behind bottles of coloured liquid – like the jars in old-fashioned chemists' shops – to achieve the kinds of effect created by modern theatrical 'gels'. Sal ammoniac in water gives a blue light, saffron gives an emerald shade and reds can be produced with wine or powdered brazilwood dissolved in water. These jewel-like coloured lamps might be placed in windows or door openings in the scenery, or could be used in the sky to represent the moon, the sun and the stars.

Aleòtti designed a temporary theatre and scenery for a play with *intermezzi* in the small town of Sassuolo near Modena, to celebrate the marriage of Marco Pio-Savoia and Clelia Farnese in 1587.[85] The set included an octagonal temple to the God Pan with a dome. The entire building was illuminated from the interior. There were lamps behind the windows and in the lantern on top of the dome. The published account of the production also mentions the use of coloured lights representing emeralds, sapphires, diamonds and rubies on the walls of the temple.[86] But it seems that apart from these, none of the other lamps was in open sight.

Leone de' Sommi was in charge of theatricals at the Gonzaga court in Mantua in the 1550s and 1560s and wrote a series of dramatised *Dialogues on Stage Affairs* in which three interlocutors discuss plays, acting and stagecraft.[87] De' Sommi's character Veridico explains that it is better not to have naked lamps in view for too long on stage, since 'a brilliant light striking directly upon the eye for any length of time becomes exceedingly irritating'.[88] It is better to shade such lights, or colour them using Serlio's bottles.

Otherwise, concealed lamps were placed in and around the set: behind the parapet at the front of the stage as footlights, behind the sides and top of the proscenium, behind houses or flats, and in the rear stage. Furttenbach describes how oil lamps can also be set behind the sections of painted scenery above the stage, the 'borders' that represent the sky. These 'cast such an exquisite glow on the scene that although it is night in the theatre it seems as if rosy-fingered dawn were drawing after her the longed-for day through the rich clouds'.[89]

Furttenbach says that a whole scene might need 50 lamps; but his theatres were small and cash strapped. I suspect that the Italian *intermezzi* employed very much larger numbers. In the Uffizi Theatre in 1589 there were 288 lamps just in the auditorium.[90] Care was taken to fix the stage lamps securely, not just for safety, but so that they did not wobble during the dancing and cause the light to flicker. For this reason, freestanding lamps were carried on metal poles that went down through holes in the stage to the solid floor beneath.

It was possible to control the direction and intensity of the lighting. Sabbattini recommends that an architectural set should be lit more strongly on the side onto which the sun notionally shines, to match the patterns of shading and shadow painted on the buildings and streets.[91] Lamps supported on poles could be turned during the performance, either to focus the lighting on selected parts of the stage or to dim the general lighting level by turning them to the walls. In some theatres the footlights could be raised and lowered. Sabbattini describes a technique for darkening oil lamps in a moment while they are still burning, and then revealing them again.[92] Metal cylinders with open tops are suspended over the lamps and lowered or raised with

cords. By joining their cords together, several lamps can be controlled simultaneously.

Control of the lighting opened the possibility that the stage might be very much more brightly illuminated than the auditorium, something never previously possible in the theatre. This would have focused the audience's eyes even more intently on the scene. Of course, candles and oil lamps could never match the brightness of modern electrical stage lighting: we are talking about the relative levels of light in the two parts of the theatre. As De' Sommi's character Veridico says:

> it is a natural fact – as no doubt you are aware – that a man who stands in the shade sees much more distinctly an object illuminated from afar; the reason being that the sight proceeds more directly and without any distraction towards this object … Wherefore I place only a few lamps in the auditorium, while at the same time I render the stage as bright as I possibly can.[93]

Veridico says that he places the small number of auditorium lamps behind the audience so that they do not distract attention from the stage.

It is clear that the auditorium was rarely if ever totally blacked out at this period, certainly not for the entire evening. The audience came to be seen and to see each other, especially to admire the ducal party. Descriptions of the *intermezzi* are full of glowing references to the charms of the younger ladies of the court, the splendour of their dresses and the glitter of their jewellery. And important parts of the action, notably the general dancing, spread out from the stage onto the *orchestra*.

Nevertheless, it seems that in the 1580s and 1590s Buontalenti and Aleòtti were working to achieve, during the drama itself, the kind of contrast in lighting that Veridico recommends. Aleòtti had in mind almost complete blackout in the hall for productions of *Pastor Fido* and another comedy in Mantua in 1592 and 1593.[94] When the spectators took their seats in the Uffizi Theatre in Florence for *La Pellegrina* in 1589, they were startled to see all the lamps in the hall light up automatically, without any attendants applying flames.[95] My suspicion is that Buontalenti had a control system using moveable metal lamp covers on cords like Sabbattini's, or possibly on springs, but on a much larger scale.[96] When the performance was started we can imagine that these were all dimmed again. For a performance of *Il Rapimento di Cefalo* [*The Kidnap of Cephalus*] in 1600, again designed by Buontalenti, the stage was darkened for a night scene, and the lights in the auditorium were simultaneously 'reduced to the size of small stars'.[97]

Callot's depiction of the Uffizi Theatre (Figure 1.7) is not of course a photograph; but taken at face value it gives a vivid impression of light being concentrated selectively on the dancers in the midst of the audience, and above all within the stage itself, whose brilliant opening fills the entire end wall of the auditorium. Elena Povoledo writes of Buontalenti's productions that, with his lighting, he turned the stage at the Uffizi into a kind of *scatola magica*, a magic box 'permeated with the restless play of images, forms, lights, sounds and colours'.[98] Armando Fabio Ivaldi says of Aleòtti's productions of this same period, 'The stage became a "camera obscura", if one could say such a thing, rigorously delimited in space by means of the stage arch.'[99] It became, in a word, cinematic.

Notes

1 The literature of the Renaissance theatre is vast. With the focus here on scenery and stagecraft, I have found a few sources particularly helpful: Lily B. Campbell, *Scenes and Machines on the English Stage During the Renaissance* (Cambridge: Cambridge University Press, 1923), whose first part is devoted to Italy; Barnard Hewitt (ed.), *The Renaissance Stage: Documents of Serlio, Sabbattini and Furttenbach* (Miami, FL: University of Miami Press, 1958), which provides translations of key contemporary texts by Serlio, Sabbattini and Furttenbach; Orville K. Larson, 'Italian Stage Machinery, 1500–1700', PhD thesis, University of Illinois (1956); and Elena Povoledo's entries under 'Scenography', 'Perspective Scenography in Italy' and 'Changeable Scenery and Perspective Illusionism in Italy', in *Enciclopedia Universale dell'Arte* (Venice and Rome: Istituto per la Collaborazione Culturale Venezia-Roma, 1958), translated as *Encyclopedia of World Art* (New York: McGraw-Hill, 1966), columns 761–7. Oscar G. Brockett, Margaret Mitchell and Linda Hardberger provide a survey from the ancient world up to the present in *Making the Scene: A History of Stage Design and Technology in Europe and the United States* (San Antonio, TX: Tobin Theatre Arts Fund, 2010). Allardyce Nicoll's classic *The Development of the Theatre: A Study of Theatrical Art from the Beginnings to the Present Day* (London: George G. Harrap, 1927, and later editions) again gives a panoramic overview; as does Giulio Ferrari, *La Scenografia: Cenni Storici Dall' Evo Classico ai Nostri Giorni* (Milan: Ulrico Hoepli, 1902). Licisco Magagnato's *Teatri italiani del Cinquecento* (Venice: Neri Pozza, 1954) has the merits of brevity, clarity and an excellent choice of illustrations. Eugene J. Johnson's *Inventing the Opera House: Theater Architecture in Renaissance and Baroque Italy* (Cambridge: Cambridge University Press, 2018) is an informative account of the buildings, although with little coverage of scenery and machines. There are several useful articles in *Bollettino del Centro Internazionale Di Studi di Architettura Andrea Palladio*, 16 (1974): special issue on 'L'Architettura Teatrale dall'Epoca Greca al Palladio'. Giorgio Vasari, *Le vite de' più eccellenti Architetti, Pittori et Scultori Italiani* (1550) is essential for details of the work of individual stage designers. The standard English translation is Gaston DuC. DeVere, *Lives of the Most Eminent Painters, Sculptors & Architects*, 10 vols (London: Philip Lee Warner, 1912–14). All the sections of the *Lives* relating to the theatre are extracted in Thomas A. Pallen, *Vasari on Theatre* (Carbondale and Edwardsville: Southern Illinois University Press, 1999): I have used Pallen's new translations.

2 One exception was the theatre built in Ferrara in 1529 on whose design the local poet Ludovico Ariosto, author of the epic *Orlando Furioso*, advised. This has been claimed as the first permanent modern theatre building in Europe. However, it burned down in 1532 and little is known of its architecture.

3 For an encyclopaedic account see Margarete Bieber, *The History of the Greek and Roman Theater*, 2nd edn (Princeton, NJ: Princeton University Press, 1961), pp. 54–73 and 108–28. Also the entry by A. M. Nagler under 'Scenography, Classical Antiquity' in *Enciclopedia Universale dell'Arte*, columns 748–52.

4 Leon Battista Alberti, *De Pictura* (1435), rendered into Italian by Alberti himself as *Della Pittura* in 1436. Edited and translated into English by Cecil Grayson and Martin Kemp, *On Painting* (London: Penguin, 1991).

5 Vitruvius, *De Architectura* [*The Ten Books on Architecture*], probably written c.20 BC, trans. Ingrid D. Rowland (Cambridge: Cambridge University Press, 1999), pp. 25 and 86.

6 Letter from Bernardino Prosperi to Isabella d'Este: quoted in Campbell, *Scenes and Machines*, p. 49.

7 Letter from Baldassare Castiglione to Ludovico Canossa, quoted in Pallen, *Vasari on Theatre*, p. 22.

8 Vasari, 'Life of Baldassare Peruzzi', trans. Pallen, *Vasari on Theatre*, p. 61.

9 However, opinions have differed about the nature of this drawing and the play to which it relates, as discussed by Fabrizio Cruciani, 'Gli allestimenti scenici di Baldassare Peruzzi', *Bollettino del Centro Internazionale di Studi di Architettura Andrea Palladio*, 16 (1975): 155–72 and plates 69–83; see 159.

10 Elena Povoledo, 'Origini e aspetti della scenografia in Italia della Fine del Quattrocento agli intermezzi Fiorentini del 1589', in Nino Pirrotta, *Li Due Orfei, da Poliziano a Monteverdi* (Turin: Edizioni Rai, 1969), pp. 371–509; see p. 425.

11 Sebastiano Serlio, *Tutte l'Opere d'Architettura et Prospetiva*, sometimes *L'Architettura*. Five volumes were published, not in their numbered order, in various places between 1537 and 1547. Two more volumes were published posthumously, plus two further titles by way of appendices. Material on perspective, and on the theatre, is in the second book: *Il Secondo Libro d'Architettura* (Paris: avec privilege du Roy, 1545). The quotations here are from the translation by Allardyce Nicoll in Hewitt, *Renaissance Stage*, pp. 21–36.

12 Serlio, *Perspettiva*, p. 25. Also Orville K. Larson, 'Sebastiano Serlio: An Inquiry', *Quarterly Journal of Speech*, 47/2 (1961): 118–23; see 119. There are many references to 'morris dances' in the *intermezzi*; these must be 'Moorish dances'.

13 Serlio, *Perspettiva*, facing pp. 64 and 66.

14 Serlio, *Perspettiva*, facing p. 68.

15 The model is illustrative, and approximate, since there are several discrepancies between the Comic Scene and the plan and section of Serlio's stage: see Philip Steadman, 'Baldassare Peruzzi and Theatrical Scenery in Accelerated Perspective', *Nexus Network Journal*, 22 (9 March 2020), https://link.springer.com/article/10.1007/s00004-020-00479-z.

16 Mari Yoko Hara, 'Capturing Eyes and Moving Souls: Peruzzi's Perspective Set for *La Calandria* and the Performative Agency of Architectural Bodies', *Renaissance Studies*, 31/4 (2017): 586–607; also Steadman, 'Baldassare Peruzzi'.

17 Gabinetto Disegni e Stampe degli Uffizi, Florence, A 268 recto and 269 recto. The drawings are reproduced, with transcriptions of the notes, by Thomas Ault ('Baldassare Peruzzi and the Perspective Stage', *Theatre Design and Technology*, 43/3 (Summer 2007): 33–49.

18 Cruciani, 'Gli allestimenti scenici': 162. Translation by Gregorio Astengo.

19 Licisco Magagnato, 'The Genesis of the Teatro Olimpico', *Journal of the Warburg and Courtauld Institutes*, 14/3–4 (1951): 209–20.

20 Nicola Sabbattini, *Pratica di Fabricar Scene e Machine ne' Teatri* (Ravenna: 1638), English translation by John H. McDowell in Hewitt, *Renaissance Stage,* pp. 43–177; Fabrizio Carini Motta, *Trattato Sopra la Struttura de'Theatri e Scene*, manuscript (Mantua: 1676).

21 The Florentine *intermezzi* are fully described, along with other court entertainments, by Alois M. Nagler in *Theatre Festivals of the Medici 1539–1637* (New Haven, CT, and London: Yale University Press, 1964). Nagler gives summaries of the action and descriptions of the costumes and sets, based on the *Descriptions* published at the time and other eyewitness accounts. The book has many illustrations. More details and pictures are given in Elvira Garbero Zorzi and Mario Sperenzi (eds), *Teatro e Spettacolo nella Firenze dei Medici: Modelli*

dei Luoghi Teatrali, catalogue of an exhibition held in the Palazzo Medici Riccardi (Florence: Leo S. Olschki, 2001).

22 The *Description* of the 1589 performance in Florence of *La Pellegrina* with its *intermezzi*, to which I will refer in detail, was by Bastiano de Rossi, *Descrizione dell'Apparato e degl'Intermedi Fatti per la Commedia Rappresentata In Firenze …* (Florence: Anton Padouani, 1589); translated into French by Anne Surgers in *La Pellegrina et les Intermèdes, Florence, 1589* (Paris: Lampsaque, 2009).

23 Nagler, *Theatre Festivals*, p. 59. Nagler gives the date as 1586, but the *Descrizione* by Bastiano de' Rossi is dated 1585. The figure for annual income is from Fernand Braudel, *The Mediterranean* (Oakland: University of California Press, 1995), although there is much uncertainty. Joseph Furttenbach in *The Noble Mirror of Art* (*Mannhafter Kunstspiegel*) (Augsburg: Johann Schultes, 1663) says enviously that in Italy 'as much as half a ton of gold has been spent for a play that would have only one performance' (translation by G. R. Kernodle in Hewitt, *Renaissance Stage*, p. 203).

24 A performance of *La Liberazione di Tirreno e d'Arnea*. Neither Tirreno nor Arnea appear in this play, nor does the monster Typhon from whom they are liberated. At one point however a voice is heard of 'a lady from Tuscany enclosed in a plant'.

25 There are biographies of Buontalenti in Raffaello Borghini, *Il Riposo* (Florence: Giorgio Marescotti, 1584), Book IV, pp. 609–13; Filippo Baldinucci, *Notizie dei Professori del Disegno da Cimabue* (Milan: Classici Italiani, 1811), vol. 8, pp. 11–31; and Gherardo Silvani, 'La vita di Bernardo Buontalenti', ed. Vera Giovannozzi in *Rivista d'Arte*, 15 (1 October 1932): 505–24.

26 Vasari, *Lives,* vol. 9, pp. 133–7, and vol. 10, pp. 16–18.

27 Oreste Trabucco, *'L'opere stupendi dell'arti piu ingegnose': La Recezione degli Πνευματικα di Erone Alessandrino nella Cultura Italiana del Cinquecento* (Florence: Leo S. Olschki, 2010), p. 93.

28 Trabucco, *'L'opere stupendi'*, p. 71.

29 Nagler, *Theatre Festivals*, pp. 84–5; also Zorzi and Sperenzi, *Teatro e Spettacolo*, pp. 178–9 and plate 43.

30 Nagler, *Theatre Festivals*, pp. 107–8, and Zorzi and Sperenzi, *Teatro e Spettacolo*, pp. 190–1 and plate 58.

31 Aby Warburg, 'I costumi teatrali per gli Intermezzi del 1589: I disegni di Bernardo Buontalenti e il *Libro di conti* di Emilio De Cavalieri', in *Commemorazione della Riforma Melodrammatica, Atti dell'Accademia del R. Istituto Musicale* (Florence: Galletti, 1895), pp. 103–46; Surgers, *La Pellegrina et les Intermèdes*.

32 Nagler, *Theatre Festivals*, p. 10.

33 Nagler, *Theatre Festivals*, p. 33.

34 See Roy Strong, *Art and Power*, 2nd edn (Woodbridge: Boydell and Brewer, 1984), p. 26.

35 Strong, *Art and Power*, p. 43.

36 Strong, *Art and Power*, p. 81.

37 Bieber, *Greek and Roman Theater*, p. 75. Figures 278 and 279 show stone sockets for the axles of *periaktoi*.

38 Vitruvius, *Ten Books*, Rowland translation, p. 69.

39 Julius Pollux, *Onomasticon* (second century AD). No modern English translation exists to my knowledge. The theatre sections are included in *Extracts concerning the Greek Theatre and Masks, Translated from the Greek of Julius Pollux,* printed with Aristotle's *Poetics* (London: 1775). There are monographs on Pollux by the nineteenth-century German classicists Erwin Rohde and Johannes Niejahr.

40 The drawing is in the Uffizi Library in Florence. It was discussed in an international symposium conducted by correspondence and reported in John Semar (ed.), 'On a Design by Sangallo', *The Mask*, 11/4 (1925): 59, 152–60, and plates 11 and 12.

41 Giacomo Barozzi de Vignola with Egnazio Danti, *Le Due Regole della Prospettiva Pratica* (Rome: Zanetti, 1583).

42 Vignola and Danti, *Le Due Regole*, p. 91.

43 See Larson, 'Italian Stage Machinery', p. 66. Larson cites W. J. Lawrence, 'A Primitive Italian Opera', *The Connoisseur*, 15 (1906): 235–40; see 236. The date of this production is known from a letter from Claudio Tolomei to Antonfrancesco Renieri: see Franz Rapp, 'Notes on Little-Known Materials for the History of the Theatre', *The Theatre Annual 1944* (New York: 1945), p. 60.

44 There have been claims that Aristotile used *periaktoi* in other productions around this time, as for example Antonio Landi's comedy *Il Commodo*, put on in the courtyard of the Medici palace in Florence in 1539. Vasari (see Pallen, *Vasari on Theatre*, pp. 77–80) gives a lengthy account of the wonderful perspective of the city of Pisa, in which Aristotile 'surpassed himself'; and his ingenious simulation of the sun moving through the sky, described below in 'Artificial Weather' (see p. 105). There were (flat) painted panels hung next to the stage. But Vasari nowhere mentions *periaktoi*.

45 Alessandro Ceccherelli, *Descrizione di tutte le Feste, e Maschera te fatte in Firenze per il Carnouale, questo anno 1567* (Florence: 1567), p. 17 v; see also Nagler, *Theatre Festivals*, p. 40.

46 Nagler, *Theatre Festivals*, pp. 41–6. Nagler points out that Danti's recollection of the scenes in *La Vedova* differs somewhat from contemporary descriptions.

47 *Raccolto delle feste fatte in Fiorenza …* (Florence: I Giunti, 1569), p. 13; Giovanni Passignani, *Descrittione dell'Intermedii …* (Florence: Bartholomeo Sermartelli, 1569), A7 v. See also Giovanni Attolini, *Teatro e Spettacolo nel Rinascimento* (Bari: Laterza, 1988), pp. 127–8.

48 Vignola and Danti, *Le Due Regole*, p. 91.

49 Larson, 'Italian Stage Machinery', p. 70.

50 Alessandra Buccheri has suggested that a sketch of 1608 by the poet Michelangelo Buonarroti the Younger (grandnephew of the painter and sculptor) in the Archivio Buonarroti in Florence illustrates *periaktoi*: *The Spectacle of Clouds, 1439–1650* (Farnham: Ashgate, 2014), p. 74. This seems very debatable. The drawing shows two rows of trapezia, which could perhaps be the bases of 'houses' viewed in perspective. The annotations refer to actors' entrances and exits between these houses. Buccheri sees the shapes as four-sided *periaktoi*, but the text gives no support to this interpretation. *Periaktoi* were certainly in use in Florentine productions at this time, but they seem to have been three-sided. A. M. Nagler, 'Sixteenth-Century Continental Stages', *Shakespeare Quarterly*, 5/4 (1954): 358–70; see 367, mentions a production of *Arimène* in Nantes in 1596 where there were four pentagonal *periaktoi*, two on each side of the stage. This is surprising: the audience would have been able to see some of the receding faces of these prisms, unless they were placed behind windows.

51 Sabbattini, *Pratica di Fabricar*; McDowell translation in Hewitt, *The Renaissance Stage*, pp. 43–177. Little is known of Sabbattini's career, but he seems to have worked in several theatres, including the Teatro del Sole at Pesaro, which he mentions specifically.

52 John H. McDowell, Introduction to translation of Sabbattini, *Pratica di Fabricar*, in Hewitt, *The Renaissance Stage*, p. 37.

53 Sabbattini, *Pratica di Fabricar*, McDowell translation, pp. 103–9.

54 Sabbattini, *Pratica di Fabricar*, McDowell translation, p. 105.

55 Joseph Furttenbach, *Architectura Civilis* (Ulm: Jonam Saurn, 1628); *Architectura Recreationis* (Augsburg: Johann Schultes, 1640); *Mannhafter Kunstspiegel* (Augsburg: Johann Schultes, 1663).

56 Joseph Furttenbach, *Newes Itinerarium Italiae* (Ulm: Jonam Saurn, 1627).

57 See the Introduction to Furttenbach's writings on the theatre by George Kernodle in Hewitt, *The Renaissance Stage*, pp. 178–84. A manuscript by Furttenbach in the Bavarian State Library in Munich (Codex Iconographicus 401) gives more details of his time in Florence and his studies with Parigi: see Jan Lazardzig and Hole Rössler (eds), *Technologies of Theatre: Joseph Furttenbach and the Transfer of Mechanical Knowledge in Early Modern Theatre Cultures* (Frankfurt: Vittorio Klostermann, 2016).

58 Furttenbach, *Architectura Recreationis*, plate 22.

59 The Garden of Calypso was one of Parigi's sets for 'Il Giuditio di Paride': see W. J. Lawrence, 'A Primitive Italian Opera': 238.

60 Furttenbach, *Architectura Recreationis*, Kernodle translation in Hewitt, *The Renaissance Stage*, p. 198.

61 Furttenbach, *Architectura Recreationis*, Kernodle translation in Hewitt, *The Renaissance Stage*, p. 99.

62 Guillaume Philandrier, *Decem Libros M. Vitruvii Pollionis de Architectura Annotationes* (Rome: 1544).

63 Servius, commentary on Virgil, *Georgics* III 24.

64 Nagler, *Theatre Festivals of the Medici*, p. 79.
65 Povoledo, 'Perspective Scenography', column 767; Charles Niemeyer, 'The Renaissance and Baroque Theatre in France: The Playhouses and the Mise-en-Scène', PhD dissertation, Department of Drama, Yale University (1942), p. 151. See also Povoledo's discussion in 'Origini e aspetti', pp. 488–9.
66 A. G. Keller, 'Pneumatics, Automata and the Vacuum in the work of Giambattista Aleòtti', *British Journal for the History of Science*, 3/12 (1967): 338–47.
67 Manoscritti Antonelli, Biblioteca Comunale Ariostea, Ferrara, ms 660.
68 Manuscript notebooks of Pietro Paolo Floriani, sheet 1 recto of Codex β; reproduced in Giuseppe Adami, *Scenografia e Scenotecnica Barocca tra Ferrara e Parma (1625–1631)* (Rome: 'L'Erma' di Bretschneider, 2003), plate 1, p. 62.
69 Per Bjurström, *Giacomo Torelli and Baroque Stage Design* (Stockholm: Almqvist and Wiksell, 1961), p. 110.
70 Sabbattini, *Pratica di Fabricar*, pp. 116–18 and Figure 51 in McDowell translation.
71 Fabio Finotti, 'Perspective and Stage Design, Fiction and Reality in the Italian Renaissance Theater of the Fifteenth Century', *Renaissance Drama*, new series, 36–7 (2010): 21–42; see 26.
72 There is a comparable design attributed to Francesco Salviati in the British Museum. An octagonal building closes the perspective street.
73 Melvin M. Slott gives a very full and clear account in 'The Stage Arch: A Theatrical Device. A Re-Evaluation of the Advent and Use of the Sixteenth and Seventeenth Century Proscenium Arch', Master's thesis, Ohio State University (1960).
74 George R. Kernodle, *From Art to Theatre: Form and Convention in the Renaissance* (Chicago: University of Chicago Press, 1944), especially ch. 7.
75 T. E. Lawrenson, *The French Stage in the Seventeenth Century* (Manchester: University of Manchester Press, 1957), p. 136: 'the origin of the proscenium arch is the arch – chiefly triumphal'.
76 Sheldon Cheney, 'The Story of the Stage', *Theatre Arts*, 7/4 (1923): 50–7.
77 See Larson, 'Italian Stage Machinery', *passim*.
78 Bernard Comment, *The Painted Panorama* (New York: Harry N. Abrams, 2000).
79 Comment, *Painted Panorama*, pp. 59 and 87. Enthusiasts for the panoramas included Sir Joshua Reynolds, Jacques-Louis David, Caspar David Friedrich and the critic John Ruskin. The diorama was the creation of the painter (and pioneer photographer) Louis-Jacques-Mandé Daguerre. John Constable was impressed by the London diorama – 'it is very pleasing and has great illusion' – although he thought it was 'without the pale of Art because its object is deception'.
80 Gabinetto Disegne e Stampi degli Uffizi, Florence, 11074 F. The curtain itself was destroyed in 1839.
81 Nagler, *Theatre Festivals*, pp. 144 and 153, mentions plays starting at these times in Florence and Parma.
82 Serlio, *Perspettiva* in Nicoll translation, p. 34.
83 Furttenbach, *Mannhafter Kunstspiegel* in Kernodle translation, pp. 236–7.
84 Leone de' Sommi, *Quattro Dialoghi in Materia di Rappresentazioni Sceniche,* manuscript c.1565 in the Biblioteca Palatina in Parma. Translated by Allardyce Nicoll in *The Development of the Theatre*, Appendix, pp. 252–78: see p. 274; also Nagler, *Theatre Festivals* p. 15.
85 Armando Fabio Ivaldi, *Le Nozze Pio-Farnese e Gli Apparati Teatrali di Sassuolo del 1587* (Genoa: ERGA, 1974).
86 Anonymous, *Narratione delle Feste sontuosissime, et superbissimi apparati, fatti nelle felicissime nozze de gl'Illustriss. SS. il Sig. Marco Pii di Savoia, Signor di Sassuolo et della Signora Clelia Farnese* (Ferrara: Vittoria Baldini, 1587), p. 5.
87 De' Sommi, *Quattro Dialoghi* in Nicoll translation.
88 De' Sommi, *Quattro Dialoghi* in Nicoll translation, p. 274.
89 Furttenbach, *Recreational Architecture* in Kernodle translation, p. 202. I have quietly emended 'purple-colored' to 'rosy-fingered', since I am sure Furttenbach's allusion is to Homer's epithet.
90 De' Rossi, *Descrizione* in Surgers translation, p. 125.
91 Sabbattini, *Pratica di Fabricar* in McDowell translation, pp. 59–61.
92 Sabbattini, *Pratica di Fabricar* in McDowell translation, pp. 111–13.
93 Sabbattini, *Pratica di Fabricar* in McDowell translation, p. 275.
94 Ivaldi, *Le Nozze Pio-Farnese*, p. 22.
95 Nagler, *Theatre Festivals*, p. 73. None of the contemporary sources say how this was done.
96 Surgers, *La Pellegrina*, pp. 128 n. 96 and fig. 24, p. 129, suggests that Buontalenti used a type of device illustrated by Hero in the *Pneumatics*, Theorems 72 and 73. It is attractive to think that Hero was Buontalenti's inspiration. But Hero's designs are for lamps in which the supply of oil is adjusted automatically, not where the light is turned on and off; and equipping each of these hundreds of lamps with such devices would have been extremely cumbersome. There is a longer Florentine tradition of automatic controls on theatrical lamps, as described in Chapter 2.
97 Surgers, *La Pellegrina*, p. 99.
98 Povoledo, 'Scenografia in Italia', p. 488.
99 Armando Fabio Ivaldi, *Le Nozze Pio-Farnese*, p. 23. Ivaldi precedes this sentence with virtually the same words as Povoledo (n. 99), but applied to Aleòtti.

Intermezzo: Moving pictures

At the exact same time as Buontalenti and Aleòtti were creating a style of theatre that might be described metaphorically as 'cinematic', an experiment was being tried in Naples with a different type of dramatic entertainment that truly can be seen as the ancestor of the cinema.

In 1558 the Neapolitan 'professor of secrets' Giovanni Battista della Porta published a highly popular book called *Natural Magic*, which went into many editions and languages.[1] Natural or white magic is to be distinguished from occult or diabolical black magic: della Porta's book describes a whole series of phenomena and effects that might seem to the innocent observer to be miraculous, but which nevertheless can be accounted for by physical causes. For the 1589 edition della Porta added an extra section to his chapter 17, 'Of Strange Glasses'. This gave an account of a new type of show with which he had often amused his friends. The text here is from the 1658 translation into English:

> That in a dark Chamber by white sheets objected, one may see as clearly and perspicuously, as if they were before his eyes, Huntings, Banquets, Armies of Enemies, Plays, and all things else that one desireth. Let there be over against that Chamber, where you desire to represent these things, some spacious Plain, where the Sun can freely shine: Upon that you shall set Trees in Order, also Woods, Mountains, Rivers, and Animals, that are really so, or made by Art, of Wood, or some other matter. You must frame little children in them, as we use to bring them in when Comedies are Acted: and you must counterfeit Stags, Bores, Rhinocerets, Elephants, Lions, and what other creatures you please: Then by degrees they must appear, as coming out of their dens, upon the Plain: The Hunter must come with his hunting Pole, Nets, Arrows, and other necessaries, that may represent hunting… Swords drawn will glitter at the hole, that they will make people almost afraid.[2]

Della Porta's friends were wholly delighted, and he found it difficult, when he revealed the secret, to persuade them that all was done by 'natural reasons, and reasons from the Opticks'.[3]

What were these 'reasons from the Opticks'? Della Porta explains that the show was produced with a camera obscura (Latin: 'dark chamber'). The camera obscura at this period was typically a blacked-out room, with a convex glass lens set in an aperture in a door or window shutter. An image of the scene outside was thrown onto a wall or screen opposite the lens. Figure A.1 shows the arrangement. In this most basic type of camera the image is upside down. The camera obscura was the forerunner of the photographic camera: in the nineteenth century modern photography was created by the addition of the light-sensitive plate, onto which the image was fixed.

The principle of the camera obscura was known in the ancient world and was described by Aristotle. Up until the sixteenth century cameras had pinholes, not lenses, and the images were very faint. Once equipped with a glass lens, however – say 10 centimetres in diameter – a camera could produce a large bright image of an outdoor sunlit scene. The image would of course be in full colour, and if anything in the scene moved, the image would move with it. Figure A.2 shows a portable booth camera illustrated by Athanasius Kircher in his

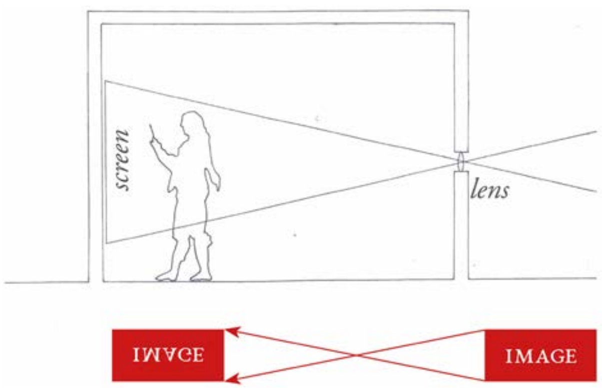

Figure A.1 Basic arrangement of a camera obscura, with a convex lens casting an image onto a wall opposite serving as a screen. As shown by the word IMAGE, the image created by the camera is both upside down and mirrored.

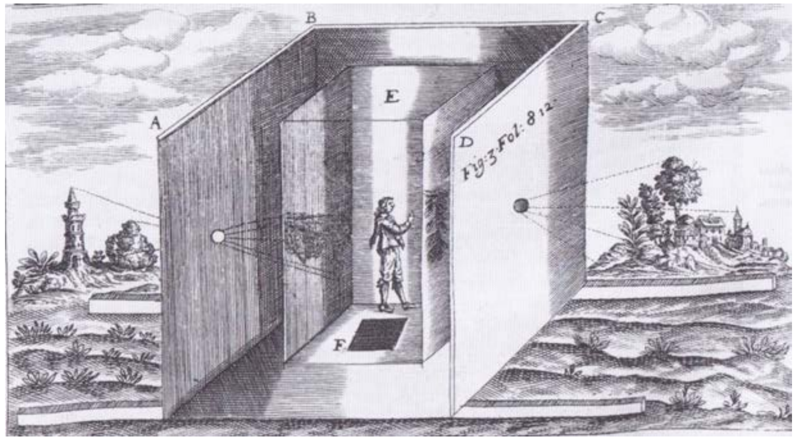

Figure A.2 Design for a portable booth camera obscura by Athanasius Kircher. The image is projected onto a translucent screen, which the artist studies from the back.

book *The Great Art of Light and Shadow*.[4] Here the image is projected onto a translucent screen made perhaps of oiled paper or thin cloth. An artist studies and traces this image from the opposite side of the screen.

Going back to della Porta: in order to create his entertainment, he must have turned a room in his house into a camera obscura. His child actors or puppets would then have performed outdoors against a background of painted or natural scenery, lit by the sun. Their moving images would have been cast onto some kind of screen. I have assisted at a recreation of della Porta's show in an English country house for a television programme. We blacked out a ground-floor drawing room and put a large convex lens into a window blind. Gentlemen in Tudor costume fought with glittering swords among the topiary in the garden outside. (The budget did not run to Rhinocerets.)

Figure A.3 shows a photograph of the scene projected onto the screen of our room-sized camera – in effect a 'still' from the 'film'.[5] Our camera was of the simplest type as in Figure A.1, and the images of the swordsmen were upside down. Perhaps della Porta had some optical means of righting his images. He mentions, albeit in vague terms, how this can be done either with concave mirrors and convex lenses in combination, or with plane mirrors angled at 45 degrees. In the eighteenth century, booth-type cameras became popular for drawing landscapes: these used mirrors, as described by della Porta, to turn the picture right way up. The optics expert Tim Jenison has recently

Figure A.3 Image obtained with a camera obscura of the type shown in Figure A.1 – hence the inversion of the image – built for a reconstruction of della Porta's optical theatre for a television programme. Focus is lost at the lower right because the aperture of the lens is large and the bushes are close to the lens. Della Porta might have arranged for the depth of his scene to be not so great, so that the image could all be in sharper focus.

recreated della Porta's camera 'cinema' using a flat mirror to rectify the image.[6]

The versatile Dutch engineer Cornelis Drebbel, writing in the early seventeenth century, described a show that was possibly another kind of camera obscura theatre. Drebbel's fame has been growing in recent years but is still not as great as it should be, for several reasons: he published little; he kept the secrets of many of his inventions, since they were his stock in trade; and he applied his advanced knowledge of physical principles and chemical processes to what were in many cases showpieces or marvels. He was nevertheless very much admired and celebrated in his lifetime. He worked in England for James I and

Charles I, and was attached for a time to the court of Rudolf II in Prague. Constantijn Huygens, Secretary to the Prince of Orange in Holland and father of the astronomer Christiaan Huygens, compared Drebbel to the great natural philosopher (and Chancellor of England) Francis Bacon, describing Drebbel as 'unequal in rank but not in talent'.[7]

In 1608 or 1609 Drebbel wrote to Ysbrandt van Rietwyck, an acquaintance in his hometown of Alkmaar.[8] In the letter Drebbel describes an entertainment in which he has the starring role:

> I take my stand in a room and obviously no one is with me. First I change the appearance of my clothing and in the eyes of all who see me. I am clad first in black velvet, and in a second, as fast as a man can think, I am clad in green velvet, in red velvet, changing myself into all the colours of the world. Nor is this all, for I can change my clothing so that I seem to be clad in satin of all colours, now cloth of gold, now cloth of silver; and I present myself as a king, adorned in diamonds, and all sorts of precious stones, and then in a moment become a beggar, all my clothes in rags …[9]

Drebbel could also become a 'tree with all my leaves fluttering as if in a breeze'. He could transform himself into a lion, a bear, a horse or a cow. He could create the illusion 'that the earth was opening and ghosts arising from it, first as a cloud and then in the forms of good spirits, such as Alexander the Great or another prince or king'.

Drebbel, true to form, offers no explanation of how this was done, and we have no accounts from anyone who saw the show. So maybe he is just 'windbagging' about all this, as the Dutch say. But he was at the very centre of optical research in the early seventeenth century, so it is possible, at least, that he could have put on a performance of this kind using some optical means.[10] He was known for his lenses, telescopes and microscopes. He was acquainted with the Middelburg spectacle-maker Zacharias Jansen and with Jacob Metius of Alkmaar, both of whom ground lenses. He made significant improvements to the design of microscopes – and he built camera obscuras.

It has been suggested that Drebbel might have put on his costume-changing show using either a camera or a magic lantern. Much later in the history of the lantern, there were indeed variety performances of exactly the kind that Drebbel describes. The American dancer Loïe Fuller became famous in the 1890s for her 'serpentine dances' in which plain colours or images of butterflies, birds or flowers were projected with slides onto her floating diaphanous white dress. Fuller starred in this act at the Folies-Bergère and was so successful that she was able to build her own theatre.[11]

The year 1608 would have been very early for Drebbel to build a lantern, however. Historians generally agree that it was the Dutch mathematician and astronomer Christiaan Huygens, son of Constantijn, who devised the first true magic lantern in the late 1650s.[12] Might Drebbel have used a camera obscura for his entertainment? Jean-Noël Paquot, historian of the Netherlands, says that Drebbel 'made instruments by means of which were seen pictures and portraits; for instance he could show you kings, princes, nobles, although residing at that moment in foreign countries; and there was no paint or painter's work to be seen, so that you saw a picture in appearance, but not in reality'.[13] This strongly suggests a camera obscura arrangement in which Drebbel had pictures or actors outside the room. Might he have extended this principle to his garment-changing show?

This is entirely conjectural, but one can imagine that he could have had an assistant in a space adjoining the camera, brightly lit by the sun but in front of a black background. The position could have been marked on the ground at which this second person should stand in order to project an image inside the camera, coinciding in position and size with Drebbel's body. The assistant would have had suits of clothes of different colours ready to hand and could have stepped in and out of position to change (or there might have been several assistants ready dressed). He would be wearing a black mask. His clothes but not his face would thus have been projected onto Drebbel's body. If Drebbel's camera were of the simple type shown in Figure A.1, his assistant would have had to be upside down, which seems improbable. Maybe he had an optical means of rectifying the image. Tim Jenison has recreated Drebbel's show in another way, with a type of lens-less 'lantern', using a large convex mirror reflecting the sky as the source of illumination.[14] Slides – which do not then need to be inverted – can be introduced to cast colours or designs onto the performer's clothing. The results are impressive.

Drebbel says that he starts out with a black velvet costume. But if he had actually been dressed in white, this would have allowed different colours (including black) to be projected onto him. The trees, cows, ghosts and Alexander the Great could have been produced as in della Porta's theatre. This, however, is all supposition. By contrast, there are descriptions of some other seventeenth-century 'camera obscura theatres' by people who actually saw them.

In 1638 a Parisian member of the Order of Minims, Father Jean-François Niceron, published *Curious Perspective*, a book about a class of trick pictures known as anamorphic perspectives.[15] In the book Niceron has a short section on the camera obscura, in which he describes an entertainment in Paris that seems to have been technically comparable with della Porta's optical theatre, but whose character appears to have been altogether more dubious and disreputable.[16] This theatre was on the Pont Neuf near the pump house known as the Samaritaine. In the seventeenth century the bridge was always busy, the crowds entertained by all kinds of street performers: jugglers, magicians, fire-eaters and tumblers. There were quack doctors, tooth-pullers, pamphlet-sellers and pickpockets.

Niceron's account is a little confusing, and it is not easy to understand quite what went on inside what was presumably a small room with seats. He says: 'This kind of ravishing Perspective has sometimes so deceived the eyes of those in the chamber, that after having lost their purse, they see this in the hands of those who count and carry away their money in a wood or on a floor, thinking this representation is made by magic.'[17] The charlatan in charge of the show uses a whistle or other signal to alert accomplices who are seen on screen by the audience, picking pockets and counting their loot on the bridge outside. If this is indeed what happened, it raises the obvious question of why people would pay good money to watch themselves and others being robbed? One point on which Niceron is clear, however, is that there are several ways of righting the inverted images in a camera 'either by means of convex spectacle lenses, or with a mirror, and also to make them larger, to make them life size'.[18]

In 1656 the French writer Jean Loret described (in verse) what sounds like another camera obscura theatre, again in Paris, but at the opposite end of the social spectrum.[19] This was at the Hôtel de Liancourt where Loret and his companion Madame de Choisy saw beautiful palaces, ballet dancers and swordsmen with flashing rapiers, appearing on a large white cloth. The dancers and swordsmen moved *with their feet in the air*.

Finally, there is an optical show described by the great natural philosopher Robert Hooke, curator of experiments to the Royal Society in London, in a paper dated 1668.[20] There is no question about the optics this time: Hooke is definitely describing a camera. He says that one must make a hole in the wall opposite where the image is to appear, and place in it a convex lens such that 'it may represent the Object distinct on the said place'. The object or objects outside must be well lit by reflecting either the sun onto them in the day, or the light from torches or lamps at night, using mirrors. Alternatively, a transparent picture can be lit from behind. The objects are to be set upside down, so that their images are the right way up. However, 'If the Object cannot be inverted, as 'tis pretty difficult to do with Living Animals, Candles &c', then a rectified image can be produced with a combination of two lenses.

This was not just a theoretical idea of Hooke's. Henry Oldenburg, publisher of the Royal Society's *Transactions*, adds in a note that he had been present at shows of this kind given by Hooke to the Society 'some years since'. Hooke says that his experiment 'hath not, that I know, been ever made by any other person this way'.[21] But we know that della Porta had anticipated Hooke by more than a century. Maybe Hooke had just been reading the English edition of della Porta's *Natural Magic*, which was published in 1658.

Why would people trouble or even pay to see a projected image, indoors, when they could stay outside and look at the real thing? On the face of it, this is odd. There are several reasons, I would suggest. It is worth reiterating that these camera obscura theatres would have showed mobile images in fine detail and full colour, which would have been even more impressive to their inexperienced audiences than were the first (black and white) movies in the late nineteenth century, especially if the actual players and sets were kept secret and out of sight.

The camera obscura image remains somehow magical even to us today who are so familiar with photographs and films. Seen in the semi-darkness, the colours give the impression of being more concentrated and luminous than in direct vision. Part of the fascination is that, even in a largely static landscape, there are small details that move: clouds drift in the sky, leaves flutter in the wind, birds wheel across the screen. This is why large camera obscuras at the tops of towers or at seaside resorts, projecting all-round panoramas, became popular in the nineteenth century, and remain so today.

Even so, judging by the paucity of descriptions, there can have been only a few of these 'proto-cinemas' actually built and exhibited in the sixteenth and seventeenth centuries. Huygens's magic lantern offered a comparable form of optical entertainment that proved much more successful. This was probably because the lantern was more versatile, it did not require actors, sets and sunshine as the camera obscura theatre did, and its subject matter was limited only by the slide painter's imagination and skill. Athanasius Kircher put on lantern shows in Rome (Figure A.4), and even hinted that he was the instrument's inventor.[22]

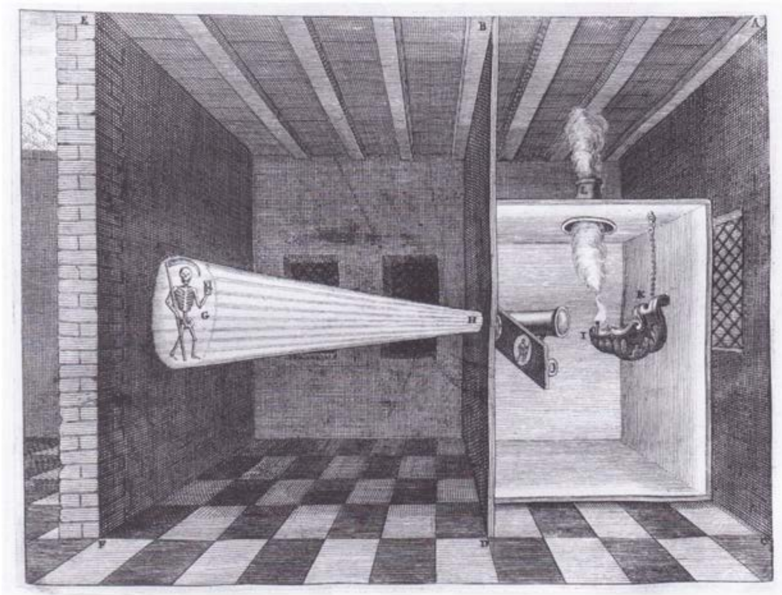

Figure A.4 A magic lantern illustrated by Athanasius Kircher in *The Great Art of Light and Shadow*, projecting an image of Death.

Right at the start of the lantern's development there were mechanisms devised by which the images on the screen could be given simple movements. Huygens himself published sketches for mobile slides showing a jaunty skeleton in several positions, taking off his own skull and examining it like Hamlet's gravedigger and poor Yorick (Figure A.5).[23] Kircher's slides featured Death with his scythe and damned souls burning in Hell. This association of the magic lantern with the diabolical and the spooky was to persist until the late nineteenth century.

The reasons were doubtless connected with the technical practicalities of early lanterns. Because the available light sources were weak, the shows had to be held at night or in curtained rooms. Candles and oil lamps gave a flickering, uneven light, and the projected images must have had a ghostly, insubstantial quality, while the focus would not have been completely sharp. The lantern was thus intrinsically suited to creating spectral visions. Like ghosts, these projections could be made to appear from nowhere, change size and disappear again just as abruptly. Paradoxically, the unreal could be represented more convincingly than the real. These were the dark reasons why the lantern was 'magic'.

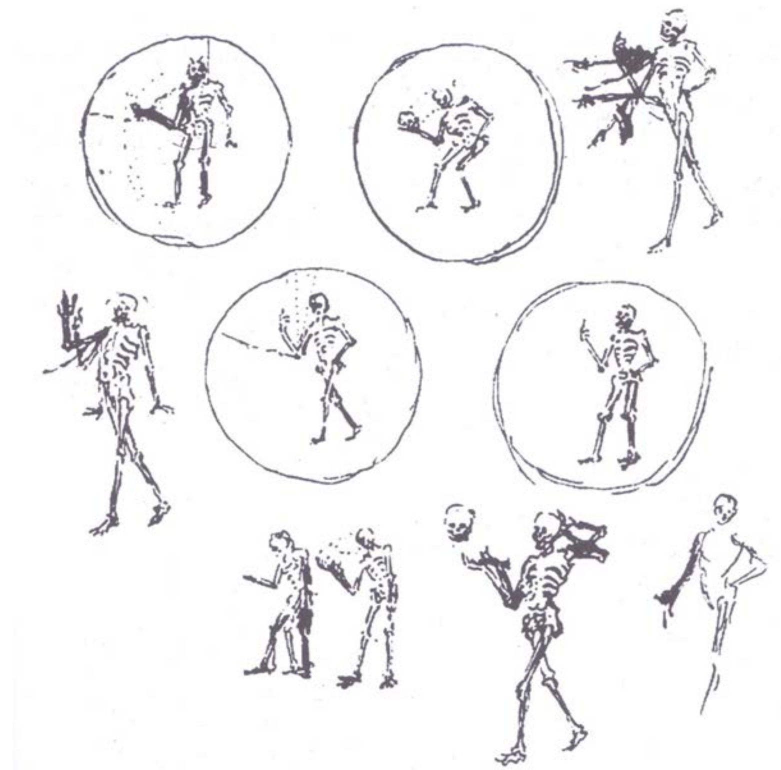

Figure A.5 Sketches made by Christiaan Huygens in 1659 for an animated lantern slide, showing a skeleton removing its own head.

Notes

1 Giovanni Battista della Porta, *Magia Naturalis*, 4 vols (Naples: 1558). A second edition was published in 1589 in 20 volumes, and many editions in other languages including English followed.
2 *Natural Magick by John Baptista Porta, a Neapolitane*, trans. Thomas Young and Samuel Speed (London: 1658), pp. 364–5.
3 *Natural Magick*, p. 365.
4 Athanasius Kircher, *Ars Magna Lucis et Umbrae* (Rome: 1646), p. 709, plate 28. Kircher had seen this design of camera in Germany. The figure shows *two* similar cameras back to back. What the purpose of this might be is unclear, unless it is a device of the illustrator to show the same set-up from two different angles.
5 'Seeying the worlde' in TV series *What the Tudors Did for Us*, BBC (2000).
6 Tim Jenison, personal communication.
7 A. G. H. Bachrach, 'The Role of the Huygens family in Seventeenth-Century Dutch Culture', in H. J. M. Bos, M. J. S. Rudwick, H. A. M. Sneiders and R. P. W. Visser (eds), *Studies on Christiaan Huygens* (Lisse: Swets and Zeitlinger, 1980), p. 37.
8 In Ms. Constantijn Huygens – bundel XLVII der Koninklijke Nederlandse Akademie van Wetenschappen, folio 207 r–v.

9 Translation by Rosalie Colie in 'Cornelis Drebbel and Salomon de Caus: Two Jacobean Models for Salomon's House', *Huntington Library Quarterly*, 18, 3 (May 1955): 245–60; see p. 254.
10 Biographies of Drebbel include L. E. Harris, *The Two Netherlanders: Humphrey Bradley and Cornelis Drebbel* (Cambridge: W. Heffer and Sons, 1961), and Gerrit Tierie, *Cornelis Drebbel (1572–1633)* (Amsterdam: H. J. Paris, 1932).
11 See entry on 'Loïe Fuller' in David Robinson, Stephen Herbert and Richard Crangle (eds), *Encyclopaedia of the Magic Lantern* (London: The Magic Lantern Society, 2001), pp. 118–19.
12 Willem Albert Wagenaar, Lodewijk Wagenaar and Margreet Wagenaar-Fischer, 'The True Inventor of the Magic Lantern: Kircher, Walgenstein or Huygens?', *Janus*, 66 (1979): 193–207.
13 Jean-Noël Paquot, *Histoire Littéraire des Pays-Bas* (Louvain: 1765–70), quoted in translation by William Brenchley Rye, *England as Seen by Foreigners in the Days of Elizabeth and James the First* (London: John Russell Smith, 1865), p. 234.
14 Tim Jenison, personal communication. The slide images are very bright and always in focus, and can be made larger or smaller by moving the slides towards or away from the target. But there is no documentary evidence that Drebbel worked this way.
15 Jean-François Niceron, *La Perspective Curieuse ou magie artificielle des effets merveilleux* (Paris: Billaine, 1638). Niceron later published an extended version in Latin, *Thaumaturgus opticus, seu Admiranda optices per radium directum, catoptrices per radium reflectum* (Paris: Langlois, 1646).
16 Jean-François Niceron, *La Perspective Curieuse*, 2nd edn in 4 vols (Chartres and Paris: 1652), vol. 1, p. 22.
17 Niceron, *La Perspective Curieuse*, vol. 1, p. 22. My translation.
18 Niceron, *La Perspective Curieuse*, vol. 1, p. 23. My translation.
19 Jean Loret, *La Muze Historique ou Receuil des Lettres en Vers* (Paris [?]: Daffis, 1877), vol. 2 (1655–8), Letter 19, 13 May 1656.
20 Robert Hooke, 'A Contrivance to Make the Picture of Any Thing Appear on a Wall, Cub-board, or Within a Picture-frame &c', *Philosophical Transactions*, 38 (Monday 17 August 1668): 741–3.
21 Robert Hooke, 'A Contrivance', p. 741.
22 Kircher, *Ars Magna Lucis et Umbrae*, 2nd edn (Amsterdam: 1671).
23 See Laurent Mannoni, *The Great Art of Light and Shadow: Archaeology of the Cinema* (Exeter: University of Exeter Press, 2000), pp. 38–9.

2
A theatre of machines

The Italian *intermezzi* astounded their audiences with the fires of Hell, ships in full sail crossing stormy seas, mountains seeming to grow out of the stage and, above all, with actors, chariots and monsters flying through the skies. All these effects were achieved with machines, or *ingegni*, whose design reached peaks of elaboration and sophistication in the early seventeenth century.[1] However, some such machinery, especially for stage flying, has a much longer history.

Gods moving in mysterious ways

The most spectacular effects in the ancient theatre were achieved by machines that lifted actors playing heroes or gods from the stage or lowered them from above. In his dictionary the *Onomasticon*, Julius Pollux lists a number of machines used in stage productions.[2] There are references too in the texts of classical plays themselves – in the very occasional stage direction, but more often through dialogue that refers explicitly to characters moving to and from 'the Heavens' on top of the *skene* building at the back of the stage.

Pollux mentions what seem to be three different machines. There were the pendant-cables, which were ropes let down from above – presumably from the top of the *skene* – perhaps using a block and tackle. There was the crane, which had some kind of swinging arm, and worked faster than the cable device. The crane, says Pollux, could be used for swooping down, grasping and lifting up a body, as the goddess of the dawn Aurora did when seizing the corpse of her dead son Memnon. Pollux also says that something called the celestial scaffold – another kind of crane on a tower perhaps – was placed at the left-hand end of the stage, at a height above the *skene*. This supported 'Gods and Heroes that are in the air'.

The crane was employed in the earliest Greek tragedies. Euripides used it in *Medea* in 431 BC, where the heroine and her two dead sons are carried up into the air in a chariot. Other plays featured characters riding on flying animals, as for example the winged horse Pegasus ridden by *Bellerophon* in Euripides' play of that title. (The animals were perhaps stuffed, or dummies.)

The classicist Donald Mastronarde has made a special study of the crane in fifth-century drama, using these various sources of information.[3] He considers various options for actors climbing up and coming down from the *skene* roof without special apparatus. But he is finally convinced that a type of crane was used in the form of a long beam pivoted close to one end, with a heavy counterweight. The actor would have been suspended from a harness or trapeze on the opposite end. The machine would have been concealed behind the (single-storey) *skene* building. Operated by two or three men, it could have swung the actor up from behind the building to land on the roof.[4]

Mastronarde points out the similarity of his proposal to a crane-like machine used widely throughout the Mediterranean world for raising water from wells or streams, called the *swape* or well sweep.[5] The historian of technology Abbott Payson Usher says that the Romans also used the *swape* in warfare for lifting men up to attack fortifications. The writer of comedies Antiphanes talked about tragic dramatists raising the μηχανη (machine) 'like a finger', which would also suggest a crane of this form.[6] Mastronarde argues that a machine of his own design could have been moved quickly enough to maintain an element of unpredictability and surprise.

One might think that actors dangling from ropes and harnesses in full view would have seemed laughable and undignified, especially in the tragic drama. Contemporary audiences seem to have been imaginative enough to accept the artifice. But later Aristophanes in his comedies mocked Euripides' frequent use of the crane. In *The Clouds*, Socrates appears in the air in a basket, explaining that this helps him 'suspend his judgment'.[7] The plot of Aristophanes' *Peace* turns on the hero Trygaeus' attempt to contact the gods by flying up to meet them on the back of a giant dung beetle.[8] Much play is made of the erratic behaviour of the crane hoisting the beetle, Trygaeus calling out to the operator 'Oh oh, I'm really scared, and I'm not joking now! Stage mechanic, pay attention, because some wind's already churning around my navel, and if you aren't careful I'll be foddering the beetle.'

As a young man, the mysterious English magus and mathematician John Dee was for a time a fellow of Trinity College Cambridge. In the late 1540s he put on a production of Aristophanes' *Peace* in the college hall.[9] The high point was the flight of Trygaeus on his beetle and their disappearance from sight. 'Whereat', says Dee, 'was great wondring, & many vaine reportes spread abroad, of the meanes how that was effected'.[10] Dee kept quiet, although he was nervous in case it might be thought he had used occult powers. But he had a great advantage over the ancient Greek theatre, that the hall at Trinity had a *roof*. This was true of the churches and theatres in the Renaissance where celestial personages also appeared and disappeared above the audience.

Flying in the *sacra rappresentazione*

From the 1430s onwards the talents of some of Florence's leading architects and engineers – Filippo Brunelleschi, Francesco d'Angelo (known as Il Cecca) and Giorgio Vasari – were enlisted in the preparation of machines for the city's special type of religious drama, the *sacra rappresentazione*. Two subjects in particular called for flying machinery: the Annunciation, when the archangel Gabriel comes down from Heaven to visit the Virgin Mary and brings her the news that she is to conceive, and the Ascension when Jesus rises to Heaven 40 days after his Resurrection.

A great deal is known about these productions from written sources, specifically Giorgio Vasari's *Lives of the Artists* and the *Itinerary* of a Russian bishop, Abraham of Souzdal, who saw an Annunciation and an Ascension in 1439.[11] Bishop Abraham was attending the Council of Florence at which the Orthodox and Roman churches met to debate doctrinal matters. Theatre historians have made reconstructions of the apparatus that so impressed the Russian visitor. There are, however, no contemporary pictures of these particular plays.

The 1439 Ascension was presented in the church of Santa Maria del Carmine. Scenery was erected on top of the *tramezzo*, a screen wall that separated the nave from the choir – something like a rood screen but much more substantially built. At the left was a castle with towers and bastions, representing Jerusalem, and at the right the Mount of Olives, a wooden construction draped in red cloth. The historian of the Florentine theatre Ludovico Zorzi and his collaborator Cesare Lisi have built a delightful model reconstructing this set from Abraham's description (Figure 2.1).[12]

Up in the roof, above the mountain, is a rectangular wooden structure with a circular opening, some 2 metres in diameter. Bishop Abraham describes this aperture:

> draped with a blue curtain, on which the sun, the moon and the surrounding stars are painted: a representation of the first celestial sphere. At the appointed time this drape is lifted, that is, the doors of Heaven are opened, and above is seen a man with a crown on his head, just like God the Father … He seems, as he hovers in the air, not to be supported by anything. Around him is a throng of little children who represent angels with pipes and lutes and lots of tiny bells, and in their midst numerous tiny candles.[13]

Abraham is not specific as to where this opening was in the box of the Heavens. Zorzi and Lisi assume it to be a vertical aperture in one of the walls, as we see in their model. But the art historian Alessandra Buccheri has argued instead that the opening was in the base of the structure, so that the audience looked upwards into Heaven.[14] God was suspended in the air seeming 'not to be supported by anything', and the angels stood precariously in a ring around the edge of the hole.

In the performance, the actor playing Jesus emerged from Jerusalem and climbed the Mount of Olives. An 'exceedingly beautiful and cleverly constructed *nuvola* [an artificial cloud]' surrounded by 'swiftly turning discs' started to descend from Heaven, carrying two child actors dressed as angels with golden wings.[15] When this cloud reached the halfway point, Jesus began to ascend towards it, blessing Mary and the Apostles as he rose. Jesus and the *nuvola* met in mid-air in a great burst of light, and together they continued upwards. As Jesus stepped out into Heaven, the music stopped and the lights faded.

Bishop Abraham explains that the cloud and Jesus were suspended on cords by means of a 'clever pulley system', and that this allowed Jesus to rise 'without wobbling'.[16] He says no more about the machinery, but we can safely assume that the ropes were lowered and raised with winches in the roof of the church. Abraham says that the 'apparatus with the ropes' for lifting Jesus was prepared, no doubt by attaching a harness, when he was on the mountain. This simple technology was not greatly different, it seems, from that used for flying up and down in ancient and medieval precursors of the *sacre rappresentazioni*.

Figure 2.1 Machinery for the Ascension in Santa Maria del Carmine, Florence in 1439: model reconstruction by Ludovico Zorzi and Cesare Lisi, photo by kind permission of Città Metropolitana di Firenze.

Vasari describes similar *ingegni* built by Il Cecca in the same church for a later Ascension play, probably in the 1460s.[17] He adds: 'Filippo Brunelleschi had made such things much earlier'.[18] On this basis it seems reasonable to assume, as most historians have, that

Brunelleschi was responsible for the machinery that Abraham saw in 1439, and that Cecca followed in his footsteps.

In Vasari's autobiographical *Life* he gives an account of the designs that he himself had made for a production of the Annunciation in the church of San Felice in Piazza, a century later.[19] Figure 2.2 shows another model built by Zorzi and Lisi, with the machinery in place.[20] Heaven was once again a structure in the roof containing a

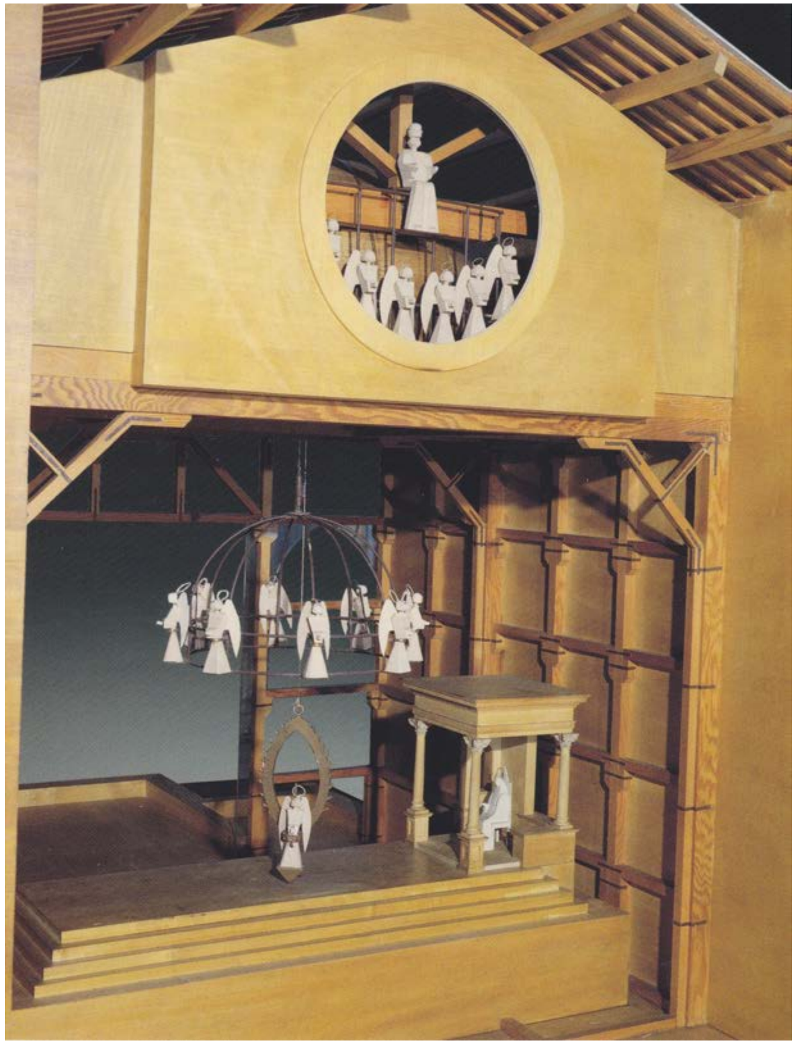

Figure 2.2 Machinery for the Annunciation in San Felice in Piazza, mid-fifteenth century: model reconstruction by Ludovico Zorzi and Cesare Lisi, photo by kind permission of Città Metropolitana di Firenze.

large hemispherical dome 'like a barber's basin facing downwards' (*not* in the side wall as in the model). Below this there was suspended an iron framework resembling a chandelier or the skeleton of a giant umbrella. On each of the eight branches was a wooden stand 'the size of a breadboard' supporting a boy angel, strapped in, but held loosely enough that he could turn in any direction. This structure was known as a *mazzo* (bouquet) – a decorative bunch of angelic flowers. Inside the *mazzo* was a *mandorla*, a frame made of copper in the shape of an almond in which a youth stood playing the part of the archangel Gabriel. He too was secured with an iron restraint that nevertheless gave him enough freedom to kneel.

The *mandorla* is an iconographical device used in religious painting and sculpture to surround the figure of Christ or the Virgin. It is a kind of halo of light around the entire body, sometimes also thought of as a cloud. The *mandorla* at San Felice had holes around the rim in which lamps were placed in tubes 'hollowed out like cannons'. Gabriel could turn these lights on and off with a spring mechanism. In the performance the *mandorla* was lowered onto the *tramezzo* and secured in position by a hidden stagehand, who also released Gabriel. The archangel then stepped out, saluted the Virgin and 'made his announcement'. As Vasari says, 'Thus the Heaven, the mazzo, God the Father, the mandorla with its infinity of lights and the sweetest music truly represented Paradise.'[21]

There are two drawings dating to around 1470 by Buonaccorso Ghiberti, grandson of the famous Florentine sculptor Lorenzo Ghiberti, that illustrate machinery for raising and lowering angels and a *mandorla*, not in a church play but in a street procession.[22] At the base of the structure is a wooden platform to be carried along by a team of strong-shouldered porters (Figure 2.3). This base supports a tall mast to which the *mandorla* is attached and, higher up, a framework for just two angels in this design. Ghiberti has shown the footrests and adjustable clamps to which the child actors are secured. The *mandorla* appears to emit flames of light.

The second sketch (Figure 2.4) illustrates the winch used to raise and lower the two moveable structures, with its gearing. The design for the *mandorla* shows in detail the large number of lamps around its edges and the mechanism with which they are hidden or revealed, hence seeming to turn off and on. This is done by moving open-ended metal cylinders over the lamps and retracting them again, with spring-loaded cords. Perhaps Buontalenti drew inspiration from this kind of device for the controllable lighting systems in the *intermezzi*, again using metal cylinders, as described in Chapter 1.

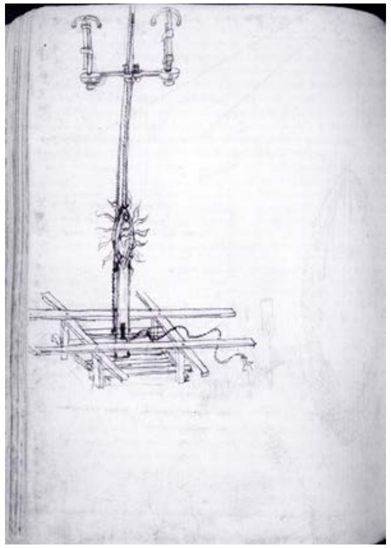

Figure 2.3 Drawing by Buonaccorso Ghiberti, c.1470, of machinery for a religious street procession. The mast carries a *mandorla* and, at the top, two brackets to which children dressed as angels are secured. By kind permission of the Biblioteca Nazionale Centrale, Firenze.

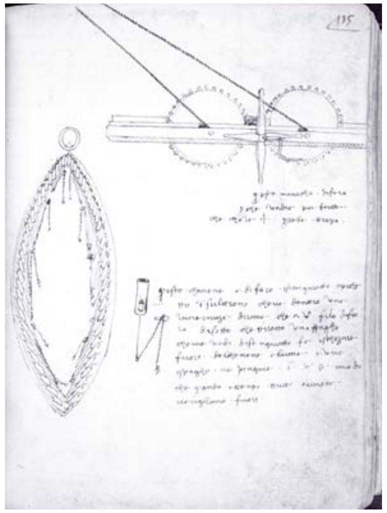

Figure 2.4 Drawing by Buonaccorso Ghiberti, c.1470, of machinery for a religious street procession, showing details of Figure 2.3. At the top is the winch with which the *mandorla* and the angels are raised, and below is the *mandorla* itself with its many lamps. The metal tube by which each lamp can be revealed or hidden is shown in a detail. By kind permission of the Biblioteca Nazionale Centrale, Firenze.

Religious plays, similar in choreography and apparatus to their fifteenth-century forerunners, are still performed today in Sicily and Andalucia. Figure 2.5 shows a scene from a modern performance in Elche, Spain, which follows a musical score composed in 1625.[23] The subject is the death and coronation of the Virgin, so here it is she who is carried up to Heaven. She travels in a fruit-like vehicle called the 'pomegranate' with petals or segments that open and close, supported and controlled from the roof of the church with ropes. Angels accompany her, playing guitar and harp, and she is crowned and showered with gold tinsel as she rises.

Finally, in this account of the Florentine *sacre rappresentazioni*, let us go back to the second play that Bishop Abraham attended in 1439, another Annunciation. I have left this to last, since the style of flying involved was distinctively different from what we have seen so far: it was horizontal rather than vertical. The performance was possibly in

Figure 2.5 The 'pomegranate' vehicle in which the Virgin rises to Heaven in the sacred play performed annually in Elche, Spain. Wikimedia Commons: Misterio di Elche, La Mangrana.

the church of the Santissima Annunziata, named for the Annunciation – although this is uncertain.[24] We can assume, on Vasari's testimony, that the designer was Brunelleschi. Figure 2.6 shows Zorzi and Lisi's model reconstruction.[25]

The two settings for the action, Heaven and Earth, were in this performance at opposite ends of the nave. The Virgin's house was on the *tramezzo* as before. Impersonated by a beautiful boy, she sat quietly reading a book. Heaven was in a specially constructed tribune, a gallery raised on columns over the church doors. God the Father sat on a throne surrounded by child angels and 500 little oil lamps, in front of a set of painted concentric circles representing the seven spheres of Heaven. The distance between these two 'stages' was some 25 metres.[26]

Brunelleschi's problem, clearly, was to propel the archangel Gabriel along the nave, over the heads of the audience. This and the Ascension machinery would hardly have been a challenge for Brunelleschi, who at this time was designing hoists and machines of great complexity and power for the erection of the huge dome of Florence Cathedral. For the

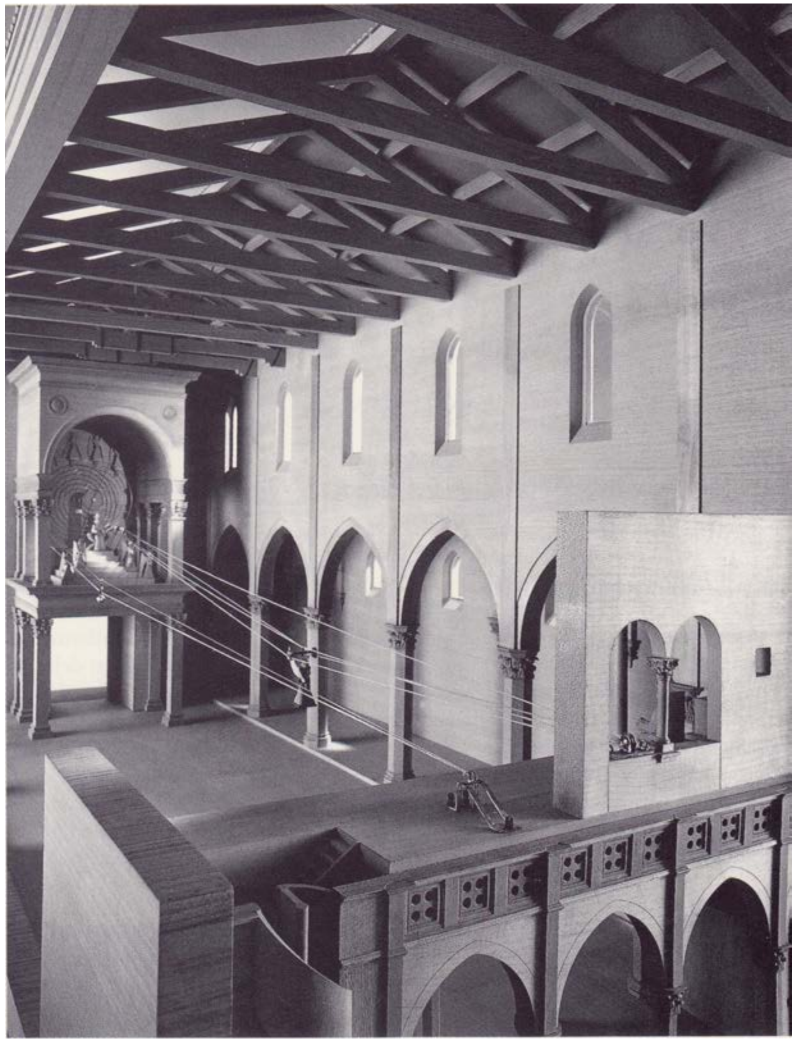

Figure 2.6 Machinery for the Annunciation in the Santissima Annunziata, Florence in 1439: model reconstruction by Ludovico Zorzi and Cesare Lisi. The ropes stretched from Heaven to earth carry the archangel Gabriel and the Holy Spirit. Photo by kind permission of Città Metropolitana di Firenze.

Annunciation he stretched five strong ropes from Heaven to earth. Two of the ropes supported Gabriel, who had two small wheels on his back attached to a harness, one running on each rope. A third rope was used to pull him along.

The play opened with a lengthy debate between four prophets. There was then a burst of thunder, and curtains opened to reveal Heaven. Gabriel emerged, holding a branch in his hand, and flew along the ropes, singing softly as he went. He arrived in front of the Virgin and courteously announced himself. Once Mary, after some doubts, understood her destiny, Gabriel started on his return journey. There was a continuous roar of thunder, and a flash that moved along the ropes to the middle of the *tramezzo* where the Prophets stood. The fire

> blazed quickly up and sprang down again, so that all the church was full of sparks … Flames came down from the upper platform and exploded all over the church with terrifying thunder, and lights all over the church which had been extinguished were lit by the flash, but it did not scorch the clothes of the spectators or harm them in any way …[27]

This fire – however it was made – seems to have run along the fourth rope, pulled with the fifth. The flame symbolised the Holy Spirit passing from God to the Virgin, usually represented as a golden ray in contemporary paintings. Bishop Abraham might have been particularly interested – although he does not write about it – given that one key theological point for discussion at the Council of Florence was the character of the third person of the Trinity. Orville Larson suggests that the fire and light were produced with a burning charcoal brazier running on the rope, which seems hugely reckless, even in days when concern for the safety of audiences was less acute than today.[28] It is more likely in my view that Brunelleschi employed a pyrotechnic device of some kind, perhaps involving powdered resin, which burns fiercely and very brightly but without excessive danger.

There is another Florentine religious festival, instituted in the eleventh century and that continues today in essentially the form to which it had evolved by the late fifteenth century, in which the Holy Spirit again flies the length of a church nave. This is the Scoppio del Carro (Explosion of the Cart), celebrated every Easter in Florence Cathedral.[29] The Carro is a tall tower-like 'machine' on wheels, packed with fireworks and towed into position in front of the open doors of the Duomo by a team of white oxen with gold-painted hooves and flowers on their heads. A wire is stretched from the Carro, passing through the cathedral doors, up the nave, to the high altar. When the choir sings 'Gloria in Excelsis Deo', the Cardinal of Florence lights a rocket carrying a model dove running on the wire, which speeds down the nave to the Carro and sets it alight (Figure 2.7). Many candles, rockets and rotating fireworks are ignited in sequence in the Carro, which continues to burn for 20 minutes or more.

Figure 2.7 The festival of the Scoppio del Carro (Explosion of the Cart) held annually in Florence. Fireworks packed into the tower-like 'cart' are ignited by a rocket-propelled dove flying on a wire connected to the high altar of the Duomo. The dove can be seen here emerging from the cathedral doors, leaving a trail of smoke. Photo by Ilaria Vangi from VisitFlorence.com.

The flying dove clearly represents the Holy Spirit, as is traditional, but otherwise the origins of the ceremony are apparently connected to fire-making flints brought back from Jerusalem during the First Crusade. It is not impossible that Brunelleschi arranged something similar for the Annunciation of 1439, although the fact that there was a second rope to pull the fire along suggests that his device was not rocket-propelled.

These church plays and festivals had a deeply serious purpose of course, and it would be frivolous to characterise them as 'fun'; but they were surely popular among an unlettered congregation who came to learn about Bible stories through dramatic re-enactments. Bishop Abraham, a theologically sophisticated observer, described what he saw as 'amazingly wonderful, even to grown men'.[30] And what is certainly true is that their imagery and machinery were directly transposed to secular plays, put on for pure entertainment, in which pagan gods on Mount Olympus replaced God the Father and his angels.

Leonardo da Vinci's revolving Heaven and Hell

Brunelleschi had created God's Heaven as a hemispherical opening in the underside of a large wooden box. Leonardo da Vinci elaborated the idea, making a paradise as a free-hanging hemisphere constructed on an iron armature. This, however, was a Heaven for a secular drama: the occasion was the marriage of Gian Galeazzo Sforza to Isabella of Aragon in Milan in 1490.

The dramatist Bernardo Bellincioni praised Leonardo's contribution in the printed preface to his play, which had the title *Paradiso* because 'here with the greatest ingeniousness and art the Paradise was built by Master Leonardo Vinci the Florentine, with all seven planets in rotation, and the planets were represented by men'.[31] One member of the audience described the structure as 'similar to a half egg, painted in gold on the inside, decorated with numerous lights resembling stars, and with holes inside where the seven planets [the actors] were seated'.[32] On the outside were the signs of the zodiac. Another contemporary noted that the half egg was built on a frame of 'iron circles'.[33] Leonardo's innovation over the type of Heaven used in Florence was thus to free it from its fixed position within the beams of a roof and somehow make it spin – just as the heavenly spheres themselves rotated.[34]

There are two pages of drawings by Leonardo in his notebook the Codex Arundel showing designs for stage apparatus of hemispherical form.[35] Although these are schematic and cryptic, the few annotations make it clear that they do indeed refer to a theatre set, marking for example the position of a dressing room. At one time Leonardo scholars believed that the sketches related to Bellincioni's *Paradiso*.[36] In fact Leonardo's design is for another play, *Favola di Orfeo ed Eurydice* [*The Story of Orpheus and Eurydice*] by Angelo Poliziano, in which Orpheus descends into the Underworld to recover his beloved Eurydice from death: the set represents not a Heaven but a Hell. It is not suspended in a roof but is built at ground level. The fact that this Hell is also hemispherical, and that *paradiso* had become a generic term for such theatrical machinery, contributed to the confusion. In the 1950s the Leonardo specialist Carlo Pedretti identified the designs with *Orfeo* and made a reconstruction of the machinery involved.[37]

One of Leonardo's thumbnail sketches is of a mountain; another of the mountain cut through to show a hemispherical space inside (Figure 2.8a). Elsewhere are what appear to be a section and plan of this hemisphere. The circular shape of the plan is divided into four quarters (Figure 2.8b). Beneath the plan is a note reading: '*a b c d* is a mountain which opens thus: *a b* goes into *c d* and *c d* goes into *e f*, and Pluto is revealed in *g* which is his residence.' From this we learn two key facts. This is indeed the Underworld, the home of Pluto, ruler of Hades (who does not appear in Bellincioni's play). And the mountain opens to reveal the scene.

Pedretti's reading of the plan and its note is that the mountain was made in three sections, two of which rotated around the third to end up with an interior in the form of a quarter sphere. The final shape of the space, produced once the mountain was fully open, was thus something like one of the outdoor 'shells' in which popular American big bands used to perform. Leonardo adds: 'When the Paradise of Pluto opens,

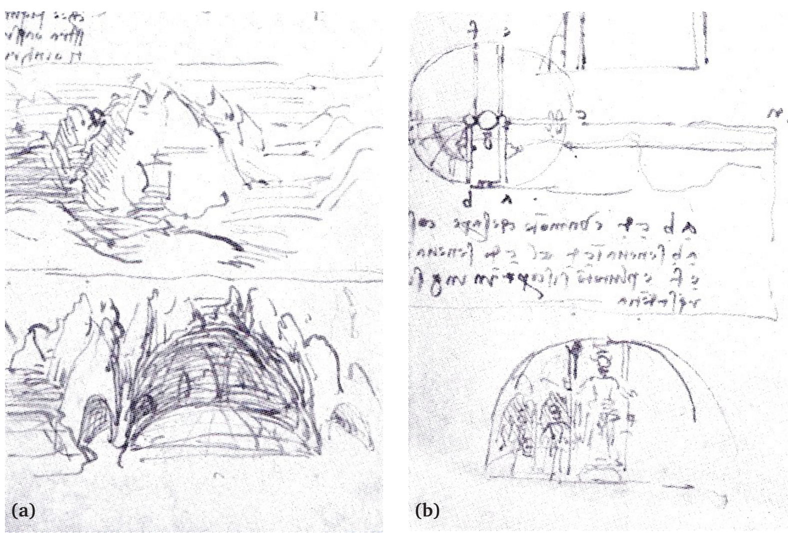

Figure 2.8 (a) Leonardo da Vinci: sketches from the Codex Arundel of a hemispherical stage for the play *Orfeo*, concealed in a mountain. The drawings show the mountain open and closed. (b) Leonardo's plan of this stage showing the moving parts. © The British Library Board, Codex Arundel 263 folios 321v and 224r.

there should be devils who play on pots to create infernal noises – here should be death, the Furies, Cerberus, and many naked weeping putti; there are also fires made in various colours; dances follow.'[38] Leonardo includes a tiny sketch of the 'pots'. The historian of music Emanuel Winternitz identifies these as what the Dutch call *rommelpots* – jars with diaphragms stretched over their mouths, vibrated with sticks to make a shrieking sound.[39]

Pedretti draws attention to the fact that Leonardo's drawing of the interior of the set shows the vault supported by two thin columns, between which is a male figure high up – perhaps seated on a throne – supported on a sphere that is half buried in the stage.[40] He interprets this as the figure of Pluto. He suggests that, as the halves of the mountain opened, Pluto was raised up from the Underworld on this sphere. Pedretti's proposals for the mechanical apparatus involved are illustrated in Figure 2.9. Two large weights *A* and *B* pull ropes that turn the two vertical posts, to which long horizontal levers are attached. The levers move the floors of the curved sections of the mountain into the open and closed positions. As the weight *A* falls and opens the mountain, the weight *B* rises, carrying with it the sphere on which Pluto is seated.

It is not known whether Leonardo was involved in the first production of Poliziano's *Orfeo* in Mantua or whether his revolving mountain was indeed built. But if so, it would have been, according to Orville Larson, 'probably the largest theatrical machine in the entire fifteenth century'.[41]

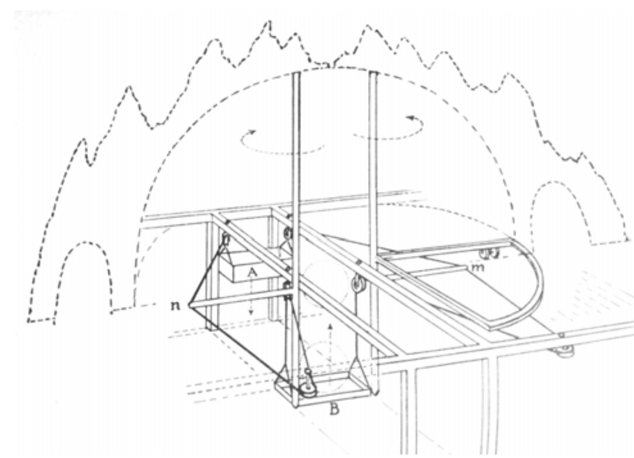

Figure 2.9 Reconstruction by Carlo Pedretti of Leonardo's machinery for the set of *Orfeo*, in which a mountain opens to reveal Hades. By permission of Librairie Droz, Geneva.

Skies and clouds

The platforms on which angels were carried in the *sacre rappresentazione* were painted and covered with wool to disguise them as clouds. These 'vehicle clouds' were then adapted for the *intermezzi*, where they came to carry many more passengers, and were made to move forwards, backwards and sideways as well as vertically. Often vehicle clouds carried their own lamps. At the same time in halls and purpose-built theatres the stages were typically roofed over with wooden and canvas panels painted to resemble cloudy skies. These 'fixed clouds' were often painted on valances or borders, arranged in such a way that the vehicle clouds and other flying machines could pass through them on their journeys up and down. An important purpose of the fixed sky was of course to conceal the machines waiting above and the structures that supported them.

Joseph Furttenbach illustrates a sky made from several borders with gaps between them in his theatre cross-section of Figure 2.10.[42] (Notice in passing the positions for oil lamps in the sky that Furttenbach has labelled with large letter *Z*s, and the footlights and lamps below the back shutter, marked with small letter *z*s.) The sky pieces are of painted canvas on wooden frames. The frames of these borders are curved – I imagine to give them rigidity – and overlap in such a way that the audience cannot see between them. They are supported on beams, shown in cross-section as black squares in the drawing.

Look at the two beams at the back of the stage on the right labelled *XX*. Furttenbach has shown a carriage spanning these beams, running on rollers, from which a vehicle cloud labelled ⊙ Δ is suspended. This has a platform on which the occupants sit. The wiggly outline indicates the wool that covers the front of the vehicle. The woolly cloud can thus move laterally across the stage, hanging from this rolling carriage; and if attached with cables it can at the same time rise and fall. Furttenbach says: 'As the cloud machine passes over it opens up to show the Gods as well as lovely musicians sitting in it. This gives the spectator great delight. In like manner triumphal cars, and whatever else is desired, can be hung and swung down according to the action of the play.'[43]

As noted in Chapter 1, there have been until recently no known technical descriptions or drawings of the sky and cloud machinery used in the Florentine *intermezzi*, other than a few notes by the engineer Girolamo Ser Jacopi who worked with Buontalenti.[44] Did Buontalenti and Parigi employ something like Furttenbach's methods? In the first *intermezzo* in 1589, for example, there were certainly some impressive

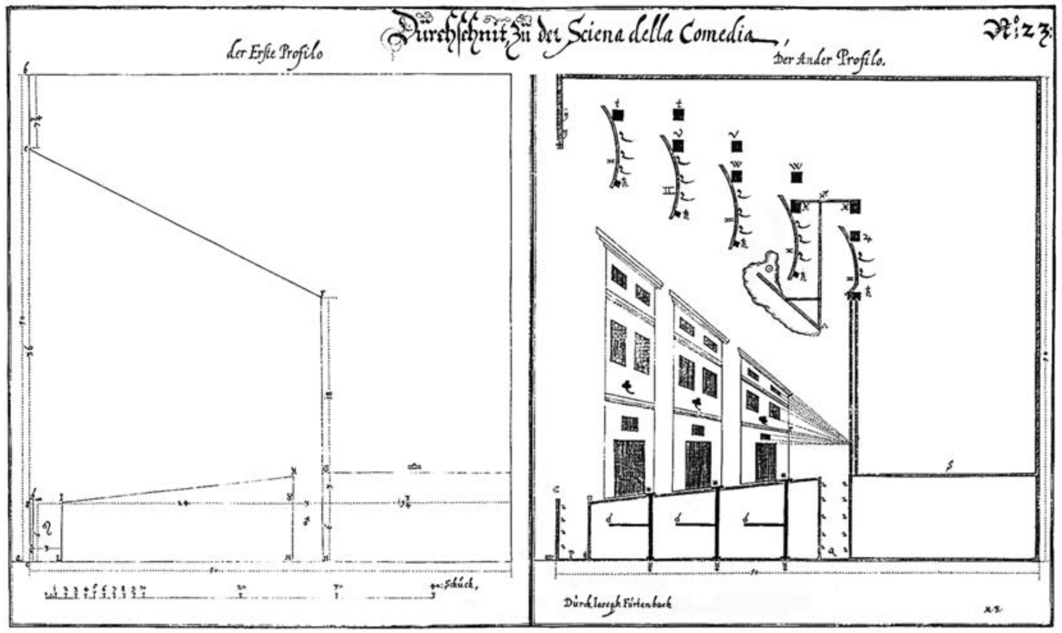

Figure 2.10 Cross-section of Joseph Furttenbach's stage and set for the comedy described in *Recreational Architecture*. The V-shaped structure in the sky suspended from the two beams *XX* is a carriage on rollers carrying a vehicle cloud. The wiggly outline depicts the wool disguising the machine. The positions of lamps in the sky are marked with large letter *Zs*. Small letter *zs* show the positions of footlights and lamps illuminating the back shutter.

changes seen in the sky: sunbeams bursting from behind clouds and full daylight transformed into a starry night sky. Three openings appeared in this sky. In Bastiano de' Rossi's *Description*: 'In its lower part, the Sky resembled a diamond sprinkled with the colours of the rainbow; higher up, it had the appearance of the most brilliant of diamonds.'[45] Buontalenti's drawing for this scene shows a set consisting entirely of clouds. Even the scenery wings are clouds. A single glowing opening in the Heavens is visible, surrounded by a vault of stars. Buontalenti might have effected some of these transformations not with machinery but by manipulating the concealed lighting.

Vehicle clouds, and free flying without clouds

Again, there have been no drawings of vehicle clouds for the *intermezzi*, although these machines appeared in every show, and often several were seen operating in the air at once. In the early years, clouds travelled vertically on ropes like those in the *sacre rappresentazioni*. For instance in the fifth *intermezzo* for *I Fabii* in 1568 a cloud machine descended carrying the three Graces and the nine Muses sitting on a bench, all safely secured with an iron belt.[46] The vehicle was covered with canvas painted as a cloud, and the belt was camouflaged with wool.

Ser Jacopi refers to *arghani* (winches) for raising and lowering clouds, and *sportelli* (windows in the sky) through which they passed.[47] In 1565 and 1569 the audience could see the hooks from which the vehicles were suspended, and saw the cars return to the Heavens once they had deposited their human cargoes.[48] In 1586 by contrast, once a complement of actors representing Blessings had stepped from their cloud, it disappeared 'as though blown by the wind, where no one could tell'.[49]

Furttenbach and Sabbattini illustrate a number of *ingegni* for propelling clouds, operated not from a grid above the sky, but from positions at the side or the back of the stage. These make use of ropes supported on masts or long levers, pulled by windlasses or capstans at their bases. Figure 2.11 shows one of Sabbattini's machines.[50] A long lever hinged to a wall at *E* carries a vehicle cloud shown in two positions: on the stage at *P* and flying in the air at *H*. The lever arm is raised and lowered with ropes and pulleys by men working a capstan *M* below stage. I imagine the timberwork would have been

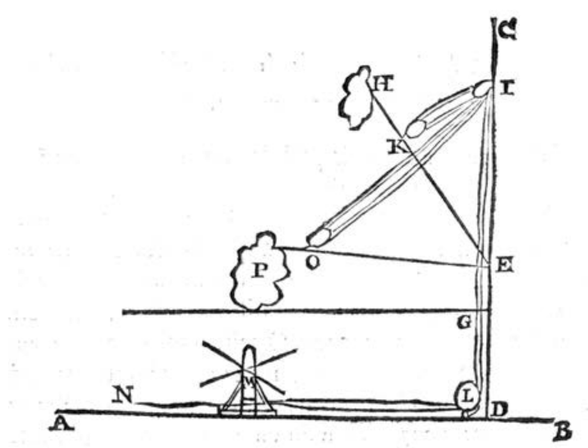

Figure 2.11 Design by Sabbattini for a vehicle cloud that is raised and lowered on a long lever.

something like ships' masts and spars. Sabbattini has another machine with a counterweighted arm, similar to the kind of crane that Donald Mastronarde imagined might have been employed on the ancient stage.[51] Furttenbach talks of a comparable device, which he compares to a 'village well-pole', that is to say a seventeenth-century equivalent of the Middle Eastern 'well sweep'.

All these types of apparatus, however, still only move the vehicle clouds vertically. Sabbattini has a method for moving a cloud from one side of the stage to the other.[52] This is achieved by fixing the cloud to a horizontal beam that slides in gaps between two pairs of beams placed across the stage. The beam holding the cloud is pulled along with ropes wound on winches. As we saw earlier, Furttenbach illustrated a carriage on rollers moving above the sky that again transports a cloud vehicle across the stage (Figure 2.10). Machinery of this kind was used to allow actors and other kinds of vehicle besides clouds to fly.

In the *intermezzi* there were animals and mythical personages who flew freely through the air, with or without carriages, supported only on ropes or wires. We saw the sorceress in her golden airborne car pulled by dragons in the fourth *intermezzo* for *La Pellegrina* in 1589 (Figure 1.9). In the third *intermezzo* for the same play Apollo descends in free flight from the realm of the gods to do battle with the monster Python, a fearsome green dragon, and kills him with arrows.[53] Inky blood oozes from the beast's wounds. Figure 2.12 is Buontalenti's drawing of the two protagonists. While in the air Apollo was represented by a puppet on an iron wire, which moved so fast the audience could not see how it was supported.[54] The puppet landed in the wings and immediately an identically dressed actor entered from that position and continued the fight.[55]

It may be possible to make some further inferences about the *ingegni* employed for flying in the *intermezzi*, on the basis of drawings of machinery in use much later in the Venetian opera. In 1665 the English traveller Sir Philip Skippon was in Venice for the carnival and saw three shows.[56] This was about 20 years after John Evelyn had attended *Hercules in Lydia* in Venice and had been so impressed by the 'Machines for flying in the aire'. In a performance of *Scipione Africano*, Skippon saw a 'remarkable flying down of one (like Fortune), with a sail from a tower'.

At the Teatro Santi Giovanni e Paolo, Skippon persuaded the management to let him backstage, where he saw various pieces of machinery including 'The Engine us'd to fly down with', of which he made a sketch (Figure 2.13). Mercury, messenger of the gods, wearing

Figure 2.12 Watercolour sketches by Bernardo Buontalenti for Apollo and the monster Python who do battle in the air in the third *intermezzo* for *La Pellegrina*, 1589. Wikimedia Commons: La Pellegrina 1589 – Intermedio 3 – Il combattimento pitici d'Apollo2.

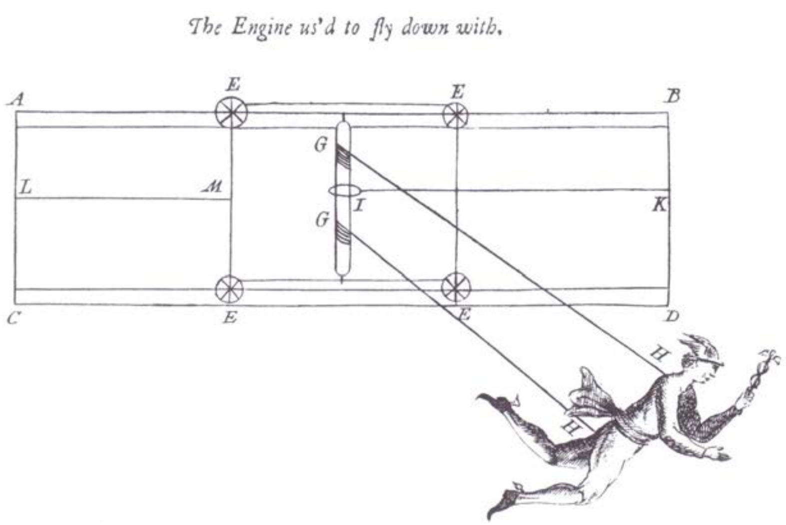

Figure 2.13 Sir Philip Skippon's sketch of a flying machine used at the Teatro Santi Giovanni e Paolo in Venice in 1665. Mercury is suspended from a trolley that runs on tracks above the sky.

his winged helmet, is suspended by two ropes from a trolley that runs in tracks above the sky. He can thus travel horizontally, vertically and, by a combination of the two motions, on a diagonal path. This is very similar to the wheeled carriage on tracks illustrated by Furttenbach. Orville Larson suspects that the weight of the flying actor in Venice was balanced by a counterweight or weights at the other end of the ropes, although Skippon does not show this.[57]

One mystery raised by the images of Buontalenti's and Parigi's Florentine *intermezzi* is that in some scenes there were 20 or more actors enthroned on clouds, many of whom came down together onto the stage. Clearly the *ingegni* involved were on an altogether different scale from Sabbattini's one- and two-seater cloud machines. How was this done? For the moment I leave this question hanging.

Mountains rising up

Several *Descriptions* of the *intermezzi* give accounts of hills and other tall structures that seemed to grow up from the stage floor in full sight. Sabbattini gives instructions for 'How to make mountains and other objects rise from under the stage'.[58] His hills, however, are modest things, more hillocks than mountains. A flat wooden framework is covered with canvas, painted and attached to a vertical post. The post is raised up with a windlass through an opening in the stage.

Small hills, perhaps made following Sabbattini's method, appeared in the third *intermezzo* for *La Cofonaria* in 1565, a production designed by Giorgio Vasari.[59] Cupid is so in love with Psyche that he has no time for his usual work of causing erotic havoc among mortals. This results in many frauds and deceptions (*inganni*). Characters clothed in leopard skins and snakeskins, representing these *inganni*, emerge from the *piccoli monticelli* (little hillocks). (Possibly these actors were hidden behind the painted shapes as these rose from their traps.) In the fourth *intermezzo* the hills have gone, to be replaced by 'small gorges'. Alois Nagler thinks that these might have been open trapdoors.[60] Dark smoke issues from the gorges, and characters personifying evil passions climb out, including two anthropophagi (eaters of human flesh) playing trombones. The company perform 'an extravagant morris dance' and run off in confusion.

Other mountains rising up in the *intermezzi* were tall, impressive and, what is more, carried numerous performers on their slopes. This means that they must have been 'practicable': that is to say, built in three dimensions, and made solid enough to be climbed and sat on. Audiences were perplexed by the fact that these structures were evidently a great deal taller than the traproom below.

For the Prologue to *The Kidnap of Cephalus* in 1600 Buontalenti engineered the raising of a mountain covered with trees and bushes to a height of 9 metres from a traproom just 2 metres high.[61] This was Mount Helicon, one of the homes of the nine Muses who sat in a grotto covered with moss, opening on the side of the hill. In a second grotto on the opposite side were the nine Pierides (the women singers who were turned into magpies). Meanwhile, on the slopes of the mountain itself sat 16 hamadryads – nymphs of the trees – on seats covered in flowers. At the very peak stood Pegasus with his wings spread. Figure 2.14 is Buontalenti's drawing for the scene.

It seems possible that Buontalenti worked this magic by means of a telescopic pyramid-like structure, as shown in the theoretical proposal by the modern theatre scholar Ferdinando Ghelli (Figure 2.15).[62] The different sections, concealed under a loose painted cloth, would have been winched up in sequence from the traproom using a system of ropes and pulleys, as the drawing shows. Looking at Buontalenti's picture we can make out a stepped structure like Ghelli's, beneath the canvas covering. Ser Jacopi mentions supports for a similar mountain featured in the *intermezzi* of 1589, to secure it in position.[63] The Muses and the Pierides would have been inside the lowest and largest section of the pyramid and would have risen with it to the level of the stage, to emerge from their grottoes. Michelagnolo Buonarroti, who wrote the *Description* of this performance, says that when the mountain disappeared it 'deflated', again suggesting a telescopic construction.[64]

In Greek mythology, wherever the winged horse struck his hoof in the ground, a spring of pure water – it was said – sprung out. The waters of the Hippocrene spring created by Pegasus on Mount Helicon were reputedly the source of artistic inspiration, hence the association with the Muses (and the poet Keats's call for a beaker full of the 'blushful Hippocrene'). Mount Helicon and Pegasus feature repeatedly in the symbolism and statuary of Renaissance fountains for this reason.

In *The Kidnap of Cephalus*, Buontalenti had arranged for what the audience saw as real water flowing out from the Hippocrene spring.[65] It would not have been beyond Buontalenti's powers to install some kind of plumbing system to achieve this effect. On the other hand, Sabbattini illustrates a method of simulating the appearance of 'A fountain that seems to throw water forth continuously'.[66] This uses a looped ribbon of soft cloth pulled continuously through slots by a hidden stagehand,

Figure 2.14 Detail of set design by Buontalenti for the Prologue to *Il Rapimento di Cefalo* [*The Kidnap of Cephalus*] in 1600, in which a mountain rose from the stage to a height of 9 metres. By kind permission of the National Art Library, Victoria and Albert Museum, London.

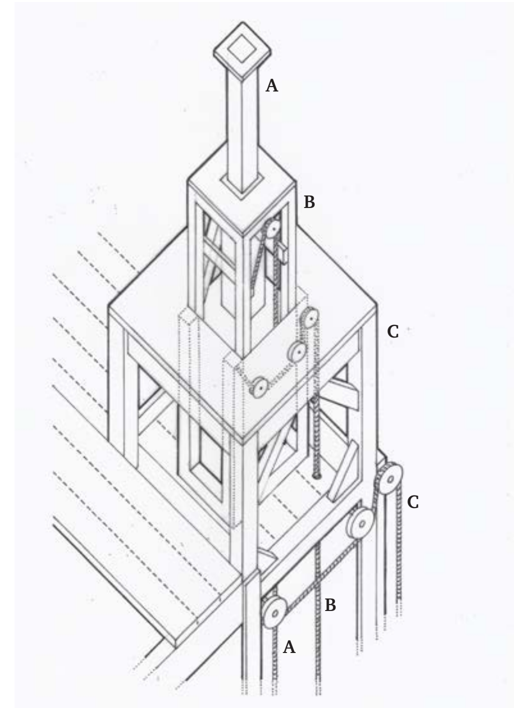

Figure 2.15 Theoretical proposal by the modern theatre scholar Ferdinando Ghelli for a telescopic machine that could have been used in the *intermezzi* for raising mountains. All the sections are raised by a single winch. (Compare Figure 2.14.) Drawing by the author after Ghelli's design.

which we can imagine was coloured white or grey, with silver tinfoil to make the 'water' sparkle.

Hell and its fires

The fourth *intermezzo* for *La Pellegrina* in 1589 was set in 'The Inferno'. Recall that the engraving by d'Alfiano reproduced in Chapter 1 (Figure 1.9) combined several successive episodes into one picture. After the flying witch left the stage in her chariot pulled by dragons, a mountain of fire appeared in the sky, came to the middle of the stage and opened up into a crescent shape, to reveal a crew of demons summoned up by the sorceress.[67] This was presumably a standard person-carrying cloud, painted in lurid flame colours. De' Rossi describes the devils' appearance:

> Their wings were made from flame-red taffeta with flashes of silver, and under the wings were lilac-coloured feathers, also flecked with silver. Their hair was long and frizzy, its colour a mixture of silver and fire, their faces glowing with beauty. [Nagler thought they might be wearing masks.] Down to the thigh they were dressed in silver and red gauze, and from thigh to knee in gold toile and green silk.[68]

The demons sang a madrigal, and the cloud closed up again and disappeared.

Then suddenly the stage was filled with a rocky landscape, full of caves belching fire. De' Rossi says that for this scene Buontalenti arranged for the stage floor to be partly uncovered, creating an opening large enough that the audience could see into the traproom, whose walls were painted to make them part of the infernal picture.[69] Ser Jacopi mentions that several stagehands were needed to 'open the mouth of Hell'.[70] Some of the figures of devils seen below stage were cardboard cut-outs. Other live devils on the stage sat on the rocks, which must therefore have been practicable. At the mouth of Hell was Charon in his boat, with a long white beard and flaming wheels around his eyes.

The monstrous figure of Lucifer himself then rose up centre stage (as seen in d'Alfiano's engraving) reaching a height of 4 metres. He had three faces, one red, one black and one yellowish white, with pairs of huge batwings beneath each face. These details are taken from Dante's *Inferno*. Buontalenti gave the job of designing Lucifer to the painter Ludovico Cigoli, whose watercolour sketch is reproduced as Figure 2.16. The figure was apparently articulated and was constructed of painted canvas and papier-mâché on a basketwork frame.[71] Ser Jacopi says it was lifted up from the trap with a winch, with machinery that might therefore have been comparable with that for raising mountains.[72]

As in Dante's verses, Lucifer was hungrily devouring the souls of sinners. Two of these, played by 'agile children', slipped out of his jaws, but were quickly recaptured by attendant demons, one speared on a pitchfork, the other caught by a devil with his claws and returned to Lucifer's maw.[73] We can only guess how all this was done. But if Lucifer's mouth was moveable, it might have been opened and shut by an operator inside; and the swallowed children might have escaped to the traproom via steps inside or behind the statue.

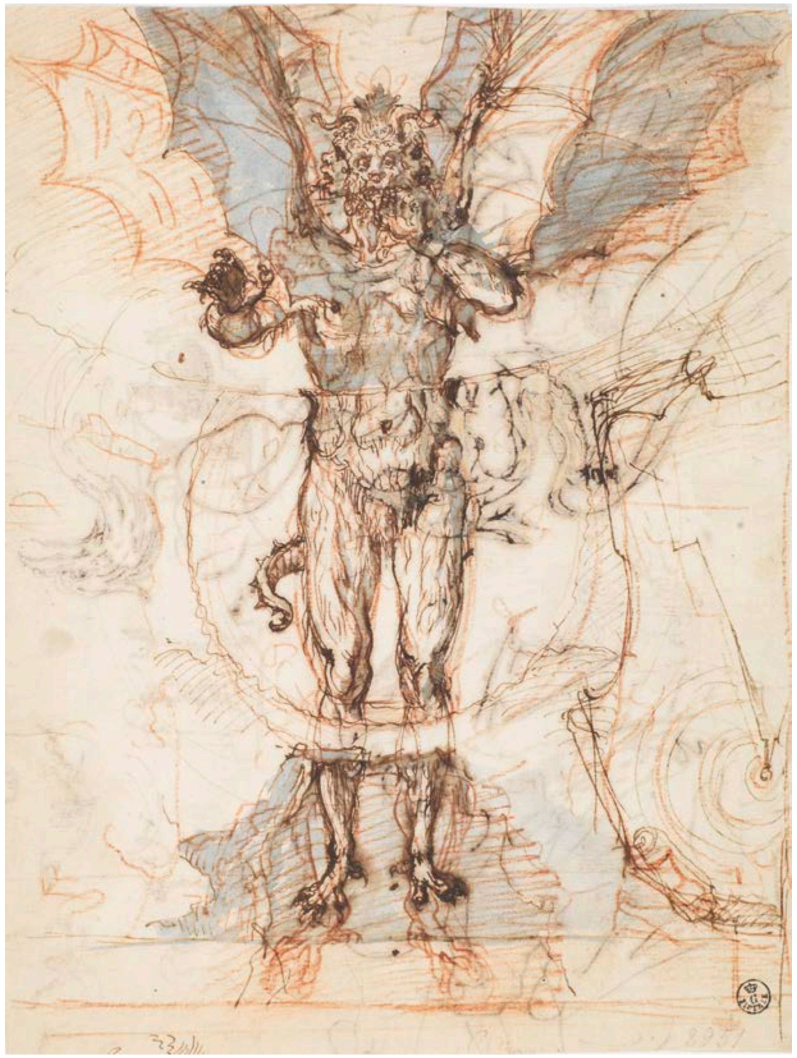

Figure 2.16 Design by Ludovico Cigoli for the person of Lucifer in the fourth *intermezzo* for *La Pellegrina*, 1589. The figure was 4 metres high, articulated and made of canvas and basketwork. Gabinetto Disegni e Stampe, Gallerie degli Uffizi, Florence.

Giulio Parigi designed 'The Forge of Vulcan' for the fifth *intermezzo* of *Il Giuidizio di Paride* in 1608. Vulcan, the god of fire, volcanoes and metalworking, is generally depicted in his underground shop with anvil and hammer. The engraving of this scene by Remigio Cantagallina (Figure 2.17) shows the stage floor removed, as in 1589, to reveal

Figure 2.17 Engraving by Remigio Cantagallina of Giulio Parigi's set for the fifth *intermezzo* of *Il Giudizio di Paride* in 1608, 'The Forge of Vulcan'. Parigi has opened part of the stage floor to reveal the Underworld. Gabinetto Disegni e Stampe, Gallerie degli Uffizi, Florence.

a 'labyrinth of caverns' in the traproom, with mysterious pieces of machinery and miners at work. Here Mars, the god of war, visits Vulcan to see his collection of 'invincible weapons' and chooses a suit of armour. The opening of the stage at this juncture is not mentioned in contemporary accounts, which say only that this happened in the sixth and final *intermezzo*. Gabriele Bertazzuolo reported on the show to the Duke of Mantua and said: 'I have seen how the stage cleaved open in front down to the earth, something which I have never seen until now.'[74]

Individual actors or small groups rose up or disappeared through smaller trapdoors.[75] Sabbattini explains different methods for opening and closing these traps quickly and smoothly, and raising actors up, using levers, ladders and platforms. With clever choreography, it is possible to make sure that several dancers stand in front of a trap and hide it while in operation, so that the numbers in the group seem

miraculously to increase. Joseph Furttenbach describes a special kind of trapdoor, designed for his play about Jonah, 'that lets godless people be swallowed up'.[76] This is a platform supported on ropes, controlled from below stage. The actors 'disappear with a great cry before the eyes of the audience', surrounded by flames and smoke. The audience, 'glad to be rid of such arrant sinners, will take this inexpensive spectacle to its heart'.

How were the effects of fire achieved in such scenes? There are no direct accounts explaining the conflagrations in the *intermezzi*, although given Buontalenti's famed expertise as a 'fire-thrower' we can expect that the pyrotechnics in his own productions were highly spectacular. Sabbattini, on the other hand, mentions hair-raising techniques for showing burning buildings and for roasting sinners in hellfire, by raising real fires on stage or setting the scenery alight. His Hell is constructed in the backstage, not otherwise used for acting, seen through the opening that is normally shuttered at the back of the main stage.[77] Two fires are started in this area, one behind the other, some little distance apart. Naked dancers cavort in apparent agony in the gap between the fires, and as viewed from the auditorium seem to be burning in the flames.

'To show the whole scene in flames', Sabbattini proposes the use of aqua vitae (pure alcohol distilled from wine).[78] The technique is used with the *periaktoi*. Pieces of cloth, the sizes of the houses that are to burn, are soaked in the spirit and attached rapidly to the back faces of the triangles. One man lights each piece, and the *periaktoi* are all turned. However, even Sabbattini admits that 'This device of making use of fire in the *intermezzi* should be avoided as much as possible, on account of the danger sometimes attendant on it.' (The 'sometimes' is cool.)

Slightly safer but still impressive bursts of flame could be made with clouds of powdered flammable material, ignited by torches or candles. I have suggested that Brunelleschi might have used powdered resin in this way for his representation of the Holy Spirit. Sabbattini explains in more detail.[79] An earthenware pot is made with a hole in the bottom, through which a torch is inserted, with the end that is to be lit emerging above the pot (Figure 2.18). The container is filled with 'Greek resin', which according to Furttenbach is a 'fine meal-like powder of a beautiful yellow colour'. Another option is to use lycopodium powder – made from the dried spores of the clubmoss plant – which is explosive and burns fiercely. The top of the pot is covered with stout paper punched with holes, to make something like a large sugar shaker.

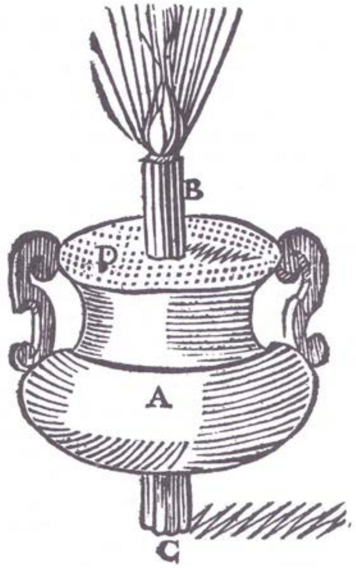

Figure 2.18 Device illustrated by Sabbattini for producing bursts of hellfire on stage. The pot contains powdered resin. This is shaken out in a cloud through the holes at *D* and ignited by the torch flame *B*.

Where the flames are to signify Hell, men carrying these pots are stationed beneath open traps. At intervals they 'throw flames of fire through the trap to the stage by raising the pots violently, but in such a way that the lighted torches are not visible'. The resin is shaken out in a cloud and set on fire by the torch, producing a 'long bright flame in the air like lightning'. 'It is necessary in these actions to take great care', Sabbattini says, 'since very often mishaps result, and fools and thick-witted persons should not be allowed to participate.' Greek resin has the virtue that the lingering odour is pleasant. But for a truly infernal smell, one must use powdered sulphur.

Ships on the sea

Instead of Hell, the backstage could be filled with a representation of the sea on which ships could sail, marine gods might appear in their seashell boats, and whales and dolphins could swim. Both Furttenbach and Sabbattini describe wave machines of different types, but whose basic principle is the same in all cases.[80] Several long pieces of wood with wave-shaped profiles, either flat cut-outs or solid rollers, are set one behind the other across the stage. These are painted in watery colours, with silver edges to represent foam. They can be slid, rocked or rotated using various techniques.

For a calm sea, the waves can just sit in place. Furttenbach describes how, for a choppy sea, a single cut-out can be slid back and forth in the groove in which the back shutter normally runs. This process can be mechanised using rollers of twisted undulating shape, like giant sticks of barley sugar. These are turned with cranks at the ends. An illustration from Furttenbach (Figure 2.19) shows, from top to bottom, a cut-out static wave, a cut-out 'billowy and active' sliding wave and a fierce stormy wave in the form of a roller. Furttenbach says that the roller is turned with a handle 'like a roast-spit'. 'Two or three such machines, one behind the other, produce a tremendous effect which can be used in many different actions.'[81]

Cut-out waves painted black with silver tops can be set between rollers, Sabbattini says, and raised gradually to give the effect of the sea swelling, darkening and becoming tempestuous. Pairs of men move the cut-outs from beneath the stage, pushing them up ever higher until they conceal the rollers. 'You might also by this means simulate a flood by raising the dark waves so far as it seems suitable'.[82]

To allow ships or sea creatures to pass, the wave devices must be spaced apart to create corridors in which the *ingegni* can be slid in grooves or propelled on trolleys. For his play about Jonah, Furttenbach constructed a sailing ship some 4 metres long to carry the hero and four other mariners (Figure 2.20).[83] This was mounted on an axle, supported on a cart 'similar to a gun carriage'. The handles labelled *yy* were used to rock the boat back and forward on the axle.

Sabbattini has a series of designs for sailing ships and galleys. Some are just simple flat cut-outs; others are built in the round.[84] His cut-out type is slid in a groove between two waves. The base of the ship has a swallowtail or inverted Y shape in section, whose two prongs serve to keep the cut-out upright. Both the groove and the base are soaped to allow the vessel to slide easily. For a galley rowed by slaves, a bank of miniature oars is made to protrude from a row of portholes. These are all connected at the back to a single bar, which is moved in a circular motion by a man below stage, making the oars seem to dip into and rise out of the water together.

Two-dimensional cut-out shapes, however realistically painted, could clearly pass only in one direction across the stage. Should ships be required to turn in view and return, they obviously had to be constructed in three dimensions. Sabbattini's account is not entirely clear to me, but

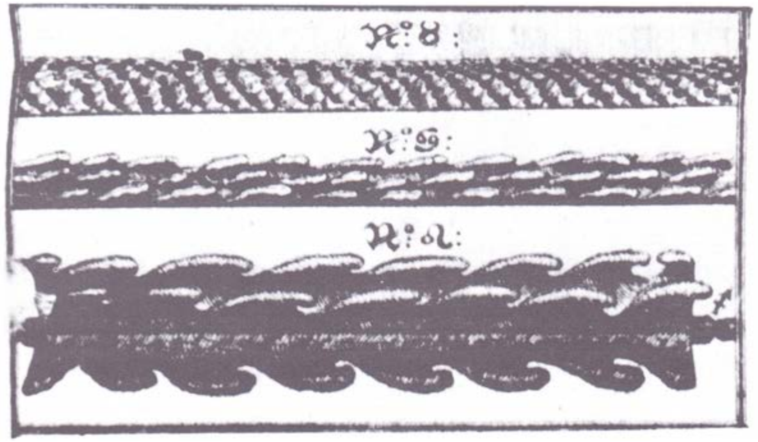

Figure 2.19 Joseph Furttenbach's designs for wave machines. Top: a static cut-out wave. Centre: a sliding, billowy cut-out wave. Bottom: a roller to represent a violent sea.

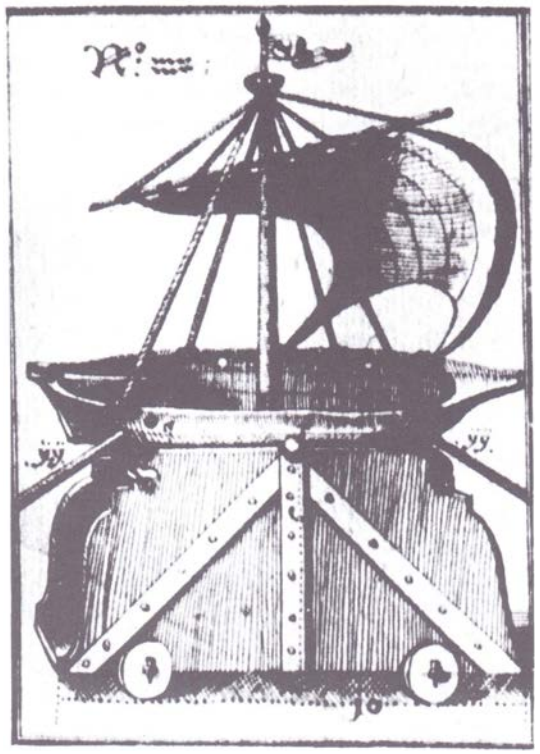

Figure 2.20 Ship designed by Furttenbach for his play of Jonah and the Whale. The vessel is rocked back and forward with the levers *yy* as it rolls along.

from what I understand, a ship of this type was pushed from beneath the stage on two rollers, fore and aft, along undulating wooden tracks, so that it pitched back and forth as it travelled. The ship had no bottom so that the men underneath, walking on the traproom floor, could steer and manipulate it from inside. Oars on a galley could be made to sweep the water as before. The sails on a sailing ship could be made of thin cloth reinforced with iron wire so that they seemed to belly out in the wind. These could be rigged or furled remotely by the men inside the ship by means of thin cords running up the masts. A ship at anchor could be made to rock gently by fixing it to a pivot and moving it with a long lever.

Buontalenti engineered seas for the *intermezzi*, specifically the 'Triumph of the Sea Gods' in 1586 and 'The Rescue of Arion' in 1589. As always, these were on an altogether grander scale than Sabbattini and Furttenbach's effects in their provincial theatres with their modest budgets. For 'The Triumph of the Sea Gods', Buontalenti filled the entire stage – not just the backstage – with a sea, save for a strip of 'impassable reefs' at the front holding the 'water' back from the auditorium.[85] Several characters including Tritons and the water goddess Thetis came up dripping from the waves. 'New sea monsters with wild eyes, scaly ears and puffed cheeks emerged, agitating the sea, so that ships in the distance seemed to dance on the billows.'[86] The ships were miniature cut-outs moved in grooves. Neptune's shell-shaped chariot, ornamented with coral and pearls, rose up to a height that was once again much taller than the traproom.

Three years later, in 'The Rescue of Arion', the sea again filled the stage completely.[87] The engraving by Epifanio d'Alfiano of Figure 2.21 records the scene. Another seashell vehicle pulled by dolphins came out of the waves, carrying an almost naked Amphitrite, surrounded by a retinue of completely naked sea nymphs who played games splashing each other. (D'Alfiano has, however, given them all clothes.) Presumably there were containers of water for the splashing, hidden between the wave machines.

When all these figures had disappeared again under the surface, a galley fitted with both sails and oars appeared from the wings, some 15 metres long, carrying a crew of 40. The ship turned in different directions, at one point facing the ducal party in the audience and lowering its sails in acknowledgement. The classical poet Arion stood on the deck and sang to the accompaniment of his harp. There are no technical accounts of how this huge vessel and its crew were moved, but it must have required a very large team using heavy tackle. It is not

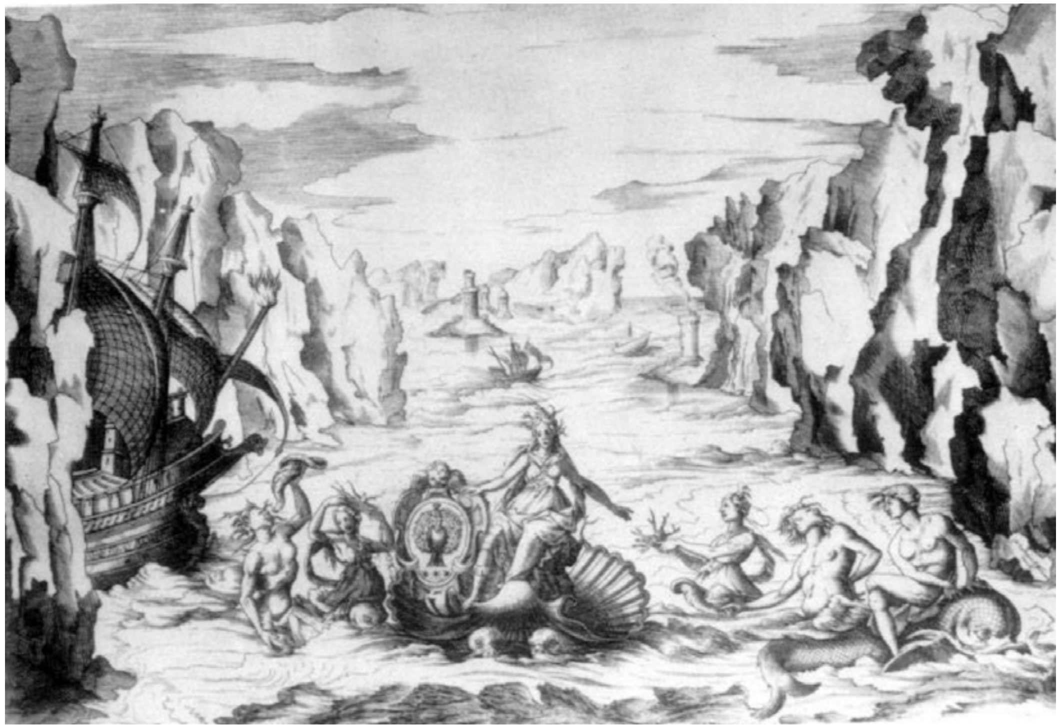

Figure 2.21 Engraving by Epifanio d'Alfiano of Bernardo Buontalenti's set for the fifth *intermezzo* of *La Pellegrina*, 1589, 'The Rescue of Arion'. The 15-metre long ship carrying Arion and 40 others is entering from the left. By permission of Ministero per I Beni e le Attività Culturali e per il Turismo/Biblioteca Marucelliana di Firenze.

easy to manoeuvre a boat of this size and weight on land using modern powered machinery.

Summing up *La Pellegrina* and the *intermezzi* of 1589, the chronicler Bastiano de' Rossi said that they were 'not inferior to any of those ever played in this city, for the beauty of the settings, the variety and charm of the perspective, the nobility and opulence of the costumes … and the quantity and ingenuity of the machines'.[88] Buontalenti, that 'superhuman genius', had surpassed himself. De' Rossi's was an official account for the Grand Duke, and it was his obligation to praise. On the other hand, the visitor from Mantua, Gabriele Bertazzuolo, who saw *The Judgement of Paris* in Florence in 1608, and was by no means uncritical of some aspects of the show, was wild in his enthusiasm for the final *intermezzo*, 'The Temple of Peace', when there were nine machines and around 300 actors on stage together.[89]

And animals

Readers will have noticed the appearance in this and Chapter 1, alongside the stage machinery, of a veritable zoo of animated birds, mammals, fishes, reptiles and monsters. There were parrots, dragons and horses flying in the sky, and whales, dolphins, frogs and more horses swimming in the water. How these were made to move, we will learn shortly. We will also see how such 'artificial creatures' went out of the theatre and began to inhabit grottoes and gardens.

Notes

1 The term 'theatre of machines' was used to describe a new type of encyclopaedic book that appeared in the sixteenth century, consisting of descriptions and illustrations of machinery of all kinds. I have misappropriated the phrase.
2 Julius Pollux, *Onomasticon*, second century AD: theatre sections included in *Extracts concerning the Greek theatre and masks, translated from the Greek of Julius Pollux,* printed with Aristotle's *Poetics* (London: 1775).
3 Donald J. Mastronarde, 'Actors on High: The Skene Roof, the Crane and the Gods in Attic Drama', *Classical Antiquity*, 9/2 (1990): 247–94.
4 Mastronarde, 'Actors on High': 292–3 (figs 3, 4 and 5).
5 See Abbott Payson Usher, *A History of Mechanical Inventions*, revised edn (Cambridge, MA: Harvard University Press, 1954), p. 123.
6 Peter Arnott, *Greek Scenic Conventions in the Fifth Century B.C.* (Oxford: Oxford University Press, 1962), p. 73.
7 Aristophanes, *Clouds, Wasps, Peace*, ed. J. Henderson (Cambridge, MA: Loeb Classical Library, Harvard University Press, 1998): *Clouds*, lines 227–9.
8 Aristophanes, *Peace*, lines 173–6.
9 See Benjamin Woolley, *The Queen's Conjuror: The Life and Magic of Dr Dee* (London: HarperCollins, 2001), pp. 13–15.
10 John Dee, *The Compendious Rehearsal* (1592): printed in *Johannis Confratris & Monachi Glastoniensis, Chronica* (London: Thomas Hearne, 1726), vol. 2, pp. 497–551; see p. 501.
11 Giorgio Vasari, *Le vite de' più eccellenti Architetti, Pittori et Scultori Italiani* (Florence: 1550). For references to the theatre I have used translations by Thomas A. Pallen, *Vasari on Theatre* (Carbondale and Edwardsville: Southern Illinois University Press, 1999), specifically the *Lives* of Brunelleschi, Cecca and Vasari himself. Bishop Abraham's *Itinerary* was translated from the Russian into German in 1877. An Italian translation was published by Alessandro D'Ancona in *Sacre Rappresentazioni dei secolo XIV, VV e XVI, raccolte e illustrate*, 3 vols, 2nd edn (Florence: 1891). Orville K. Larson gives an English translation in 'Italian Stage Machinery 1500–1700', PhD thesis, University of Illinois (1956), pp. 281–8. A more recent translation into English by Nerida Newbigin from a different manuscript is included in *Feste d'Oltrarno: Plays in Churches in Fifteenth-century Florence*, 2 vols (Florence: Leo S. Olschki, 1996). The quotations here are from Newbigin's translation.
12 See Elvira Garbero Zorzi and Mario Sperenzi (eds), *Teatro e Spettacolo nella Firenze dei Medici* (Florence: Leo S. Olschki, 2001), pp. 124–7 and plate 2.
13 Abraham, *Itinerary*, in Newbigin, *Feste d'Oltrarno*, pp. 60–1.
14 Alessandra Buccheri, *The Spectacle of Clouds, 1439–1650: Italian Art and Theatre* (Farnham: Ashgate, 2014), pp. 35–7. Buccheri also proposes that the 'swiftly turning discs' were concentric – not separated as in Zorzi's model – and that they represented the heavenly spheres.
15 Abraham, *Itinerary*, in Newbigin, *Feste d'Oltrarno*, pp. 62–3.

16 Abraham, *Itinerary*, in Newbigin, *Feste d'Oltrarno*, p. 62.
17 Life of Cecca [Francesco d'Angelo] (1447–88), extracted and translated in Pallen, *Vasari on Theatre*, pp. 53–8; see pp. 54–5.
18 Life of Cecca in Pallen, *Vasari on Theatre*, p. 55.
19 Alessandra Buccheri has argued that in his *Life* of Brunelleschi, Vasari for political and diplomatic reasons is actually describing this production of his own a century later and attributing it retrospectively to his heroic predecessor: *Spectacle of Clouds*, pp. 30–1.
20 Zorzi and Sperenzi, *Teatro e Spettacolo*, pp. 128–9 and plate 3.
21 Life of Brunelleschi in Pallen, *Vasari on Theatre*, p. 53.
22 In the Biblioteca Nazionale Centrale, Firenze, MS, Banco Rari 228, f.115 v, r.
23 The play has been performed annually over two days in the Basilica de Santa Maria in Elche since the fifteenth century. It is now protected by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and features in a UNESCO video on YouTube: www.youtube.com/watch?v=bj34GC4giGM.
24 Newbigin, *Feste d'Oltrarno*, p. 3, argues that the location was not the Santissima Annunziata but San Felice in Piazza. This question has been much debated by historians.
25 Zorzi and Sperenzi, *Teatro e Spettacolo*, pp. 118–21 and plate 1.
26 The seven spheres are mentioned in a different manuscript version of Abraham's *Itinerary* from that translated by Newbigin. Abraham gives measurements in Russian *sagenes*. Newbigin believes that this is an error and the units should be paces or yards, which is what the measurements given here are based on: see *Feste d'Oltrarno*, p. 9.
27 Bishop Abraham, *Itinerary*, in Newbigin, *Feste d'Oltrarno*, p. 7.
28 Larson, 'Italian Stage Machinery', p. 31.
29 Alan St H. Brock, *A History of Fireworks* (London: Harrap, 1949), p. 128. Many photos and videos of the modern Scoppio del Carro are to be found online.
30 Newbigin, *Feste d'Oltrarno*, p. 6.
31 Bernardo Bellincioni, *Rime del arguto et faceto poeta Bernard Belinone fiorntino* [*sic*] (Milan: Ph. de Mantegazzi, 1493), vol. 1, pp. 26, 72; vol. 2, pp. 208–22; trans. Kate Trauman Steinitz.
32 An anonymous audience member, quoted in Edmondo Solmi and Arrigo Solmi (eds), *Scritti vinciani* (Florence: La Voce, 1924), pp. 12–13; translated by Alessandra Buccheri.
33 Tristano Calco, quoted by Mariangela Mazzocchi Doglio, 'Leonardo apparatore di spettacoli a Milano per la corta degli Sforza', in *Leonardo e gli spettacoli del suo tempo* (Milan: Electa, 1983), pp. 41–76; see p. 46.
34 Carlo Pedretti, on the other hand, believes that the Paradise did not turn, and that the 'revolving' referred to by Bellincioni was 'nothing but the actors [representing the planets] walking around': *Leonardo Architect* (London and New York: Thames and Hudson, 1986), p. 290.
35 Codex Arundel, 263, British Library F321 verso and F224 recto.
36 Kate T. Steinitz, *Leonardo Architetto Teatrale e Organizzatore di Feste*, IX Lettura Vinciana (Florence: G. Barbèra, 1970), p. 11.
37 Carlo Pedretti, 'La machina teatrale per l'Orfeo di Poliziano', *La Scala, Rivista dell'Opera* (June 1956), pp. 52–6. Reprinted in C. Pedretti, *Studi Vinciani* (Geneva: Droz, 1957), pp. 90–8.
38 Translation by Emanuel Winternitz, *Leonardo da Vinci as a Musician* (New Haven, CT, and London: Yale University Press, 1982), p. 79.
39 Winternitz, *Leonardo da Vinci*, pp. 79 and 183.
40 Pedretti, 'La machina teatrale', p. 93.
41 Larson, 'Italian Stage Machinery', p. 34.
42 Joseph Furttenbach, *Architectura Recreationis*, G. R. Kernodle translation in Barnard Hewitt (ed.), *The Renaissance Stage: Documents of Serlio, Sabbattini and Furttenbach* (Miami, FL: University of Miami Press, 1958), Figure 11, p. 201.
43 Furttenbach, *Architectura Recreationis,* trans. G. R. Kernodle, p. 202.
44 Anna Laghi published an article in two parts on the machines and scenic devices used by Buontalenti: 'Le macchine e gli ingegni di Bernardo Buontalenti per gli "Intermezzi" del 1589', *Antichità Viva*, 6 (1977): 49–57; and *Antichità Viva*, 1 (1979): pp. 27–36. This makes use of the *Descrizione* by De' Rossi, the *Memorie e Ricordi* of Ser Jacopi and the seventeenth-century books of Furttenbach and Sabbattini. Laghi includes drawings of reconstructions of the stage, the scenery and the machines. But these are all extremely speculative, based on tenuous evidence and in some cases in my view misconceived.
45 Bastiano de' Rossi, *Descrizione dell apparato e degli'intermedi fatti per la commedia …* (Florence: Anton Padovani, 1589) p. 28. The *Descrizione* is published in French translation by Anne Surgers, with many illustrations, in *La Pellegrina et les Intermèdes* (Paris: Lampsaque, 2009), pp. 91–245.
46 Alois M. Nagler, *Theatre Festivals of the Medici 1539–1637* (New Haven, CT, and London: Yale University Press, 1964), p. 39.
47 Girolamo Ser Jacopi, *Memorie e Ricordi*, Archivio di Stato, Florence: extracts reprinted in Aby Warburg, *Gesammelte Schriften*, Gertrude Bing (ed.) (Leipzig: Teubner, 1932), vol. 1, pp. 397–408; see p. 399.
48 Bastiano de' Rossi, *Descrizione del magnificentiss. apparato, e de' maraviglioso intermedi …* (Florence: Giorgio Marescotti, 1585), p. 7r.
49 De' Rossi, *Descrizione del magnificentiss. apparato*, p. 7r, translation by Nagler.
50 Nicola Sabbattini, *Pratica di Fabricar Scene e Machine ne' Teatri* (Ravenna: 1638), translation by John H. McDowell in Hewitt, *The Renaissance Stage*, p. 145.
51 Sabbattini, *Pratica di Fabricar*, p. 143.
52 Sabbattini, *Pratica di Fabricar*, p. 151.
53 Nagler, *Theatre Festivals*, p. 83.
54 Ser Jacopi, *Memorie*, in Warburg, *Gesammelte Schriften*, vol. 1, pp. 400, 403.
55 Nagler, *Theatre Festivals*, p. 83.
56 Philip Skippon, 'An Account of a Journey made thro' part of the Low-Countries, Germany, Italy and France', in A. Churchill (ed.), *A Collection of Voyages and Travels* (London: John Walthoe et al., 1732), vol. 4, pp. 359–736; see pp. 507–8. Skippon's experiences and sketches are discussed by Orville K. Larson in 'Giacomo Torelli, Sir Philip Skippon, and Stage Machinery for the Venetian Opera', *Theatre Journal*, 32/4 (1980): 448–57.
57 Larson, 'Giacomo Torelli': 457.
58 Sabbattini, *Pratica di Fabricar*, McDowell translation, p. 128.
59 Nagler, *Theatre Festivals*, p. 19.
60 Nagler, *Theatre Festivals*, p. 19.
61 Nagler, *Theatre Festivals*, p. 80, says this drawing by Buontalenti relates to the Second Intermezzo in 1589 (when there was indeed a somewhat smaller mountain that rose up from the traproom); but Roy Strong in *Art and Power*, 2nd edn (Woodbridge: Boydell and Brewer, 1984), p. 148, says this is wrong, and that it is for *Il Rapimento di Cefalo* in 1600.
62 Ferdinando Ghelli, reconstruction of a telescopic machine for raising a mountain from below stage; in Zorzi and Sperenzi (eds), *Teatro e Spettacolo*, p. 175 and fig. 37.
63 Ser Jacopi, *Memorie*, in Warburg, *Gesammelte Schriften*, vol. 1, p. 403.
64 Michelagnolo Buonarroti, *Descrizione delle felicissime Nozze Della Cristianissima Maestà di Madama Maria Medici Regina di Francia e di Nauarra* (Florence: 1600); cited in Nagler, *Theatre Festivals*, p. 96.
65 Nagler, *Theatre Festivals*, p. 96.
66 Sabbattini, *Pratica di Fabricar*, McDowell translation, pp. 145–6.
67 The author of a diary describing the *intermezzi* of 1589, Giuseppe Pavoni, said that the cloud became triangular.
68 De' Rossi, *Descrizione 1589*, p. 51; my translation.
69 De' Rossi, *Descrizione 1589*, p. 51.
70 Ser Jacopi, *Memorie* in Warburg, *Gesammelte Schriften*, p. 403.
71 Cigoli's sketch is in the Uffizi in Florence, and is reproduced in Surgers, *La Pellegrina,* Plate 8; see also pp. 205–6.
72 Ser Jacopi, *Memorie* in Warburg, *Gesammelte Schriften*, vol. 1, p. 405.
73 Nagler, *Theatre Festivals*, p. 86.
74 Published in Angelo Solerti, *Musica, Ballo e Drammatica alle Corte Medicea dal 1600 al 1637* (Florence: Bemporad, 1905), p. 56; translation by Nagler.
75 Sabbattini (*Pratica di Fabricar*, McDowell translation) discusses trapdoors and their operation in Sections 17 to 21, pp. 119–25.
76 Furttenbach, *Mannhafter Kunstspiegel*, Kernodle translation, pp. 228–9.
77 Sabbattini, *Pratica di Fabricar*, McDowell translation, p. 126.

78 Sabbattini, *Pratica di Fabricar*, p. 111.
79 Sabbattini, *Pratica di Fabricar*, pp. 126–7. See also Furttenbach, *Mannhafter Kunstspiegel*, Kernodle translation, p. 229.
80 Sabbattini, *Pratica di Fabricar*, McDowell translation pp. 130–5; Furttenbach, *Mannhafter Kunstspiegel*, Kernodle translation, pp. 239–40.
81 Furttenbach, *Mannhafter Kunstspiegel*, Kernodle translation, p. 240.
82 Sabbattini, *Pratica di Fabricar*, McDowell translation, p. 134.
83 Furttenbach, *Mannhafter Kunstspiegel*, Kernodle translation, pp. 243–4.
84 Sabbattini, *Pratica di Fabricar*, McDowell translation, pp. 135–42.
85 Nagler, *Theatre Festivals*, p. 65.
86 Nagler, *Theatre Festivals*, p. 65.
87 Nagler, *Theatre Festivals*, pp. 87–8.
88 De Rossi, *Descrizione 1589*, p. 5, my translation.
89 In Solerti, *Musica*, p. 56.

Intermezzo: Artificial weather

Thunder and lightning

In the Renaissance theatre, in fireworks shows and most surprisingly in sixteenth- and seventeenth-century gardens, there were various methods and devices used for creating man-made meteorological phenomena, or 'artificial weather'. The very idea of simulating weather in the open air using technical means might seem paradoxical, given that gardens are already subject to the real weather. But the paradox was part of the pleasure for Renaissance visitors, as it was with the 'natural' appearances of man-made grottoes.

Julius Pollux describes machines used for simulating electric storms in the ancient theatre.[1] The *keraunoskopeion* or 'lightning-tower', Pollux says, was a sort of 'high wheel-machine' – but his description is otherwise obscure. The classicist Peter Arnott suggests that the tower might have supported a kind of horizontal *periaktos* rotating on an axle, up high, painted with bright flashes on a black background.[2]

Sabbattini, writing in the seventeenth century, describes another kind of lightning machine.[3] This consists of a board divided into two parts with a zigzag cut, one half of which is moveable and the other fixed. A second board behind is 'covered with shining golden tinsel' illuminated by a dozen candles. The whole apparatus is set high in the Heavens above the stage. The gap in the front board is opened and shut rapidly with ropes, to reveal momentary jagged flashes of brightness.

Pollux's *bronteion* or thunder-maker was a copper vessel placed backstage into which bags of stones were thrown.[4] This was essentially the way in which sounds of thunder continued to be produced in the theatre, with heavy stone or metal objects either dropped into

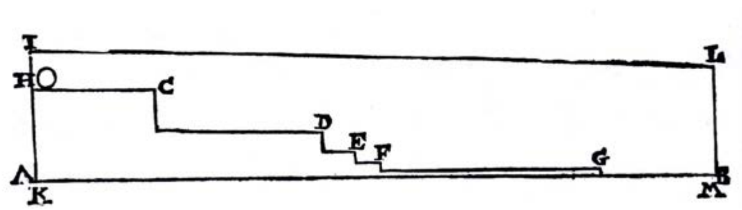

Figure B.1 Nicola Sabbattini's thunder machine. Heavy stone or iron balls are rolled down a channel with unequally spaced steps.

containers or rolled down tracks, from classical times right up to the nineteenth century. Serlio, writing in 1545, talks about rolling a large stone ball on the floor of the room above the hall where the production is taking place.[5] A century later, Sabbattini is more specific: two or three stone or iron balls are rolled down a sloping wooden channel which has in it a series of unevenly spaced steps (Figure B.1).[6] Identical machines can still be found in some theatres today.

Thunderous sounds and flashes are produced, obviously, by many fireworks. This fact was exploited dramatically in some Renaissance theatrical productions. We saw how Brunelleschi engineered a bolt of lightning in the *Annunciation*, probably using some type of pyrotechnic device pulled along a rope. In other sacred plays a lightning strike was represented with a rocket running on a wire, like the rocket-powered dove in the Explosion of the Cart. The wire served to guide the bolt to its target. When the squib hit its mark – perhaps a pagan idol – a small charge of gunpowder was exploded and the idol disappeared through a trapdoor.[7]

Wind

If a dramatic story demanded a complete storm, the thunder and lightning could be accompanied by artificial or real wind. Sabbattini explains how to imitate the sound of wind. 'Thin pieces of walnut or other hard wood, 1½ feet long and 1 inch or a little more [wide], are required, which must be pliable like a ruler used in drawing.'[8] These pieces are attached to short strings, with which the operator whirls them around his head. Readers may possibly remember making similar devices with rulers and string at school. Furttenbach says that one can, at the same time, send out a real wind 'through hidden bore holes into the audience' using a large bellows.[9] Furttenbach combined all these effects together to create a 'tremendous terrifying storm' in his

dramatisation of the story of Jonah and the Whale. 'Such a sight made the hair of the spectators stand on end …'[10]

Sunshine

Pyrotechnic 'suns' of enormous brightness were made by arranging many fixed firework units in radial patterns and lighting them all at once. Very large assemblies of this kind, known as 'glories', featured in shows at Versailles to celebrate the reign of the Sun King Louis XIV. By the mid-eighteenth century glories were being constructed up to 60 feet in diameter. Figure B.2 shows the frontispiece of a treatise on fireworks by Amédée-François Frezier with a gigantic sun at the top.[11] The

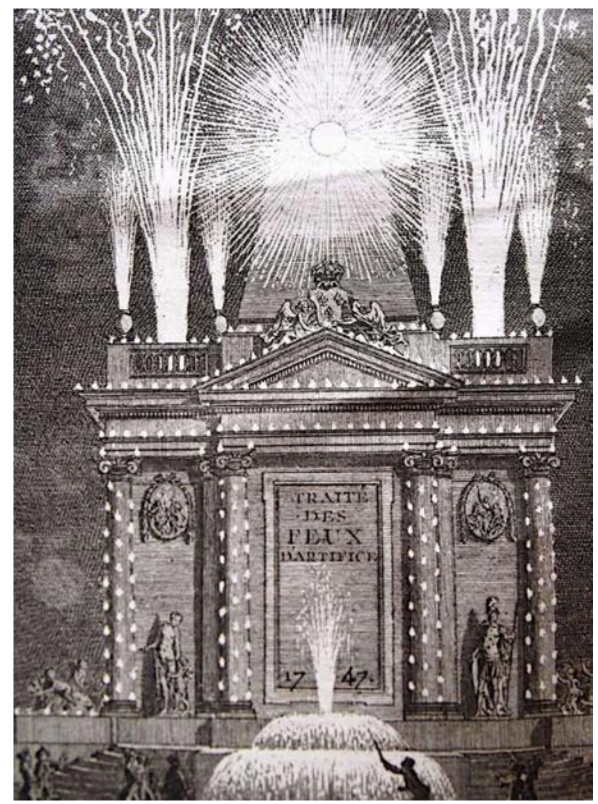

Figure B.2 On top of the classical temple is a 'glory' made of many fixed golden fireworks, to create an artificial sun. From Amédée-François Frezier, *Treatise on Firework Shows*.

classical building is a fireworks 'machine' that will burn to the ground at the end of the show.

In the theatre, the simulation of brilliant sunshine presented greater challenges in the days before electricity. Furttenbach describes what he calls a 'Glory Box' (Figure B.3), which has a window 2 feet square covered by a sliding door.[12] Inside are several strong lamps with copper hoods, behind a glass globe filled with water. The water is lightly tinted with red dye. The interior of the box is lined with gold tinsel. At the front of the box is a metal image of the sun, which has 16 'points or flames, no thicker than a knife blade, of well-coloured brass cut from a barber's basin shining like beautiful gold and highly polished with brickdust'.

These sunbeams are rotated with rods. The shutter can be opened to reveal the sun as required, and the whole box can be turned in different directions, 'to send a beautiful splendour with shimmering beams towards the spectators, causing them great wonder'. Furttenbach

Figure B.3 A 'glory box' designed by Joseph Furttenbach to simulate the sun on stage. Sunbeams made of polished brass are rotated in front of a glass globe filled with water, lit by several lamps. The box is lined with gold tinsel.

does not explain, but presumably the glass sphere acted as a large lens, magnifying the images of the lamps.

The stage designer Aristotile da Sangallo used a similar ball of glass in a production that he designed for the marriage of Cosimo Grand Duke of Tuscany to Eleonora of Toledo in 1539. Vasari gives an account:[13]

> He then arranged with much ingenuity a lantern of wood in the manner of an arch, behind all the buildings [on the stage set], with a sun one braccio [2 feet] high, in the form of a clear glass ball filled with distilled water, behind which were two lighted torches, which rendered the sky of the scenery and prospect-view so luminous, that it had the appearance of the real and natural sun.[14]

The events of the drama took place over a single day. The sun started at the bottom of one side of the arch, and was moved slowly with a winch around the entire semicircular structure, such that 'at the beginning of the performance the sun appeared to be rising, and then, having climbed to the centre of the arch, it so descended that at the end of the piece it was setting and sinking below the horizon'.

The performance was bracketed by the appearance of two actors representing Dawn and Night, at the opening and the finale.[15]

A sweet rain

In Chapter 5 we will see how false rain, the sounds of thunder and real rainbows were created in gardens with the water from fountains. In the theatre the audience might be subjected in person to artificial weather, and not just wind from bellows. On warm days, Furttenbach says, a 'rain of water perfumed with roses and other odours' can be dropped through holes in the ceiling, 'but only on the heads of the most prominent ladies and their sons'.[16] 'Or, instead of rain, a sugared hail can be produced of sugared confections of coriander, almond, cinnamon, etc., to bring the play to a happy close.'

Notes

1 Julius Pollux, 'Extracts concerning the Greek Theatre' [from the *Onomasticon*] (second century AD), p. 11.

2 Peter Arnott, *Greek Scenic Conventions in the Fifth Century B.C.* (Oxford: Oxford University Press, 1962), p. 89.
3 Sabbattini, *Pratica di Fabricar Scene*, in Barnard Hewitt (ed.), *The Renaissance Stage: Documents of Serlio, Sabbattini and Furttenbach* (Miami, FL: University of Miami Press, 1958), pp. 170–1.
4 Pollux, 'Extracts concerning the Greek Theatre', p. 11.
5 Sebastiano Serlio, *Il Secondo Libro d'Architettura* (Paris: avec privilege du Roy, 1545), translation by Allardyce Nicoll in Hewitt, *The Renaissance Stage*, p. 35.
6 Sabbattini, *Pratica di Fabricar Scene*, p. 172.
7 Orville K. Larson, 'Italian Stage Machinery, 1500–1700', PhD thesis, University of Illinois (1956), p. 30.
8 Sabbattini, *Pratica di Fabricar Scene*, p. 170.
9 Joseph Furttenbach, *Mannhafter Kunstspiegel* (Augsburg: Schultes, 1663), trans. George R. Kernodle in Hewitt, *The Renaissance Stage*, p. 230.
10 Furttenbach, *Mannhafter Kunstspiegel*, p. 244.
11 'M. F*** D.D.F.D.B' (Amédée-François Frezier), *Traité des Feux d'Artifice pour le Spectacle* (Paris: Nyon, 1747), frontispiece. This is the second edition: the first was published by Jombert in 1706.
12 Furttenbach, *Mannhafter Kunstspiegel*, pp. 224–7.
13 Vasari says that San Gallo was called Aristotile 'because it truly seemed that he was to perspective what Aristotle was to philosophy': *Life* of Bastiano da San Gallo, in Thomas A. Pallen, *Vasari on Theatre* (Carbondale and Edwardsville: Southern Illinois University Press, 1999), p. 75.
14 *Life* of Bastiano da San Gallo, in Pallen, *Vasari on Theatre*, p. 78.
15 As described in a contemporary account by P. F. Giambullari: see Pallen, *Vasari on Theatre*, p. 30.
16 Furttenbach, *Mannhafter Kunstspiegel*, in Hewitt, *The Renaissance Stage*, p. 231. Lily B. Campbell, *Scenes and Machines on the English Stage During the Renaissance* (Cambridge: Cambridge University Press, 1923), p. 92, describes a production of *Dido* at Oxford in 1585 in front of Queen Elizabeth. The audience was showered with similar delights in the course of a tempest 'wherein it hailed small comfects, rained rose water, and snew an artificial kind of snew, all strange, marvellous, and abundant'. The confectioners were working hard on this occasion: the centrepiece of the banquet for the queen was a model of the destruction of Troy in marzipan.

3
The automata of Hero of Alexandria

We now turn to Hero, the engineer introduced along with Vitruvius in the Introduction, who worked in Alexandria in the first century AD. Much of Hero's body of writing is lost, but two of his surviving works, as mentioned, were of crucial importance for Renaissance designers. One is the *Pneumatics*.[1] This book was translated from the Greek and printed in the late sixteenth century: it was widely circulated and read with great enthusiasm by Renaissance philosophers and designers, in particular Buontalenti and Aleòtti.[2]

The second is *On Automata-Making*, which describes model theatres in which short plays were performed mechanically without human intervention.[3] The contents of this book of Hero's find strong echoes, I will argue, in late Renaissance stage machinery. *On Automata-Making* was printed in Italy in 1589, but was and has remained much less read than the *Pneumatics*.

Hero's works are only original in parts. His *Pneumatics* takes much of its material from another book of the same title by Philo, who worked in Byzantium in around 250 BC.[4] Hero is also quite explicit that his book on automaton theatres is in part a commentary on, and elaboration of, Philo's ideas.[5] But Philo's *Pneumatics* survived only as a much-altered partial version in Arabic, and his work on model theatres was lost; so Renaissance designers mostly studied Hero.

Italian engineers in the fifteenth century, including Giovanni Fontana and Leonardo da Vinci, nevertheless read Philo's *Pneumatics* in manuscript. The work's contents are by no means identical with Hero's, and Philo has many schemes for hydraulic devices that were influential on Islamic designers in the Middle Ages, and through them on fountain design in the Renaissance.

Hero's automaton theatres

Of the two theatres described in Hero's *On Automata-Making* the first is fixed in place. The other moves: it rolls on wheels into position, stops, gives its show and rolls away again, all on its own initiative. The subjects of the short plays put on by the theatres are drawn from classical mythology. It is possible that these were toys for the rich, to provide entertainment at *symposia* – Greek drinking parties. There are other indications, though, that they might have been designed to present their dramas to public audiences. Several classical writers, including Aristotle, Xenophon and Plato, refer to popular shows featuring puppets and automata.[6] Susan Murphy, who has recently translated Hero's book into English for the first time, speculates that an automaton theatre might have provided a 'short, silent prelude to a full-scale drama'.[7]

The mobile theatre presents *The Apotheosis of Dionysos*, Dionysos being the god of wine, merrymaking and, significantly, theatre. Although Dionysos (Bacchus in Latin) was the son of Zeus, it was only after living on earth for a time as a mortal that he underwent *apotheosis* or elevation to divine status. The theatre's structure consists of a pedestal with four large columns on top. These support a platform on which a miniature circular temple stands. The illustrations in manuscripts of Hero's book had been 'barbarised' by successive copying, according to Bernardino Baldi who made the 1589 Italian translation. So Baldi had new diagrams drawn, including the one shown in Figure 3.1, which depicts the mobile theatre.

A figure of Victory stands on top of the temple roof, wings extended, holding a crown. Dionysos himself is inside the building, holding a cup and a *thyrsos* – a staff tipped with a hollow metal pine cone. A panther lies at his feet. There are two altars with fires laid on them on either side of the temple. The building is surrounded by a ring of *bacchantes*, the dancing revellers who followed Dionysos.

Once the theatre has manoeuvred itself into place, the play begins. The fire on the altar in front of Dionysos ignites, spontaneously as it seems. Milk flows from Dionysos' *thyrsos*, and he spills wine from his cup over the panther. Wreaths appear suddenly on the sides of the pedestal. The bacchantes dance round the temple for a time to the sound of cymbals and drums. Dionysos and Victory turn to face in the opposite direction. The second altar fire bursts into flame. More wine and milk are spilled. The music begins again and the dancers make a second tour. This ends the performance and the theatre withdraws.

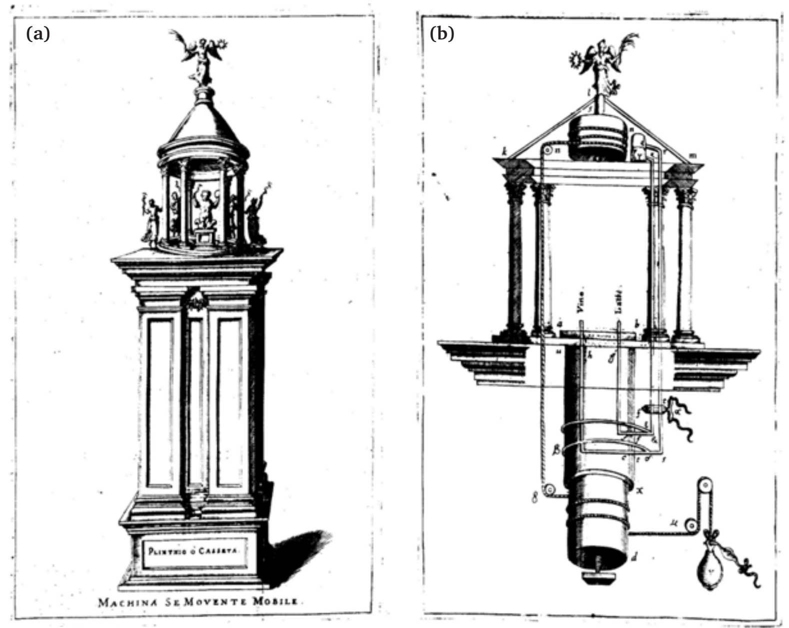

Figure 3.1 Hero's mobile theatre, from Bernardino Baldi's translation of *On Automata-Making* of 1589: (a) general view and (b) cross-section.

A longer play, *The Legend of Nauplios*, is presented in Hero's fixed theatre.[8] Nauplios was one of the Argonauts, the band of heroes who sailed with Jason in the *Argo*. After the fall of Troy, the Greeks wrongly executed his son Palamedes for treachery. The Greek fleet then set off for home and ran into a storm. Nauplios got his revenge for his son's death by using a torch to lure the Greek ships onto rocks off the coast of Euboea, where they were wrecked. In the midst of this catastrophe the goddess Athena killed the great warrior Ajax with a lightning bolt.

The theatre takes the form of a miniature classical temple supported on a pedestal. Figure 3.2 shows a computer model built by Richard Beacham, historian of the ancient theatre, and Janis Atelbauers. The temple has a pair of doors in the front that open and close to reveal the successive scenes. In the first scene, visible in this view of the model, we see Greek boatbuilders on the shore preparing their ships for the journey. They are working with saws, axes and hammers. The doors close, and open again on the next scene to reveal the open sea. Greek ships appear in formation and row past. Dolphins frolic in the water around them. The sky darkens and the sea becomes rough.

Figure 3.2 Working digital model of Hero's fixed theatre. The doors in the temple front open and close to reveal the scenes. The weight-driven motor can be seen in the pedestal. Dry sand running out into the hopper below lets the weight fall slowly. This scene from *The Legend of Nauplios* shows Greek boatbuilders at work. By kind permission of Richard Beacham and Janis Atelbauers.

In the third scene we meet Nauplios, with Athena standing beside him. Nauplios is holding up his torch to attract the Greeks. The torch ignites a beacon fire in the roof of the theatre that is visible through an opening above the stage. The final scene shows the wreck of the Greek fleet. Athena appears on stage again. We hear the sound of thunder, lightning flashes from the sky, and Ajax disappears into the sea.

How the automaton theatres worked

Both theatres, the mobile and the static, are extremely complex in their workings.[9] In fact, very few machines of this complexity are known from the ancient world, and these are the only such machines for which detailed written technical descriptions survive. I will pick out some key features. Hero gives dimensions for both theatres, saying they are small enough to dispose of any idea that there might be human operators inside.[10] The motors consist of large lead weights that move slowly down the supporting pedestals. The weights sit on top of hoppers containing millet or mustard seeds in the mobile theatre, dry sand in the fixed theatre. The seeds or grains of sand run out through small holes in the bases of the hoppers, so that the weights are lowered slowly and steadily, like the weights in grandfather clocks. Sand can be seen pouring from the hopper in Beacham and Atelbauers's model (see Figure 3.2). The mobile theatre has a second weight that powers some of the actions of the figures separately.

The mobile theatre moves on three wheels: one free-running wheel at the rear, and two drive wheels on an axle or axles at the front. The weight-driven motor pulls on a cord wound round the drive axle. The cord turns the axle and the wheels rotate. Although at one point Hero mentions guiderails, he goes on to describe methods by which the theatre can be 'programmed' to steer itself on a flat surface along a straight, curved or snaking path, and can go backwards as well as forwards. For example, to reverse direction, the cord is wound first one way round the axle, then in the opposite sense, as shown in Figure 3.3. One way for the theatre to travel along a curved path is to give one of the drive wheels a somewhat larger diameter than the other. Finlay McCourt has recently made a technical analysis of these proposals.[11] He has worked out that the theatre, given the dimensions specified by Hero, might have propelled itself over a maximum distance of 4 metres.[12]

Moving to Hero's scenery, his characters and their actions: several details of both theatres make use of mechanisms and devices that are explained in more detail in the *Pneumatics,* as we will see shortly. The wine and milk poured by Bacchus in *The Apotheosis of Dionysos* are supplied through tubes from containers in the roof of the temple. The music of the *bacchantes* is produced by releasing lead pellets from a box with a retractable lid. The pellets fall onto a drumhead and rebound onto a little cymbal.

The doors of the fixed theatre are opened and closed by cords beneath the stage floor, wrapped around rotating posts on which the

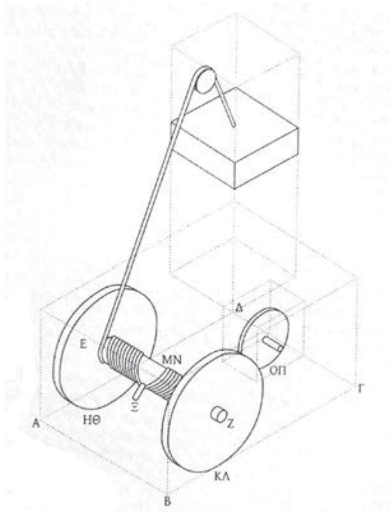

Figure 3.3 Diagram by Finlay McCourt to show how Hero's mobile theatre could move forward and then backward. The cord from the weight-driven motor is wound first one way, then the other way, around the drive axle. By kind permission of Finlay McCourt.

doors are hung. The fire lit by Nauplios is made with an oil lamp, already burning, concealed in a box in the stage roof. A metal plate over the flame is drawn back, and wood shavings above are set alight. Figure 3.4 shows how the arm of a Greek shipbuilder is made to move up and down with an axe in his hand.[13] The arm and its tool are painted on a shaped piece of horn, attached to a lever that has a spike at one end. The spike engages with a toothed wheel that rotates and tips the lever. A counterweight (at the left) pulls the lever back again, and so on repeatedly. The arm rises and falls. This and other mechanisms are hidden behind a backdrop on which the static parts of the workmen are painted.

The dolphins are cut-out figures mounted on bars attached to a rotating wheel (Figure 3.5).[14] The wheel is below stage and the dolphins appear and disappear through an aperture in the stage floor. Hero's own account of how the figure of Athena is made to move reads: 'One cord will raise her by pulling from behind her hips, and will keep her balanced. After this cord is released, another, set around her waist, pulls her in a circle, until she returns to the spot from which she started.'[15] It seems possible that her path was guided by a racetrack-shaped slot in the stage.

By far the most ingenious part of the design of both theatres is the way in which the movements of the various parts are controlled,

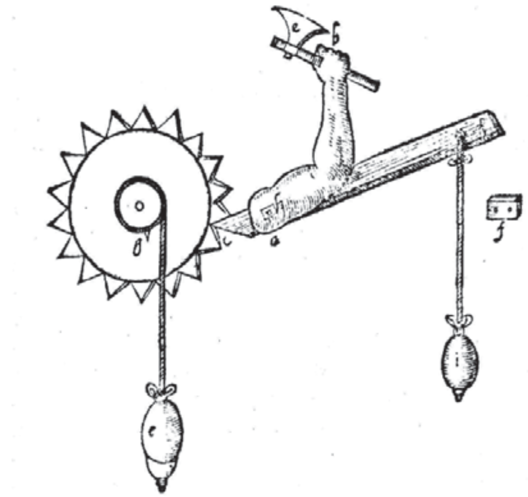

Figure 3.4 Device for making the arm of a shipbuilder move up and down carrying an axe, in *The Legend of Nauplios*.

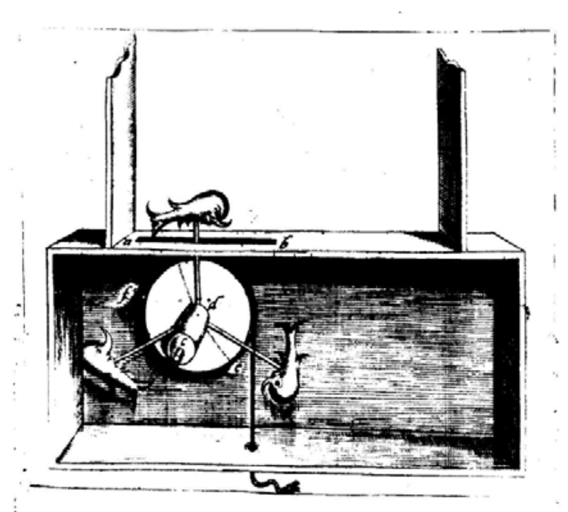

Figure 3.5 Dolphins in *The Legend of Nauplios* mounted on a wheel, so that they rise from below the stage.

such that they are activated in the correct sequence and for the required length of time. All are linked to the weight-driven motors by cords. Some of these cords are wrapped round drums of different diameters, which as a result pull the cords at different speeds appropriate to the mechanisms they control. The cords are of carefully calculated lengths,

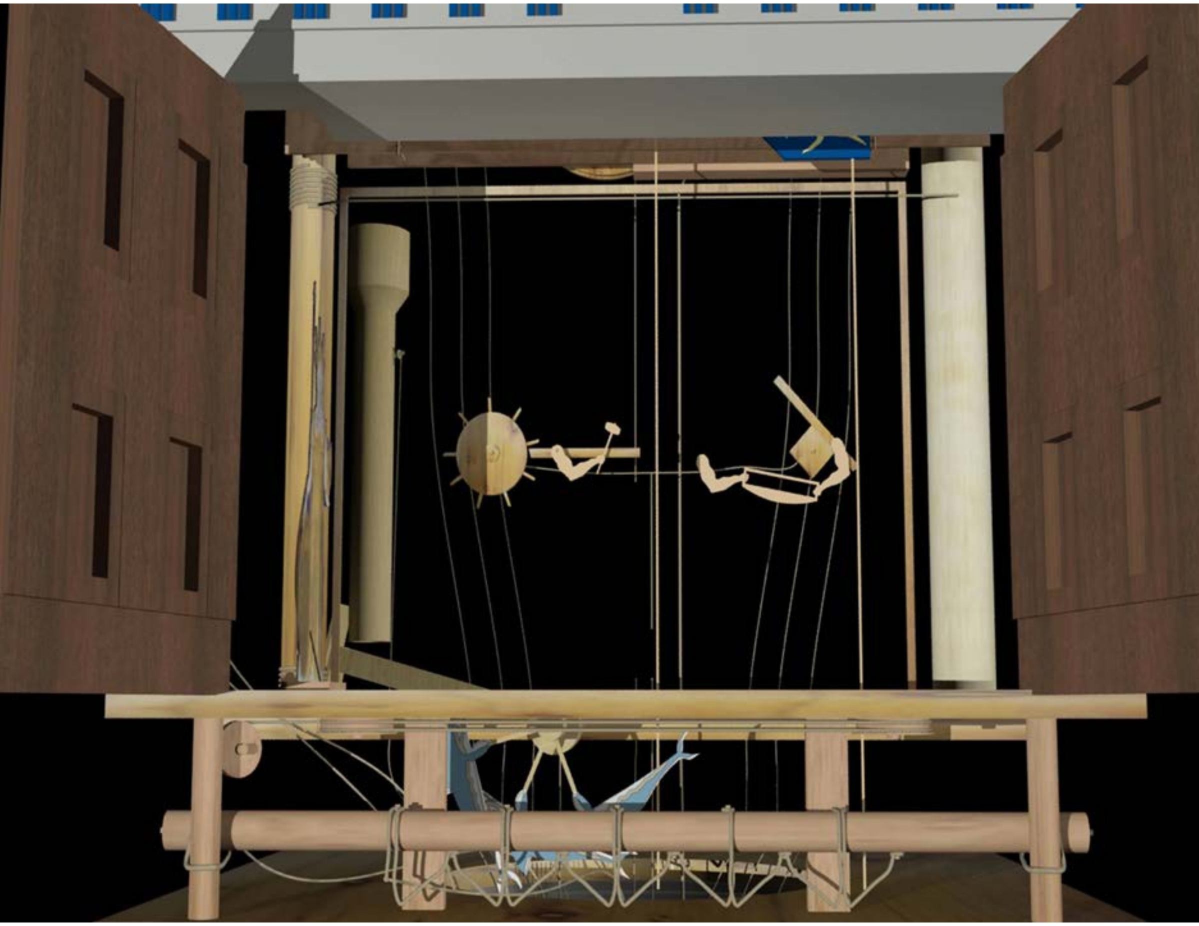

Figure 3.6 Backstage view of Beacham and Atelbauers's model of Hero's fixed theatre. We see devices for *The Legend of Nauplios*: the boatbuilders' arms and tools; the dolphins below stage; and the cords wrapped around the horizontal rod that is linked to the doorposts and turns the doors. By kind permission of Richard Beacham and Janis Atelbauers.

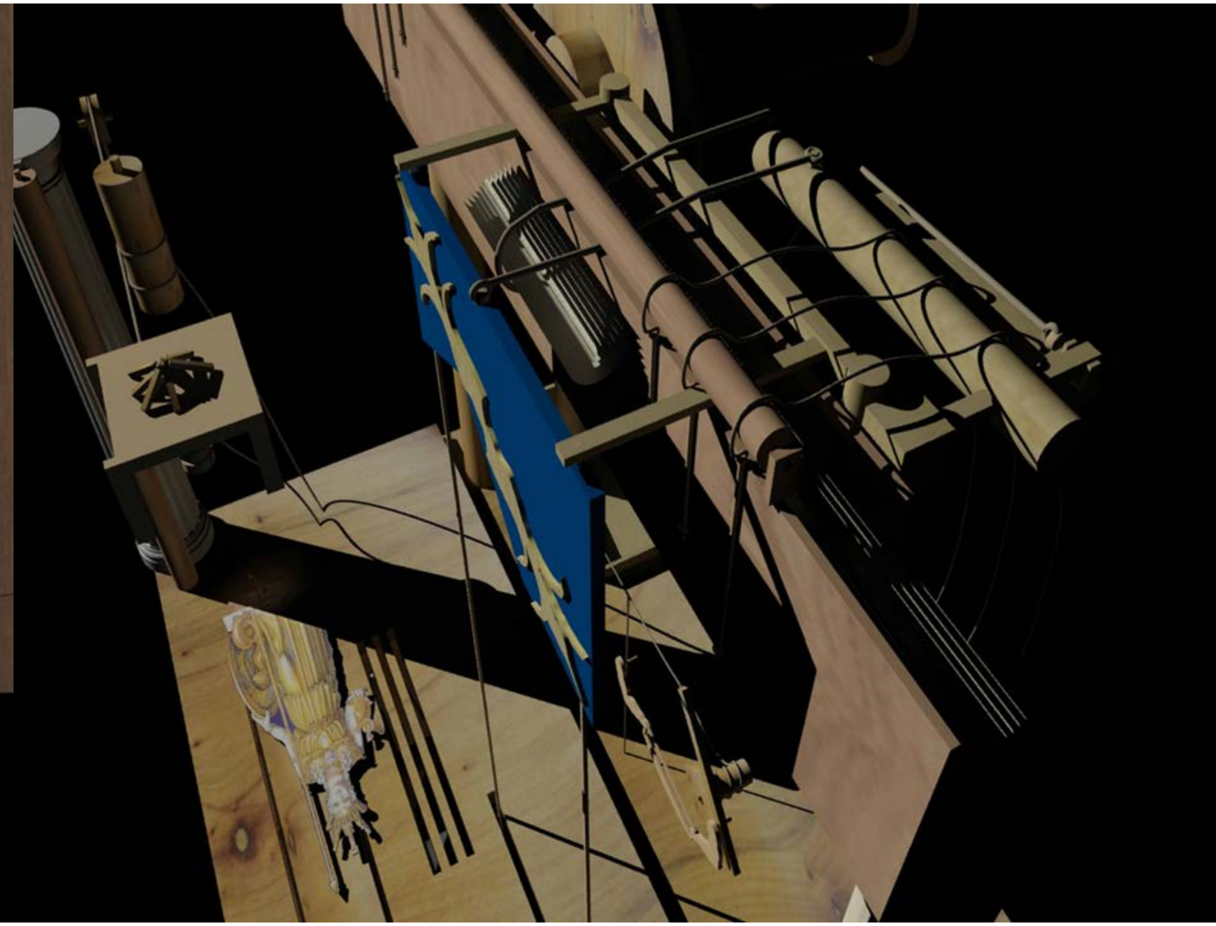

Figure 3.7 Another view of Beacham and Atelbauers's model of Hero's fixed theatre, from above. We see (left) the beacon lit by Nauplios; on stage the recumbent figure of Athena; the blue board carrying the golden bolt of lightning; and cords on drums for lowering and raising scenery. By kind permission of Richard Beacham and Janis Atelbauers.

and the slack is bunched in loops. The slack is gradually taken up, and at the appropriate moment when each cord becomes taut, it activates the relevant component or device.

The digital model of the mobile theatre built by Beacham and Atelbauers gives a complete presentation of *The Legend of Nauplios*.[16] In their entrancing video of this performance we also go backstage to see all the machinery in operation. Figure 3.6 shows the mechanisms that drive the boatbuilders' arms as they work with hammer and saw. Below stage are the dolphins ready to emerge from the waves, and in front is the rod with its system of cords that opens and closes the temple doors. Figure 3.7 gives a view looking down from the 'flies' above the stage. Athena is lying flat waiting to be raised up and made to circle the stage. The fire lit by Nauplios is on the platform at top left. The sky-blue board at the centre carries the bolt of lightning that is dropped from above and kills Ajax.

Notice the many differences between the form of Hero's fixed theatre and its large-scale classical counterparts, of which it is by no

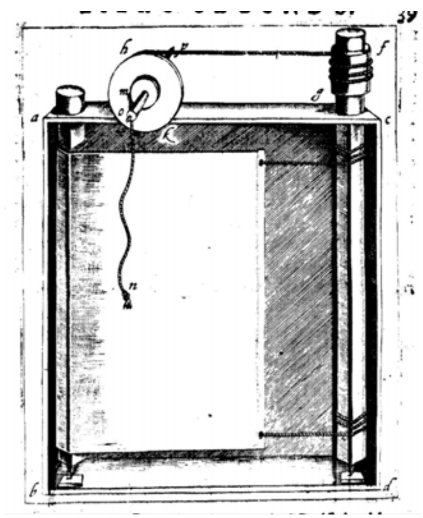

Figure 3.8 Backdrop moved across the stage with vertical rollers. In *The Legend of Nauplios*, this is painted with a scene depicting the Greek fleet at sea.

means a reduced scale model.[17] Unlike the ancient open-air theatres, Hero's theatre has a proscenium arch that frames the action and can be closed with doors. The scenery in *The Legend of Nauplios* seems to have provided coherent pictorial representations of specific locales: the seashore, the open sea, the rocks off Euboea. By contrast, it appears that locations in the ancient theatre proper were signalled just by scattered conventional or symbolic images painted on the *periaktoi*.

In Hero's theatre, scenery to create these illusions is dropped from the 'flies'. In one scene a backdrop is introduced sideways from the 'wings': the sea and Greek fleet are painted on a long strip of cloth that is moved from right to left on rollers (Figure 3.8). Athena moves, it seems, in a slot in the stage floor, and the dolphins appear from below stage through another slot. Finally, there is the extensive use of cords and counterweights to control all this apparatus.

Renaissance echoes of Hero's fixed theatre

Hero's fixed theatre may not have been anything like the full-size ancient theatre, but it does bear uncanny similarities to theatres of the kind that were being built in Italy at the turn of the sixteenth and seventeenth centuries. This fact has not, I believe, been commented on by theatre historians, nor by historians of automata, with one exception.[18] Victor Prou, an engineer who translated part of Hero's *On Automata-Making* into French in the nineteenth century, makes the connection. He remarks on 'the startling resemblance of the static automaton theatres [of Philo and Hero] to the scenic conditions of the modern theatre'.[19] By 'modern', Prou presumably means theatres of the nineteenth century, but these were in many essential respects unchanged from Buontalenti's Uffizi Theatre, and Aleòtti's Teatro Farnese at Parma.

What exactly are these similarities? First, the proscenium frame: the outstanding feature shared by Hero's fixed theatre, the Uffizi and the Teatro Farnese, behind which all their machinery is hidden. Second, the rotation of scenic elements by means of ropes below stage: the doors of Hero's theatre and the new *periaktoi* of the sixteenth century. Third, scenery lowered from above stage: the bolt of lightning in Hero's theatre, the cloud machines in the *intermezzi*. Fourth, flats brought in from the side: the scrolling backdrop of the ocean and the Greek fleet in *The Legend of Nauplios*, Aleòtti's flat scenery in Parma. Fifth, sea creatures appearing through traps from below stage: Hero's leaping dolphins, Buontalenti's whales, marine gods and dolphins in his sea scenes. Sixth and finally: Hero has an automatic device in his theatre roof for uncovering an already burning lamp, which ignites the fire above, while Buontalenti at the Uffizi has an automated method for dimming and raising all the lights at once, possibly using a similar mechanism.[20]

Perhaps another echo of Hero's door-opening machinery is to be detected in Leonardo's mountain set for *Orfeo*, whose sides open in two parts, pulled by ropes wound on twin vertical posts. Leonardo was familiar with the work of both Hero and Philo. But of course, Leonardo of all people would have been more than capable of devising this apparatus himself.

Several manuscript copies of *On Automata-Making*, held in the collections of Italian libraries, were circulating among scholars from the early sixteenth century.[21] Daniele Barbaro in his 1556 edition of Vitruvius's book includes – along with numerous mentions of the *Pneumatics* – a lengthy passage about *The Apotheosis of Dionysus*. Barbaro also says that he has 'translated the books [plural] of that author into our language', although these manuscripts seem to have been lost.[22] The first published Italian translation of Hero's automaton book was by Bernardino Baldi: it was printed in 1589, the year of Buontalenti's production of *La Pellegrina* – although Baldi had made the translation much earlier and had put it aside, as he explains in his preface.

Buontalenti and Aleòtti were both deeply fascinated by Hero's second book, the *Pneumatics*; indeed Aleòtti made and published his own translation, and Buontalenti commissioned another translation that remained unpublished. Bernardo Davanzati translated the preface to the *Pneumatics* and sent a copy to Buontalenti with a letter referring to 'your Hero'.[23] In this context, it is hard to imagine the two men were not also aware of Hero's book on theatres. There is, however, no documentary evidence for this, so far as I am aware.

On the other hand, Hero is mentioned explicitly in a long book called *The Mask, or the Building of Theatres*, by the poet and musician Ercole Bottrigari, written in around 1598 but never printed. Bottrigari is reminiscing about street entertainers and mentions one 'who himself pulled along a big wooden machine shaped like a theatre, in which various little figures modelled in relief were moved by the power of wheels, in the way that Hero the mechanic teaches in his book on Automata'.[24] The scene showed knights fighting in a piazza, both on foot and on horseback, with beasts and monsters. Arquebusiers (gunmen) and artillery laid siege to castles. Bottrigari says nothing more about how this show actually worked. But the important point is that a writer who is very knowledgeable about theatre design and equipment is aware, at this date, of Hero's book.

None of this is to try to make some definitive case for Hero being the sole source and inspiration for the complex machinery of the late Renaissance theatre. Clearly there are many other sources, as I have already enumerated, in Vitruvius and Pollux, and the medieval religious drama. Nor do we have to search for ancient precedents in the ropes, winches, windlasses, pulleys and crane-like devices described by Sabbattini – all of them in widespread contemporary use in building construction, the rigging of ships and military engineering.[25] Ideas for other theatrical *ingegni* could well have occurred independently to the inventive Renaissance designer faced with some specific problem of staging.

But at the very least we can imagine that Aleòtti and Buontalenti would, when reading *On Automata-Making*, have recognised with excitement many of the features of their own theatres. As the historian of the Renaissance Eugenio Battisti writes of Hero and Philo:

> [they] arrived at the construction of mechanical theatres that were quite as ingenious as those of the 16th to the 18th century (and with much smaller dimensions, despite the complication of the mechanisms), capable of putting on veritable 'pièces à machines' by which the highly cultured Buontalenti was surely inspired; like the famous tragedy of Nauplios in five acts …[26]

The machinery of Aleòtti's Teatro Farnese went even further than its predecessors in adopting 'Heronian' technologies, as we will see; the opera houses of Venice went further still. Here all the moving flats were controlled centrally with cables wound on rotating drums, and counterweights were used to balance the forces involved. The theatre as a whole became – it is not too much to say – a Heronian machine.

Hero's *Pneumatics*

Let us now look at Hero's *Pneumatics*. The book is arranged as a series of 'theorems'. Figure 3.9 shows Theorem 40.[27] In Hero's words:

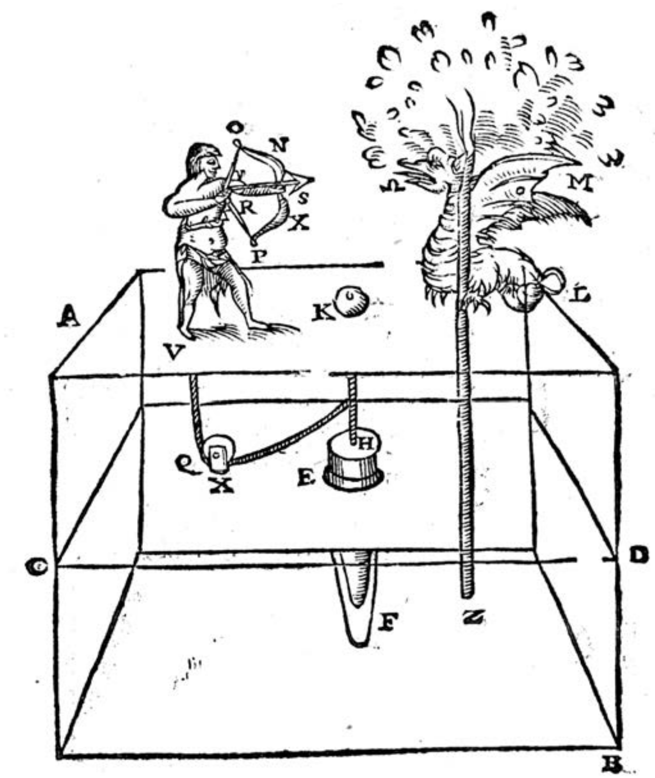

Figure 3.9 Theorem 40 from Hero's *Pneumatics*: 'On an apple being lifted, Hercules shoots a dragon which then hisses'.

> On a pedestal is placed a small tree round which a serpent or dragon is coiled; a figure of Hercules stands near shooting from a bow, and an apple lies upon the pedestal: if one raises, with the hand, the apple a little from the pedestal, the Hercules shall discharge his arrow at the serpent and the serpent hiss.[28]

The allusion is to the 11th Labour of Hercules, when he was charged to steal golden apples from the Garden of the Hesperides. The Hesperides were elusive nymphs of the evening, and their apples – which conferred immortality on those who ate them – were guarded by the hundred-headed dragon Ladon.

There are physical effects of different kinds exploited in this automaton. The operator draws Hercules's bow in advance and places an arrow in it ready to fire. The pedestal is divided into two chambers, the upper one filled with water. The apple is a control knob that sets events in train. When it is lifted, it pulls a cord that is linked to Hercules's trigger finger, which releases the bowstring and fires the arrow. Simultaneously, another cord removes a plug at *H* that lets water run into the lower chamber, raising the pressure of the air inside. Air is forced up through the tube *Z* and sounds a whistle hidden in the tree, to make the snake hiss.

The illustrations reproduced here are from the first printed Renaissance translation of the *Pneumatics* into Latin of 1575.[29] This was made by Federico Commandino of Urbino, who translated many ancient mathematical texts. Much older pictures exist in the form of Persian miniatures and in medieval manuscripts.

Clearly, Hero's book bears very little resemblance to a modern scientific text. Indeed, despite the title, it is only partly devoted to the effects of air pressure: quite as much attention is given to water pressure or hydraulics, as well as the actions of heat, weights and mechanical forces. It has a short theoretical introduction, followed by separate descriptions of 78 devices and models, with pictures. In the 1940s A. G. Drachmann analysed the *Pneumatics* in great detail.[30] He thought it was an incomplete draft and concluded that 'If [Hero] had finished and published his book, we should not have found a treatise on applied physics, still less a vademecum for conjurors; we should have found a technical handbook on the construction of pneumatic instruments, meant for the workshop that had to turn them out.'[31]

A large number of Hero's devices are vessels where siphons are used to draw off liquids or to move liquids from one container

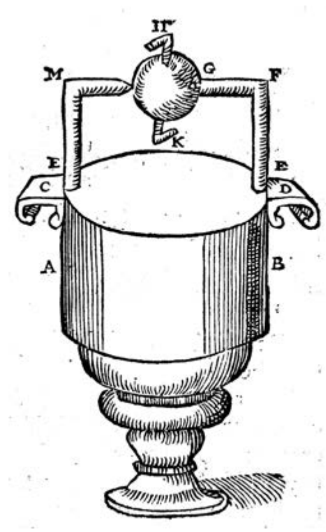

Figure 3.10 Theorem 50 from Hero's *Pneumatics*: the *aeolipile* or 'steam engine'. Steam issuing from the angled jets causes the ball to spin.

to another. Many more are trick jugs and drinking vessels of various kinds, for example 'A Drinking-Horn from which a Mixture of Wine and Water, or pure Water, may be made to flow alternately or together at pleasure'.[32] One can imagine these, like the theatres, providing talking points at *symposia*.

In the wider history of science and technology the most famous of Hero's machines is the *aeolipile* (Figure 3.10).[33] This is a metal sphere supported on pivots (*L* and *G* in the figure). Steam is introduced to the sphere through the pivots from a boiler beneath. The steam escapes through two little tubes *H* and *K*. Because these tubes are bent into L-shapes, the jets of steam issue sideways and cause the sphere to revolve. Many have seen the *aeolipile* as the ancestor of the steam engine, and there have even been (extremely controversial) reports that a Spanish ship was driven by paddle wheels powered by an *aeolipile* in the 1530s.[34]

For our purposes, however, the most relevant of Hero's machines are those where animal and human figures move, temple doors open and close automatically and musical instruments play by themselves. Derek de Solla Price has written that 'Amongst historians of technology [of whom de Solla Price was one] there seems always to have been private, somewhat peevish discontent because the most ingenious mechanical devices of antiquity were not useful machines but trivial toys.'[35] This disapproval was shared by German classicists who worked on ancient scientific manuscripts in the nineteenth century. But as Marie Boas Hall says, this was precisely what the Renaissance reader loved: ‘the mixture of serious theoretical discussion and detailed directions for constructing toys, ingenious machines and practical instruments’.[36]

Hero begins his introduction with the philosopher Empedocles’ argument that the world is constituted from four basic elements: Earth, Water, Air and Fire. These can occur separately or can be combined to create different substances. As Hero puts it, ‘by the union of [the elements] and the concurrence of three, or four, elementary principles, various combinations are effected, some of which supply the most pressing wants of human life, while others produce amazement and alarm’.[37] Hero agrees with Aristotle that there are no continuous vacuums – no large volumes filled with nothingness – in nature. But he differs from Aristotle in believing that minute vacuums are distributed throughout the four elements. This is why in the case of air, for example, it can be compressed by force, or can be rarefied or thinned out by heating. Many of the devices in the *Pneumatics* depend on such processes.

Each of the four elements behaves and moves in its characteristic way. Earth tends to move downwards towards the centre of the world, while water ‘finds its own level’. Hence both can be used as weights to drive machines. Meanwhile air and fire tend to move upwards, in the form of water vapour, steam, flames and smoke. The realm of air lies above the earth and the seas. The realm of fire, associated with the greatest source of heat – the sun – lies above all the others.

The reason why Hero and his predecessors were so intrigued by the siphon was that it broke the law of nature that water always moves downwards. The siphon in its simplest form is an inverted U-shaped tube with one arm in a vessel full of liquid. The bottom of the arm of the siphon outside the vessel is below the bottom of the other arm immersed in the liquid. If liquid is initially sucked into the tube by mouth, it continues to flow by itself until the vessel is emptied. The flow of water upwards in one half of the tube is what seemed ‘unnatural’. But Hero explains how, otherwise, a large vacuum would be created in the tube; and that is impossible. These applications of the theory of the elements to the movement of water in pipes would become central to the Renaissance understanding of fountains and their workings.

By means of ‘theorems’ resulting from the principles inherent in the four elements, Hero says, ‘many curious and astonishing kinds of motion may be discovered’.[38] Let us look at some more examples. Figure 3.11 shows a figure of a bird standing on a pedestal.[39] (This drawing is *not* from Commandino, who just shows a bare box; but from the English translation by Bennet Woodcroft of 1851. Woodcroft has had the nice conceit of making the bird a heron.) If a cup of water is brought to the bird’s beak, it ‘drinks’ the cup dry. Inside the body of the bird is a simple siphon *EFG*. The end at *G* is lower than the end in the heron’s beak at *E*. The siphon is filled with water before the trick is demonstrated: it sucks the water up from the cup and deposits it in the pedestal.

The machine shown in Figure 3.12 opens and closes a pair of doors on a ‘small temple’ that could be either a real building or more likely a scale model.[40] The fire on the altar at the left heats air that passes into the spherical vessel below. This displaces water into a bucket via the tube *KLM*. The weight of the water causes the bucket to fall and pull on a pair of ropes twisted round two vertical posts. The posts are linked by rods to the doors above, so that, as the ropes unwind and the poles turn, the doors are opened. See how the ropes are twisted in opposite directions on the two poles so that the doors at left and right turn in the correct senses. When the fire on the altar dies down the whole process is reversed, and the counterweight at bottom right pulls the doors closed again. As an elaboration of this machine, Hero shows a separate device by which the opening of a temple door causes a trumpet to sound automatically, by forcing air through it, using water pressure.[41]

There is a close resemblance, clearly, to the mechanism with which the doors are opened on Hero’s fixed theatre. The source of power is different; and in the theatre the doors are opened and closed several times; but the way in which the doorposts are turned with twisted ropes is the same in both cases.

A final example: the machine of Figure 3.13 is entitled ‘Figures made to dance by Fire on an Altar’.[42] This works on a similar principle to the *aeolipile*. The figures stand on a turntable rotated by hot air produced in the altar. The air issues in jets from four angled tubes. The dancers are enclosed in a transparent case made of glass or horn.

How are we to interpret all these strange machines? Did they really exist? If so, what was their purpose? Were they ‘laboratory demonstrations’ of the physical and mechanical principles involved? Hero does not describe them in those terms, but simply gives explanations of what they do and instructions for how to build them. Were they amusing novelties, like the wine jugs and cups? Were some, such as

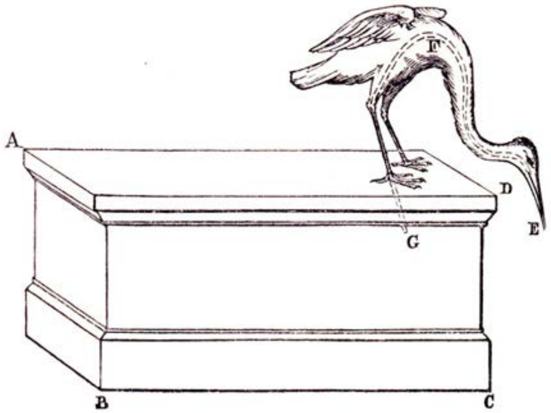

Figure 3.11 Theorem 30 from Hero's *Pneumatics*: 'An automaton which will drink any quantity that may be presented to it.' The bird (a heron) contains a siphon that 'drinks' water from a cup and deposits it in the pedestal.

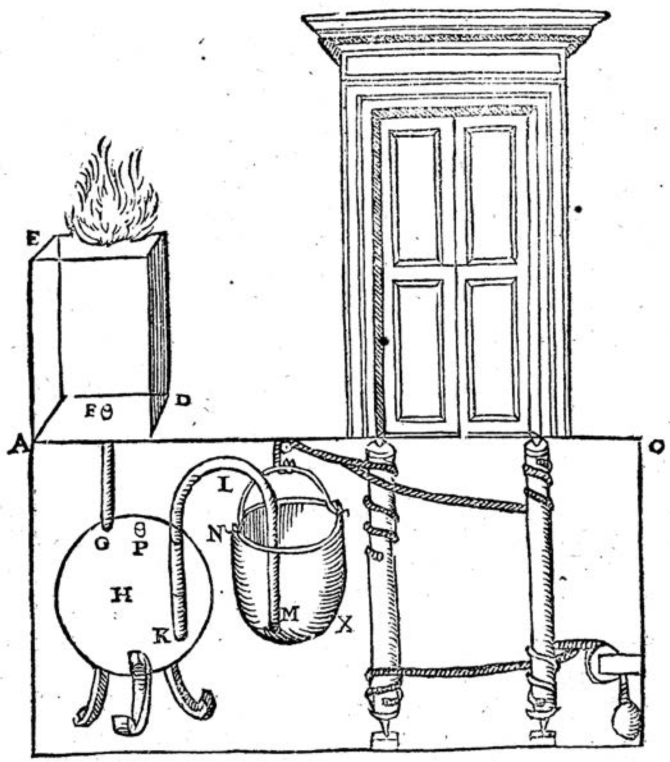

Figure 3.12 Theorem 37 from Hero's *Pneumatics*: 'Temple doors opened by fire on an altar'.

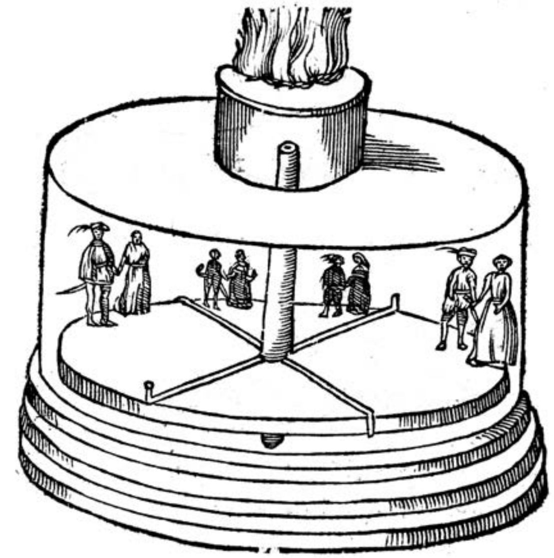

Figure 3.13 Theorem 70 from Hero's *Pneumatics*: 'Figures made to dance by fire on an altar.' Jets of hot air rotate the turntable.

the temple door mechanism, intended to strike awe into the minds of worshippers?

To the modern mind, the devices in the *Pneumatics* – since Hero reveals their workings – might seem reasonably simple, but they were inexplicable to ancient and Renaissance audiences. This was surely because most everyday machines of the time consisted of just one or a few moving parts – levers, balances, wheels – performing repetitive single tasks. Moreover, their motive power – animal muscle, human muscle, the weight of water – was in full sight. Hero's devices by contrast performed compound actions, and both the mechanisms and the internal sources of power were hidden.

Hero's intellectual and technical influence in the late Renaissance was very great and has not yet been completely studied. His 'theorems' were recreated, directly and in many variants, in the great gardens of Italy. They adorned fountains and found places in grottoes. These versions were not limited to the little animated scenes with animal and human figures. The principles of the siphon and the *aeolipile* – Hero's 'steam engine' – were also applied in entertainments. And those devices of both Hero and Philo that involved water under pressure were turned into miniature fountains, designed as table decorations. We will look at automata and fountains in Chapters 4 and 5.

Notes

1 *The Pneumatics of Hero of Alexandria*, with introduction by Marie Boas Hall (London: MacDonald, and New York: Elsevier, 1971): facsimile of edition by Bennet Woodcroft (London: Taylor, Walton and Maberly, 1851). Hall gives a publication history of the book. Translations were made in the twelfth and thirteenth centuries.

2 The full text of the *Pneumatics* was first published in Latin translation by Federico Commandino as *Heronis Alexandrini Spiritalium Liber* in Urbino in 1575. Several Italian translations followed from 1582, including one by G. B. Aleòtti (*Gli Artifitiosi et Curiosi Moti Spiritali di Herrone* (Ferrara: V. Baldini, 1589). The book was alluded to by Leonardo, and discussed by the philosopher Girolamo Cardano in *De Subtilitate* (1550). *On Automata-Making* was translated into Italian by Bernardino Baldi in the 1570s, and published (with illustrations) as *Di Herone Alessandrino De Gli Automati, overo Machine se Moventi* (Venice: Girolamo Porro, 1589). Oreste Trabucco speaks of the 'vast fortune' of the works of Hero in Italy in the sixteenth century in *'L'opere stupende dell'arti più ingegnose': La recezione degli* Πνευματικα *di Erone Alessandrino nella cultura italiana del Cinquecento* (Florence: Leo Olschki, 2010). By the early seventeenth century the *Pneumatics* was very well known throughout Europe.

3 Victor Prou, *Les Théâtres D'Automates en Grèce au IIe Siècle avant l'Ère Chretiénne, D'Après les* αυτοματοποιικα *D'Héron D'Alexandrie* [*Automata Theatres in Greece in the 2nd Century BC, after the Automatopoiika of Heron of Alexandria*], *Mémoires présentés par divers savants étrangers à l'Académie des Inscriptions et Belles-lettres*, series 1, vol. 9, part 2 (Paris: Académie des Inscriptions et Belles-Lettres, 1881), pp. 117–248. This gives a translation into French of the second part of Hero's book, on the static theatre, with extensive commentary. (Prou has Hero's dates wrong: he lived in the first century AD.) Susan Murphy gives a complete English translation, again with commentary, in 'Heron of Alexandria's On Automaton-Making', *History of Technology*, 17 (1995): 1–44. Both Prou and Murphy provide numerous diagrams. Wilhelm Schmidt made a translation into German, again with figures, published in Leipzig in 1899.

4 The issue of Hero's intellectual debts is analysed in detail by A. G. Drachmann, 'Ktesibios, Philon and Heron: A Study in Ancient Pneumatics', *Acta Historica Scientiarum Naturalium et Medicinialium*, vol. 4 (Copenhagen: Ejnar Munksgaard, 1948).

5 See Murphy, 'Heron of Alexandria's On Automaton-Making': 3; and Prou, *Les Théâtres D'Automates*, p. 125.

6 Murphy, 'On Automaton-Making': 5.

7 Murphy, 'On Automaton-Making': 6.

8 Murphy ('On Automaton-Making': 6) speculates that *The Legend of Nauplios* might have been based on a play by Sophocles, *Nauplius Pyrkaeus*.

9 For detailed explanations see the diagrams and extended notes in Murphy, 'On Automaton-Making': 39–44; and the diagrams and discussion in Prou, *Les Théâtres D'Automates*, pp. 138–95.

10 Murphy, 'On Automaton-Making': 15.

11 Finlay McCourt, 'An Examination of the Mechanisms of Movement in Heron of Alexandria's On Automaton-Making', in Teun Koetsier and Marco Ceccarelli (eds), *Explorations in the History of Machines and Mechanisms*, Proceedings of HMM2012 (Dordrecht: Springer, 2012), pp. 185–98. McCourt suggests that Hero's theatres might have provided entertainment at symposia.

12 McCourt, 'An Examination of the Mechanisms', pp. 196–7.

13 Prou, *Les Théâtres D'Automates*, pp. 216–17 and fig. 11, p. 218.

14 Prou, *Les Théâtres D'Automates*, p. 236 and fig. 14.

15 Murphy, 'On Automaton-Making': 38. Murphy says, however (note 61, p. 44), that versions of the Greek text differ in detail at this point, and Hero's meaning is not entirely clear. A conjectural reconstruction by H. Querfurth is overly elaborate.

16 Richard Beacham and Janis Atelbauers, 'Heron's automata 3D', https://www.youtube.com/watch?v=5LBlusUD3Kg.

17 Richard Beacham argues that Hero's theatres might have more closely resembled temporary wooden theatres in the ancient world, described in several sources: 'Heron of Alexandria's "Toy Theatre" Automaton: Reality, Allusion and Illusion', in Kara Reilly (ed.), *Theatre, Performance and Analogue Technology* (Basingstoke: Palgrave Macmillan, 2013), pp. 15–39; see pp. 31–2.

18 Madeleine Horn-Monval came close to making these connections between Hero and late sixteenth-/early seventeenth-century stage machinery in a fascinating but flawed article 'La grande machinerie théâtrale et ses origines', *Revue de la Société d'Histoire du Théâtre*, 9/4 (1957): 291–308. She mentions Buontalenti and Aleòtti's editions of Hero's works, and argues that they and other theatrical engineers were inspired to use hydraulic power to move stage machinery. Other than in some very special cases (see Chapter 8) this is quite misconceived: the sources of power were human strength and counterweights. It seems that Horn-Monval had not studied Hero's *On Automata-Making*, perhaps not appreciating that it dealt with theatres.

19 Prou, *Les Théâtres D'Automates*, p. 153.

20 Anne Surgers in *La Pellegrina et les Intermèdes, Florence, 1589* (Paris: Lampsaque, 2009) suggests (note 96, p. 128) that Buontalenti's method for controlling the lamps remotely was based on two of Hero's 'theorems' from the *Pneumatics*, Numbers 72 and 73. This seems to me unconvincing. These are devices for raising the oil level in lamps, either pneumatically or hydraulically, not for lighting or extinguishing them. (Also Surgers' fig. 24 on p. 129 is of Theorem 74, whose purpose is different again.)

21 Marcello Cervini made a translation in 1533, which remained unpublished, from a manuscript in the Library of San Marco in Venice.

22 Vitruvius, *I Dieci Libri dell' Architettvra di M. Vitruvvio*, trans. Daniele Barbaro Francesco (Venice: Marcolini, 1556), p. 466. My thanks to Kim Williams, whose translation of Barbaro this is, for drawing my attention to this sentence.

23 Letter from Bernardo Davanzati to Bernardo Buontalenti of 22 May 1582, printed in Bernardo Davanzati, *Della Natura del Voto di Erone Alessandrino* (Florence: Del Monitore, 1862).

24 Ercole Bottrigari, *La Mascara, overo, Della Fabrica de' Teatri et dello apparato delle Scene Tragisatiricomiche*, Museo Internazionale e Biblioteca della Musica di Bologna, Catalogo Gaspari B.45, pp. 43–4.

25 For the parallels with military engineering, see Giuseppe Adami, *Scenografia e Scenotecnica Barocca tra Ferrara e Parma (1625–1631)* (Rome: 'L'Erma' di Bretschneider, 2003), pp. 31–3.

26 Eugenio Battisti, *L'Antirinascimento* (Milan: Feltrinelli, 1962), p. 250.

27 Commandino, *Heronis Alexandrini Spiritalium*, no. XL, pp. 93–4.

28 *Pneumatics of Hero*, Woodcroft edition, Theorem 40, pp. 62–3.

29 Commandino, *Heronis Alexandrini Spiritalium*. The illustrations in the Woodcroft edition of 1851 are adapted from Commandino's.

30 Drachmann, *Ktesibios, Philon and Heron*.

31 Drachmann, *Ktesibios, Philon and Heron*, p. 161.

32 Commandino, *Heronis Alexandrini Spiritalium*, no. LXV, p. 136. Commandino's drawing differs from Woodcroft's. Some trick cups and vessels of the Renaissance inspired by the *Pneumatics* are described in Natasha Mao, '"Bevi Se Puoi": An Italian Renaissance Tantalus Cup in the Museo Internazionale delle Ceramiche in Faenza', *Faenza*, 2 (2016): 36–53.

33 Commandino, *Heronis Alexandrini Spiritalium*, no. L, p. 107.

34 Marie Boas, 'Hero's *Pneumatica*: A Study of its Transmission and Influence', *Isis*, 40, 1 (February 1949): 38–48; see 45: 'Poggendorff believes that an eolipile supplied the power for the paddle-wheel boat which Blasco de Garay is supposed to have tested in 1534 …'. De Garay was a captain in the Spanish Navy responsible for several inventions including the paddle wheel. But the Museo Naval in Madrid has cast serious doubt on reports of a steam-powered vessel.

35 Derek J. de Solla Price, 'Automata and the Origins of Mechanism and Mechanistic Philosophy', *Technology and Culture*, 5/1 (Winter 1964): 9–23; see 15.

36 *Pneumatics of Hero*: Introduction by Hall, p. xi.

37 *Pneumatics of Hero*, p. 1.

38 *Pneumatics of Hero*, p. 10.

39 Commandino, *Heronis Alexandrini Spiritalium*, No. XXX, p. 75.

40 Commandino, *Heronis Alexandrini Spiritalium*, No. XXXVIII, p. 88.

41 Commandino, *Heronis Alexandrini Spiritalium*, No. XVII, p. 54.

42 Commandino, *Heronis Alexandrini Spiritalium*, No. LXX, p. 146.

Part II
The machine in the garden

4
Artificial creatures

The Fountain of the Owl at the Villa d'Este

Theorem 15 in Hero's *Pneumatics* is entitled 'Birds made to sing and be silent alternately by flowing water'.[1] An owl sits on a post, next to a tree filled with songbirds (Figure 4.1). The owl looks towards the birds, who are frightened, and go quiet. The owl turns away, and the birds resume their singing.

The machine is powered by a continuous stream of water that flows into a closed tank. As the tank fills, air is forced out through thin tubes that run up, through the branches of the tree, to the beaks of the birds. The beaks contain whistles that are blown by the escaping air. Inside the tank is a special type of siphon consisting of two concentric tubes, known as a *diabetes*.[2] This works very much like a U-shaped siphon. Sunk in a water tank, it does not have to be filled by mouth.

When the tank is full, the *diabetes* starts to operate, and the water drains into the bucket below. With its extra weight the bucket pulls on a rope wound around the post on which the owl sits. The post turns and the owl turns with it to face the little birds. When the bucket is full, it too is drained by a second siphon. The counterweight at the far end of the rope turns the post back again and lifts the bucket to its original position. The owl looks away.

The sizes of the various components are calculated nicely such that the owl's movements are coordinated in time with the singing and silence of the other birds. Hero has other variants of this automaton in which birds are again made to sing intermittently, by means of systems of water tanks and siphons.

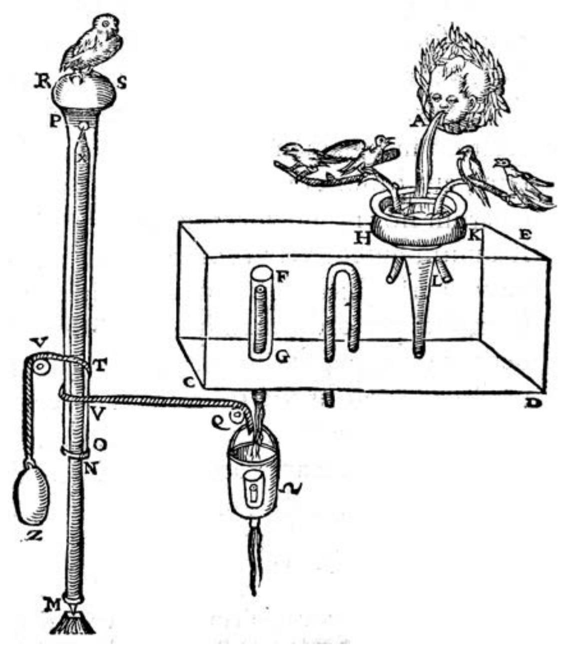

Figure 4.1 Theorem 15 from Hero's *Pneumatics*: 'Birds made to sing and be silent alternately by flowing water'. The birds are frightened into silence by the owl at the left.

In the late 1560s work was nearing completion on the gardens of the Villa d'Este at Tivoli, built for Cardinal Ippolito d'Este of Ferrara; the many fountains and cascades are among the most spectacular in Italy. Ippolito employed the painter and architect Pirro Ligorio to assist in their design.[3] One of Ligorio's many fields of interest was hydraulic engineering, and he had read Hero's *Pneumatics*.[4] His Fontana della Civetta, the Fountain of the Owl at Tivoli (Figure 4.2), is an exact recreation of Hero's Theorem 15.

The engineer Luc Leclerc built the mechanism, while the architectural frame with its columns and pediment was the work of Giovanni del Duca and Raffaello Sangallo. There were 20 birds – nightingales, goldfinches and linnets – made of bronze, painted in their natural colours, sitting on the branches of two metal olive trees. This was the 'noble Aviarie' that John Evelyn saw in 1645. The French philosopher and essayist Michel de Montaigne visited the Villa d'Este in April 1581 on his travels through Italy and mentioned the Fountain in his *Journal*: 'by another device an owl is made to appear on the top of a rock, whereupon all the harmony ceases at once, the birds being terrified

Figure 4.2 Fountain of the Owl in the gardens of the Villa d'Este at Tivoli, devised by Pirro Ligorio and designed by Luc Leclerc. The fountain incorporates a version of Hero's automaton of the owl and singing birds (Figure 4.1). The birds are in the metal trees, but where is the owl? (Some original sculpted figures have been replaced with painted cut-outs.) Photo: Alamy.

by his presence'.[5] The birds are still singing today. The machinery was reconstructed in 2002, when the restorers discovered and replaced several of the original components.

A classification of 'artificial creatures'

The Fountain of the Owl is one of numerous examples of the direct transfer of Hero's designs for automata into the gardens and grottoes of late sixteenth-century Italian villas. These were not, however, the first mobile creatures to appear in the various worlds of Renaissance entertainment by any means. Theatrical performances, festivals and processions, and firework shows since the Middle Ages, had been full of simulacra of animals, men and monsters. Many of these creatures moved their separate limbs, or moved bodily, either under their own power or by hidden human agency. How can we find some order in this prodigious man-made menagerie?[6] Since the focus here is technical and mechanical, it seems appropriate to categorise the creatures along two dimensions: the types of movement of which they are capable – walking, flying, moving their mouths or limbs – and their sources of motive power.

In fact, some contemporary writers made classifications on just these lines. Bernardino Baldi added a preface to his translation of Hero's *On Automata-Making*, giving a survey of examples of mechanical men and animals, ancient, medieval and modern.[7] He distinguishes those that are 'self-moving' – where the sources of power and means of control are hidden and internal – from those, such as puppets on strings, that are evidently powered and controlled directly by human operators.

In 1648 John Wilkins, one of the founders of the Royal Society in London, published a little book entitled *Mathematicall Magick* in which he takes a broad view of the scope of mathematics.[8] In four short chapters on automata, Wilkins develops Baldi's ideas, in effect, and draws a further distinction between automata that are 'fixed and stationary' and those that are 'moveable and transient' – 'which move not only according to their several parts, but also according to their whole frames'.[9] The distinction is that between Hero's static theatre and his mobile theatre.

The class of mobile automata, according to Wilkins, can be further subdivided into 'gradient' (walking) and 'volant' (flying).[10] There were artificial creatures of several kinds in the Renaissance that 'flew' after a fashion. We now have a full set of distinctions as follows:

- Moved directly by humans, or self-moving;
- The self-moving, divided into those fixed in place and those moving themselves bodily;
- Those moving bodily, divided into those walking or flying.

The forces by which all the true automata are powered can include weights, the force of falling water and the pressure of air or steam – as we saw in the *Pneumatics*. Some Renaissance automata were driven by means not available to the ancients, in particular gunpowder.

Artificial creatures worked by human operators

Armed with this classification, let us begin with artificial creatures worked by concealed human operators. I am going to pass over string and hand puppets, but this still leaves many other types, especially in the theatre. We have already seen two monstrous figures devised by Buontalenti for *La Pellegrina*: the giant Lucifer into whose jaws his assistants forced poor sinners and the dragon Python killed by Apollo. Both Lucifer and Python were built on wooden frameworks with papier-mâché details. The dragon was covered with small mirrors. *La Cofonaria* in 1565 featured the three-headed dog Cerberus, guardian of the gates of the Underworld, who emerged from a trapdoor amid smoke and flames.[11] And in *I Fabii* in 1568 the seven-headed serpent Hydra appeared breathing fire from all its mouths.[12]

Contemporary accounts do not say whether these particular beasts were articulated figures whose limbs could be moved independently. (Serlio says annoyingly that he will not speak of 'the effigies of satyrs, nymphs, sirens and monsters, skilfully put together to be worn by men and children suitable to the height of each animal'.)[13] There is, however, an early seventeenth-century drawing of a theatrical sea monster in the Palatine Library in Parma in which we can see something of how a creature of this kind was constructed and manipulated (Figure 4.3).[14] It is built on a light framework of laths, and has a hinged mouth and a flexible tail – made of what look like wire rings – presumably all to be covered in painted cloth. The body has a hinged door on top, like the cockpit canopy of a fighter aircraft, through which the human operator enters. The creature is supported by a post on a mobile stand and can be turned and moved in different directions by crouching stagehands.

In one case we have details of the specific movements of creatures on stage. The source is the official *Description* for *L'Amico Fido* in 1585, for which Buontalenti was the designer.[15] Neptune's chariot appeared in the fourth *intermezzo*, pulled by four horses. These 'were entirely capable of functioning just as their live counterparts: they whinnied, chewed foam-covered bridle bits, and plowed the waves with their forelegs'.[16] The chariot's wheels turned in the sea. When Neptune made his exit, the vehicle disappeared beneath the waves 'without rumbling or rattling'.

However, there are no drawings or further details of the way in which these horses worked. One possibility is that they were like pantomime horses and each had a pair of actors inside. Another is

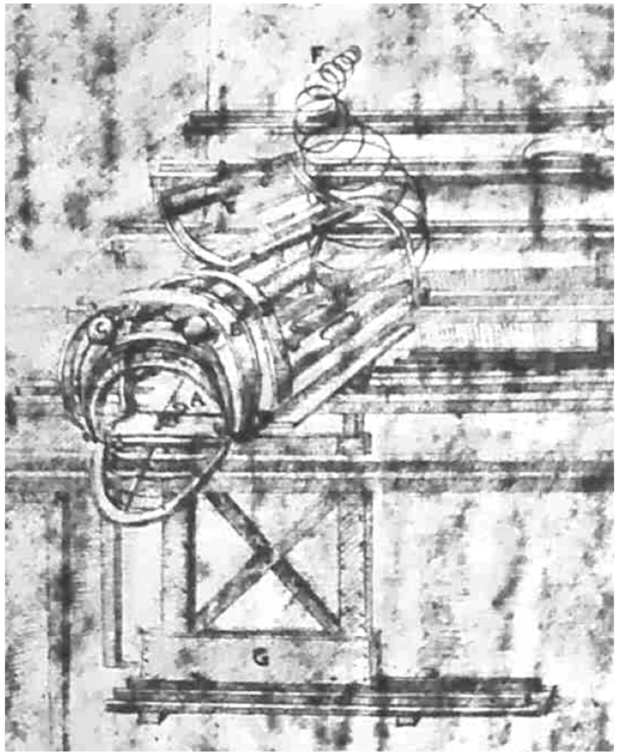

Figure 4.3 Structure for a mobile theatrical sea monster, from an early seventeenth-century drawing. The mouth and tail can be manipulated by the operator, who enters through the hinged door on top. There are rails below stage, on which the frame supporting the creature can be moved laterally by other stagehands. Parma, Biblioteca Palatina Ms Parm f.1, courtesy of the Ministry of Cultural Heritage and Tourism.

suggested in a drawing by an unknown fifteenth-century artist that shows the mechanism for a theatrical centaur (Figure 4.4).[17] The (artificial) horse's legs at the back are linked by rods to the (real) man's legs at the front. Neptune's horses in *L'Amico Fido* might have been made to move in a similar way. In either case, the actor at the front would have been responsible for the whinnying, chewing and plowing.

The giant eagle at centre stage of Figure 4.5 is from a drawing of another scene by Buontalenti.[18] Alois Nagler thinks this might have been an idea, later abandoned, for a different *intermezzo* in *L'Amico Fido*. We can see in this case how the creature was to have been manipulated, since there are five pairs of human legs just visible beneath the bird's body. Presumably an eagle of this size was not intended to fly. But

Figure 4.4 Drawing of a theatrical centaur by an unknown fifteenth-century artist, perhaps from Siena. The man's legs at the front move the artificial legs at the back. Notice the actor's elegant high-heeled 'hooves'. Copyright, The British Library Board, Add MS 34113, folio 176v.

Buontalenti might have been thinking that the hidden team would walk the bird back and forward, and maybe flap the huge wings.

Figure 4.6 reproduces a drawing of a costume for a warrior riding on the back of a giant swan, made by the painter Francesco Primaticcio who worked in France in the mid-sixteenth century.[19] It seems that the man's legs tucked up against the bird's flanks are false and his real legs are those on which the swan walks. Meanwhile the actor can move the swan's head and neck with his hands.

Some 'walking' creatures were pushed or carried along by men inside. An English priest and traveller, Richard Lassels, visited the Grand Duke's menagerie in Florence in the mid-seventeenth century.[20] The (real) lions, leopards, tigers and bears were made to fight each other. Afterwards the beasts were herded back into their 'dens' by a 'Fearful *Machine* of Wood made like a great Green Dragon, which a man within it roles upon wheels'. The dragon had lighted torches in its eyes to further alarm the live animals.

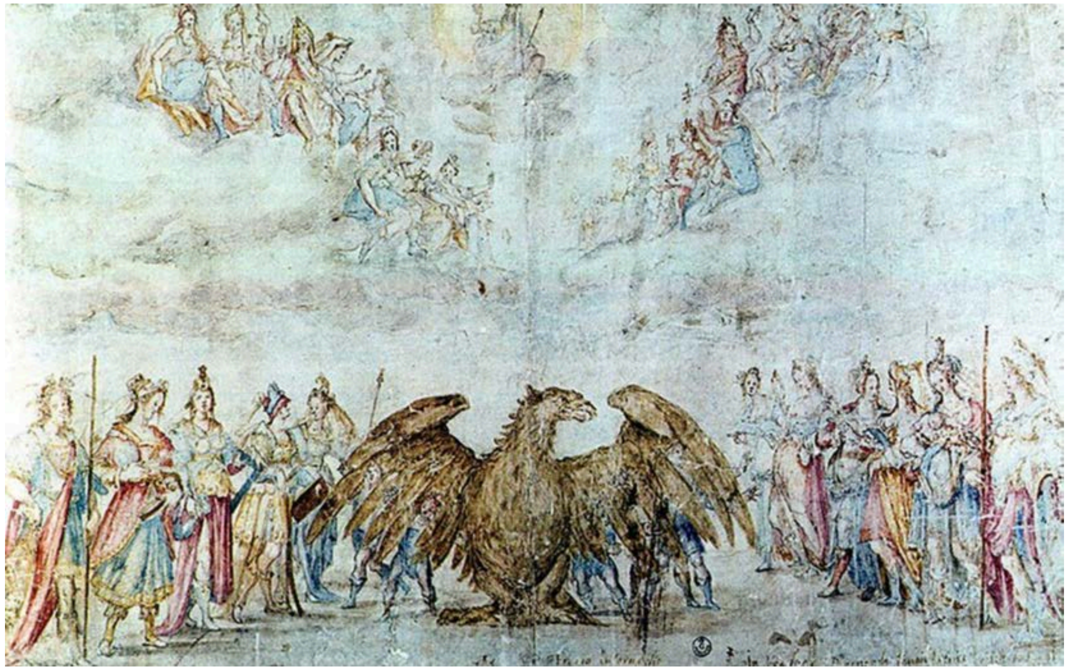

Figure 4.5 Detail of a scene by Bernardo Buontalenti, perhaps an abandoned idea for one of the *intermezzi* for *L'Amico Fido* in 1586. Five pairs of human legs are visible beneath the giant eagle. Gabinetto Disegni e Stampe, Gallerie degli Uffizi, Florence.

In other cases the operators carried the bodies of such creatures on their backs and provided the legs themselves, like the dragons in Chinese festivals. The English musician Charles Burney saw more mobile dragons at a pageant in Bologna, featuring in a dramatisation of the poet Tasso's story of the sorceress Armida and her lover Rinaldo. This involved both griffons and dragons spitting fire. As Burney says, 'The whole of this was comical enough – as it was all burlesque – sometimes the machinery of the monsters took fire and burnt the men underneath, upon which they throw off the whole apparatus and appear half-naked to the spectators.'[21]

Marco da Gagliano wrote a preface to the text of his production of the opera *Dafne* in Mantua in 1608.[22] Like *La Pellegrina*, this featured Apollo battling the dragon Python. Gagliano says the two should fight in time with the music:

> The serpent should be large; and if the painter who makes it knows how to make the wings move and [the Python] breathe fire, as I have seen, it will be a fine sight. Above all it must writhe; the wearer of the costume must go on all fours, with his hands on the ground.[23]

Figure 4.6 Costume for a warrior riding on a swan by Francesco Primaticcio, mid-sixteenth century. The man's legs at the sides of the bird are false; his real legs are those on which the swan stands. Wikimedia Commons: Primaticcio – The Knight of the Swan.

One rare example of a detailed specification for how to make an artificial creature propelled on wheels is to be found in Joseph Furttenbach's *Noble Mirror of Art*, where he describes the whale built for his play about Jonah (Figure 4.7).[24] The beast is 3 metres long and its jaws are 1 metre across. The lower half of the body is carved from linden wood and is large enough to contain Jonah. The upper half is made from wooden hoops covered with painted cloth. The eyes are inlaid with mirrors so that they glint. Two men push the animal along on a three-wheeled trolley in a gap between two wave machines. The body is supported on a pivot so that the whale can be made to rock back and forth while 'swimming'. The jaw is opened with a cord and is closed again by a counterweight.

Figure 4.7 Joseph Furttenbach's design for the whale in his play about Jonah. The creature is pushed along between the waves on its trolley. The jaws are opened with a cord.

In Furttenbach's show the whale pursued Jonah's ship, and other members of the crew sacrificed Jonah and threw him into the sea, where he was swallowed by the whale. The sea then became calm. 'The stormy wave was taken out and shoved under the stage, and the sea was left at its normal *tempo*. This whole action produced a great effect and almost broke the hearts of the audience.'[25]

Buontalenti also designed a whale for *Il Rapimento di Cefalo* in 1600. This was 6 metres in length and, according to Nagler:

> Not only did [it] have quills which it could thrust out and retract again, but it could flap its ears, roll its great yellow eyes, and submerge its head and raise it dripping to the surface, spouting jets of water. White fangs projected from red gums over its wrinkled lips, crunching the gleaming fish which leapt from the waves.[26]

Buontalenti was evidently a bit hazy on cetacean anatomy. In his *Manual* Nicola Sabbattini describes a device to make a whale, a dolphin or 'other marine monster' like Buontalenti's seem to spout water as it swims.[27] This is done by attaching a cardboard cone, filled with fragments of silver tinsel or talcum powder, behind the head of the creature. A tube is attached to the bottom of the cone, and a stagehand blows through this tube to shoot out sparkling white showers. 'By means of reflection of the light', Sabbattini says, 'it will truly seem that water comes out of the head.'

'Walking' automata

Mobile creatures with men inside were 'walked' either on the men's real legs or were pushed on wheels. John Wilkins has a category of 'gradient' automata that walk by themselves. Several writers on automata in the sixteenth and seventeenth centuries, including Wilkins, refer to statues that supposedly walked on their own in the ancient world, including those made by the legendary craftsman Daedalus, famous for building the wings with which he and his son Icarus were able – for a time – to fly. Socrates says that these statues had to be tied up, otherwise they would 'play truant and run away'.[28] Homer in the *Iliad* describes mobile tripods built by Hephaestus – the Greek counterpart of the Roman god Vulcan – which could 'go of their own selves to the assemblies of the gods, and come back again'.[29] Several classical authors besides Homer allude to these mobile metal humanoids.

Even to start to speculate about how such mythical robot figures walked would be a kind of madness. But it is curious all the same that the creatures made by Hephaestus are described as 'tripods'. A walking tripod is highly improbable in biomechanical terms. H. G. Wells's Martians in *The War of the Worlds* might have been tripods, but no earthly animal or robot walks on three legs, since the configuration is dynamically unstable and fundamentally implausible. However, Homer goes on to say that these ancient 'three-legged' automata did *not* walk. Hephaestus set them on *bases*, rolling on golden wheels.[30] Could it be that Philo and Hero consciously created their three-wheeled mobile theatres in the spirit of these fabled ancient 'tricycles'?

There is an intriguing passage in Aristotle's book on physiology, *Movement of Animals*, in which the philosopher draws comparisons between animal locomotion and the way that certain automata operate. The machines, he says,

> are set moving when a small motion occurs: the cables are released and the pegs strike against one another: and like that of the little cart (for the child riding in it pushes it straight forward, and yet it moves in a circle because it has wheels of unequal size: for the smaller acts like a centre …).[31]

The type of automaton Aristotle has in mind thus moves on a wheeled base and is controlled or propelled with cords. (He says nothing about any motor.) The mention of the child riding in the cart might suggest a toy vehicle steered by its occupant. But then Aristotle makes it reasonably clear that the child is *not* in control; and his use of the word αυτοματα (automata) reinforces the point that such vehicles control themselves. One detail is especially suggestive: the device can follow a curved path by having wheels of different diameters. This is one of two ways described by Hero for making his mobile theatre steer around a curve. But Aristotle lived in the fourth century BC, four hundred years before Hero and a century before Philo, from whom Hero inherited his basic theatre designs. This tradition of wheeled and steerable automata seems to go back even earlier than Philo.

We are on slightly surer ground with those few mechanical creatures that 'walked' in the Renaissance. The most famous of these are the robot lions made by Leonardo da Vinci to greet French kings. There are brief mentions of these creatures by three writers, the first of whom is Vasari, who says: 'During his lifetime the king of France came to Milan, and he begged Leonardo to make something unusual, and so Leonardo made a lion which walked a few steps before his chest was opened, revealing it to be filled with lilies.'[32]

The second writer is Giovanni Paolo Lomazzo, who got his information from Leonardo's pupil and assistant Francesco Melzi. Lomazzo refers to another occasion, in 1515, when François I – Leonardo's patron at the end of his life – entered Lyon in France and was greeted by a mobile lion. Other than the difference in location, Lomazzo's description is almost identical to Vasari's.[33] The lilies, associated with the French monarchy, were a compliment to the king, while the lion was the heraldic symbol of both Lyon and Florence. (Leonardo might also have enjoyed the oblique reference to his own name.) Elsewhere Lomazzo reports Leonardo as saying: 'I teach the way … to make a Lion move by force of wheels.'[34]

The Leonardo scholar Carlo Pedretti has discovered a third reference in an official *Description* by Michelangelo Buonarroti – grandnephew of the great sculptor – of marriage celebrations that took place in 1600, again in Lyon.[35] This is long after Leonardo's death. Buonarroti talks of a new automaton lion that moved on a banqueting table, stood up on two legs from a sitting position and opened its chest to reveal lilies. It then transformed itself into an eagle with two heads. It was similar, he says, to Leonardo's animal of 1515.

There have been several attempts to make working reconstructions, some of which have succeeded in getting a creature either to move on wheels or actually walk on jointed legs and perform the sequence of actions described in these accounts. The problem is that there is no technical sketch of the animal or explanatory note by Leonardo himself, only these few sentences by other writers. Any supposed mechanism must therefore be entirely conjectural. Lomazzo's words 'by force of wheels' (Italian: *per forza di ruote*) might be taken to mean either internal gearing of some kind, or else 'road wheels' on which the lion rolled.

On the other hand, Leonardo has drawings in his notebook the Codex Atlanticus for another self-moving machine, which are elaborately detailed (Figure 4.8).[36] These have often been interpreted as designs for the world's first automobile. However, both Pedretti and Martin Kemp, Leonardo's modern biographer, believe that they show a mobile platform on which an artificial animal or human figure, featuring in a festival or court entertainment, would have 'walked'.[37] It might even have provided the undercarriage for Leonardo's lion. As John Wilkins puts it, all 'gradient' automata 'require some *basis* or bottom to uphold them in their motions'.[38] The machine has attracted the attention of a whole series of historians and engineers since the 1920s, some of whom have made reconstructions. (Today one can even buy ready-made kits of parts.) The most recent is the robotics engineer Mark Elling Rosheim, whose version is illustrated in Figure 4.9.[39]

I do not propose to go into great technical detail, but just comment on some of the issues and difficulties over which specialists have argued. The bird's-eye view at the top of the sheet in Figure 4.8 is incomplete. Leonardo appears to be thinking out various alternatives as he draws. It is not even clear how many road wheels the vehicle has: reconstructions have given it three wheels or four. The single extra wheel on a 'tiller' at the left appears to be for steering – although this would imply a human driver. The road wheel at the right has pegs around its periphery that engage with a cylindrical 'lantern gear' above, through which the drive is transmitted.

The plan view in the lower part of the sheet is more finished, with two large horizontal gearwheels, and at the top two S-shaped 'arbalest' springs. An arbalest was a big military crossbow, its arms made of some strong and flexible wood. Some of those who have studied Leonardo's drawings have concluded that these springs provide the cart's motive power, and that they move the big gearwheels, which in turn drive

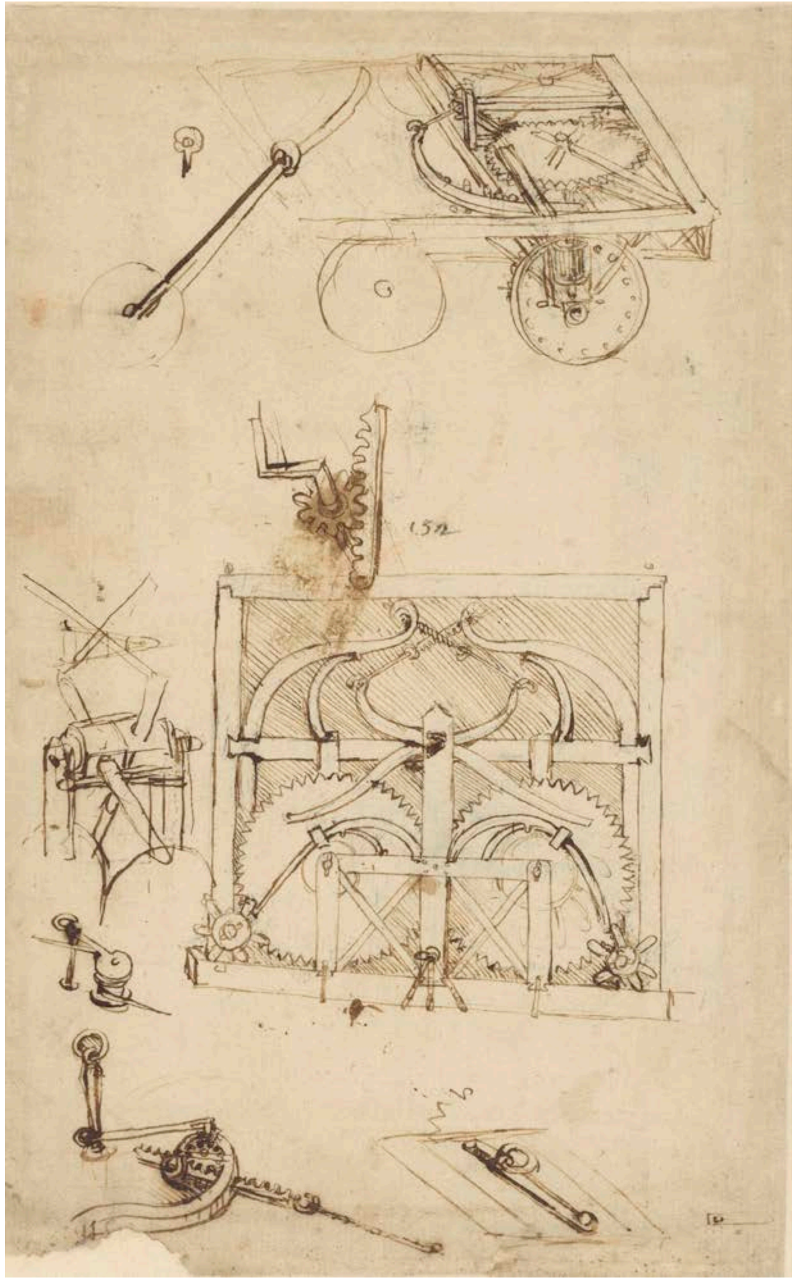

Figure 4.8 Drawings by Leonardo da Vinci from the Codex Atlanticus for a self-propelled vehicle, probably designed to carry an animal or human figure in a festival or court entertainment. Bridgeman Images.

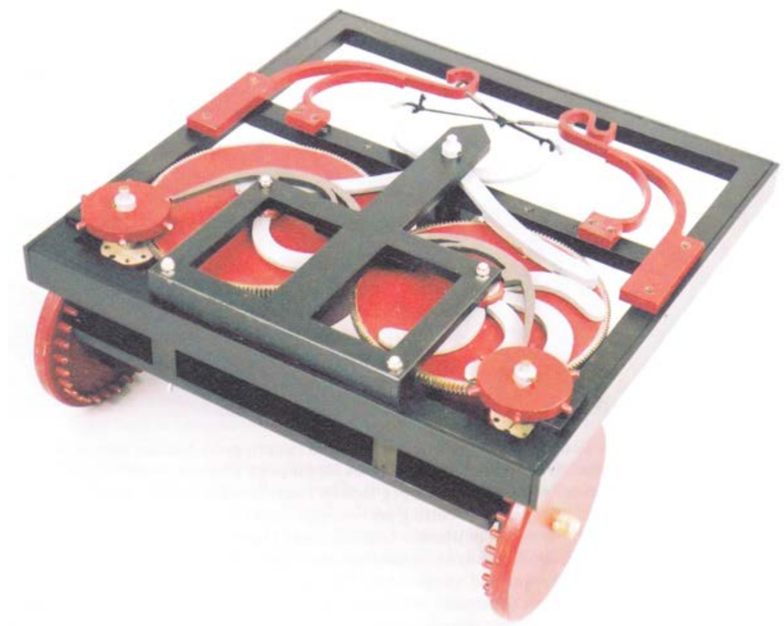

Figure 4.9 Working reconstruction of Leonardo's vehicle of Figure 4.8 by Mark Elling Rosheim. By kind permission of Mark Elling Rosheim and Springer Verlag.

the roadwheels. They have further suggested that the two gearwheels constitute a 'differential' of the kind used in the transmission of modern automobiles.

Neither of these ideas is plausible, however, as Augusto Marinoni and Mark Elling Rosheim have pointed out.[40] The gears do not have anything like the configuration of a differential; the arbalest springs would not be capable of delivering sufficient sustained power; and in any case Leonardo does not show any link between the springs and the gearwheels. Despite this, cords have been introduced into some reconstructions to make these connections, as in a version by the engineer Giorgio Canestrini who studied Leonardo's vehicles in the 1930s.[41]

Pedretti, and following him Rosheim, have assumed that Leonardo would instead have used two much more powerful coil springs sitting underneath the large gearwheels to provide the motive power. The objection here is that no such coil springs are visible in either of Leonardo's sketches. Rosheim has ingeniously interpreted the arbalest springs and other components, not as a motor but as a means for controlling the car's movement, making it start, stop, turn and move along curves. His reconstructed vehicle does all these things successfully and can be 'programmed' beforehand to carry out different sequences of motions, by inserting different numbers and sizes of cams (the white banana-shaped pieces in Figure 4.9). One can just make out parts with this shape in Leonardo's plan drawing.

However, Rosheim has taken the design of some of these extra components from unrelated sketches elsewhere in Leonardo's many notebooks and has further drawn quite unhistorical inspiration from a Japanese 'tea carrier' automaton of the eighteenth century. Meanwhile there are no written accounts by Leonardo or others of the planned or actual motions of his car, if indeed it was ever built. And if a mobile platform was in fact the basis of the mobile lion, that only 'walked' in a straight line; it is not described as taking a curved or snaking path. A simpler car than Rosheim's could have provided the lion's wheeled base.[42] The beast's chest must then have been opened with some special additional device, as Rosheim recognises. Just imagine for a moment that Leonardo's lions *did* travel on platforms with wheels, like the 'automobile'. They moved forward, came to a halt and gave 'performances'. Is the resemblance to Hero's mobile theatre significant, or just a coincidence?

Bernardino Baldi gives descriptions in his preface to Hero of two smaller 'walking' creatures. The first is a silver mechanical turtle made by the sixteenth-century sculptor and metalworker Bartolomeo Campi of Pesaro.[43] This was designed to propel itself through a dining room (presumably on the table) 'moving the feet, the tail and the head, and go to the centre where it opened up its top, like a box, to distribute toothpicks'. It is striking how this sequence of movements – moving, stopping, opening its body – repeats those of Leonardo's lions.

In 1589 Hans Schlottheim, a goldsmith working in Augsburg, constructed two mechanical lobsters that scuttled across the floor, opening and closing their claws. They were made of metal and painted red-brown. One of these is today in the collection of the Staatliche Kunstsammlungen museum in Dresden (Figure 4.10).[44] It is powered by clockwork and runs on wheels. (The legs are non-functional.) It is reasonable to suppose that Campi's turtle was similarly wheeled and powered by clockwork, although since it came to a standstill and opened up its back, the mechanism must have been rather more elaborate.

'Flying' creatures

Besides walking lions, Leonardo also made little creatures that could fly. Vasari describes in his *Life* of the artist how Leonardo modelled these from

Figure 4.10 Mechanical 'walking' lobster made by Hans Schlottheim of Augsburg in 1589, now in the Staatliche Kunstsammlungen museum in Dresden. The creature runs on wheels and is powered by clockwork: it also opens and closes its claws. Photo: Alamy.

a wax paste, and that 'while he walked, he made inflatable animals which he blew into, making them fly through the air; but when the air ran out, they fell to the ground'.[45] And Leonardo has a rough sketch of a model bird flying on a line, labelled (in his mirror writing) with the phrase 'ocel de la comedia' – a bird for a theatrical comedy (Figure 4.11).[46] This looks as though it has a wheel that is turned as the bird runs down the cord under gravity. The wheel has cranks fixed to it that flap the wings. A weight hanging underneath keeps the body upright.

Mechanical birds are not original to Leonardo. The thirteenth-century French artist Villard de Honnecourt, famous for his sketchbook, depicts an otherwise unexplained bird, but which has some sort of wheel and string apparatus inside.[47] Leonardo and Villard's designs seem to be similar in their workings to nineteenth-century bird toys that ran on lines and flapped their wings.

Birds or other aerial creatures flying on wires became standard devices in the Renaissance, both in the theatre and in firework shows. Some of these were simple cardboard cut-outs, hung on the wires with rings and pulled along with dark threads. Serlio explains how to make planets or other heavenly bodies 'pass through the air' on stage in this way. He says that they should be 'so far back that neither the thread nor the wire can be seen'.[48] The same principle could obviously be applied to creatures. A masque put on in Whitehall in London on Twelfth Night in 1607 featured 'artificial Battes and Owles' that ran on wires.[49] We can imagine that the parrots that passed across the South American sky in the Florentine *intermezzo* of 1608 were similarly contrived.

There were two supposedly free-flying automata in the Renaissance that became famous, of which there are many accounts.[50] The first was a wooden eagle made by the astronomer and mathematician Johannes Müller, known as Regiomontanus, which he built to greet the Holy Roman Emperor on his visit to Königsberg on 7 June 1470. The bird, it is said, flew out of the city to greet the emperor, came back, landed on the city gates, stretched its wings and bowed. The second was a metal fly, also made by Regiomontanus, that, according to Baldi, 'flew from the hand, flew around and, finally, as if tired, came back to the hand'. Baldi was a sceptical writer, and would have found this hard to credit had there not been 'testimony from many men'.[51]

Stage magicians have tricks in which they command apparently free-flying balls or balloons to move as directed. The balls are in fact suspended on fine threads that are difficult to see. This is very speculative, but it seems just possible that this was the secret of Müller's fly. Before modern plastic threads became available, magicians favoured human hairs – preferably mouse-brown – which are very strong and thin.[52] A model fly suspended on a hair could be made to return to its owner's hand.

An eagle, in the open air, would be a very different matter. A century after the flight of Regiomontanus's bird, the citizens of Vienna were delighted to see the Imperial eagle again, this time descending from the spire of St Stephen's Cathedral to welcome the Emperor Maximilian II.[53] A contemporary engraving (Figure 4.12) reveals the banal explanation of its mode of flight.

Rocket-powered flying creatures

Some creatures flying on wires were propelled by rockets. We have seen an example of this kind of 'running rocket' powering the dove that sets off the Explosion of the Cart in Florence, and then flies back to the high altar. The return flight is achieved by fixing two rockets nose to tail, connected by a fuse. When the dove, powered by the first rocket, hits the cart, the second rocket is ignited. This drives the bird back in the opposite direction.

Possibly the earliest illustration of a rocket-powered bird is to be found in a manuscript by Giovanni Fontana, written at the beginning of the fifteenth century.[54] Fontana lived in Venice and Padua, where he practised as an engineer and physician.[55] His real name was Giovanni di Michele: he acquired his professional name through his expertise in fountain design. His manuscript is called the *Book of Military Machines*

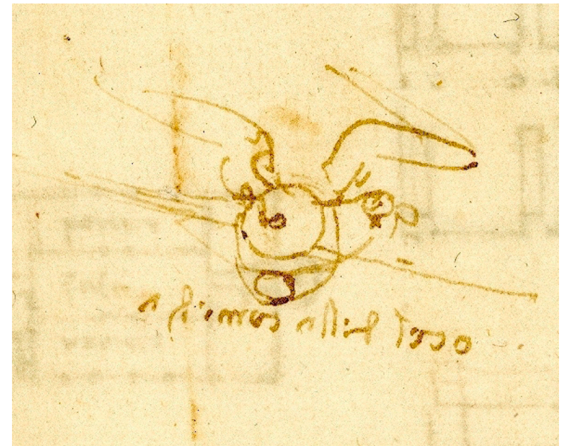

Figure 4.11 Mechanical bird for a theatrical comedy 'flying' on a wire, sketched by Leonardo da Vinci. Biblioteca Ambrosiana Milan and Bridgeman Images.

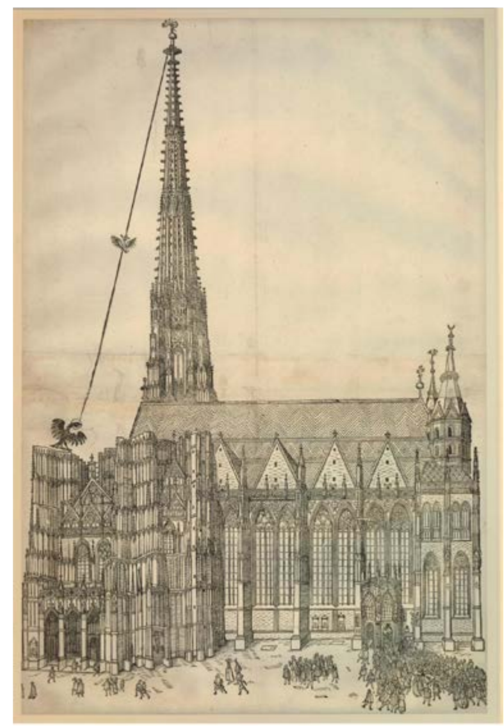

Figure 4.12 Eagle descending from the spire of St Stephen's Cathedral in Vienna in 1563: woodcut by Donat Hübschmann. By permission of The British Museum, under a Creative Commons licence.

and consists of a series of coloured drawings with captions in Latin and brief texts in cipher. (The cipher has been broken.) The book does indeed cover siege engines, incendiary devices and other weapons; but these are all mixed up with designs for mazes, a wheeled sailing ship, a mechanical somersaulting skeleton, a helter-skelter and a cylindrical shadow lantern that projects a magnified image of a naked she-devil. There is also a car propelled by the occupant using ropes and gears, a crude ancestor of Leonardo's machine. We will see more of Fontana's work on fountains and hydraulics in Chapters 5 and 6.

Fontana's bird (Figure 4.13) is in fact carried by a free-flying rocket with a stick, which was perhaps inspired by, or inspired, similar

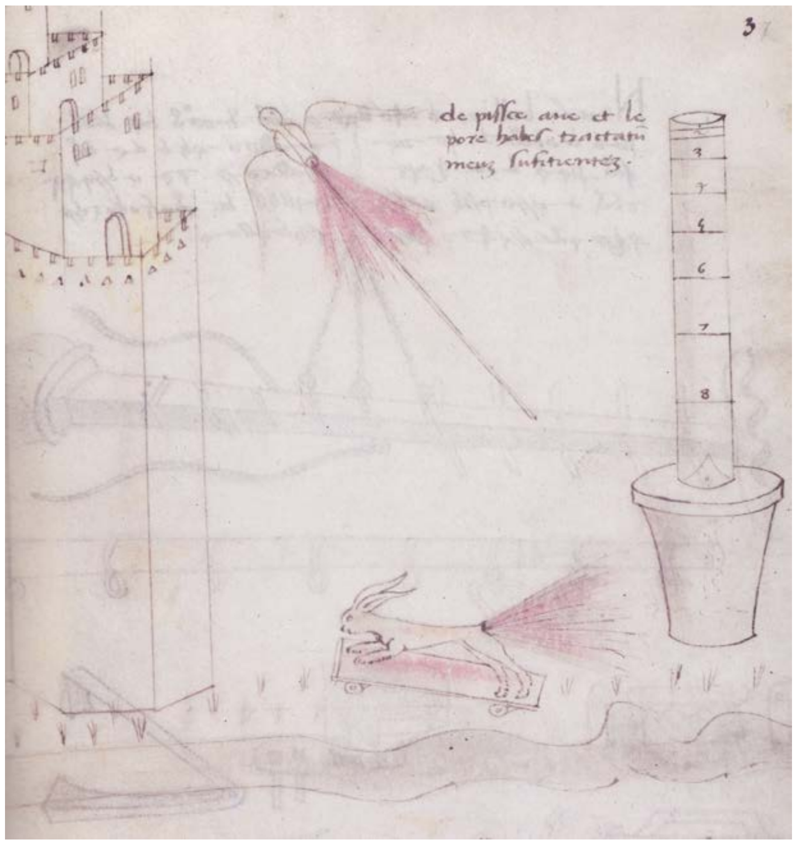

Figure 4.13 Designs for a rocket-propelled bird and hare on wheels by Giovanni Fontana, early fifteenth century. These are (in theory) devices for measuring distances, using known quantities of gunpowder. By kind permission of Bayerische Staatsbibliothek, Munich.

designs of running rocket. The picture also shows a rocket-powered hare on wheels. According to Fontana, these – improbably – are intended as devices for estimating heights and distances. They are propelled by known quantities of gunpowder measured in the container at the right.

Dragons on wires were favourites in firework shows throughout the Renaissance, for the obvious reasons that they were creatures that could both fly and breathe fire. Figure 4.14 shows an elaborate late example from John Babington's *Fireworks* of 1635.[56] This creature is supported on its cord with little wheels, and spurts fire from several orifices, not just the mouth.

What was perhaps the most impressive and mysterious of Renaissance flying dragons appeared over the Field of the Cloth of Gold in 1520, where Henry VIII of England and François I of France met for a diplomatic summit and tournament. The creature can be seen in a painting of the event (Figure 4.15) now at Hampton Court Palace. It was not part of the official celebrations, and struck a sinister and disquieting note. Jacobius Sylvius wrote a poem giving a description: 'Its eyes blaze, and with quivering tongue it licks its mouth; the dragon hisses through its gaping jowls … Heavy with its long bulk it swims slowly through the empty ether, rowing with its wings and with the assistance of its feet.'[57] Historians have wondered whether the creature was a large kite, perhaps with fireworks attached.[58] Sylvius mentions 'a wagon pulling from afar a thin cable'.

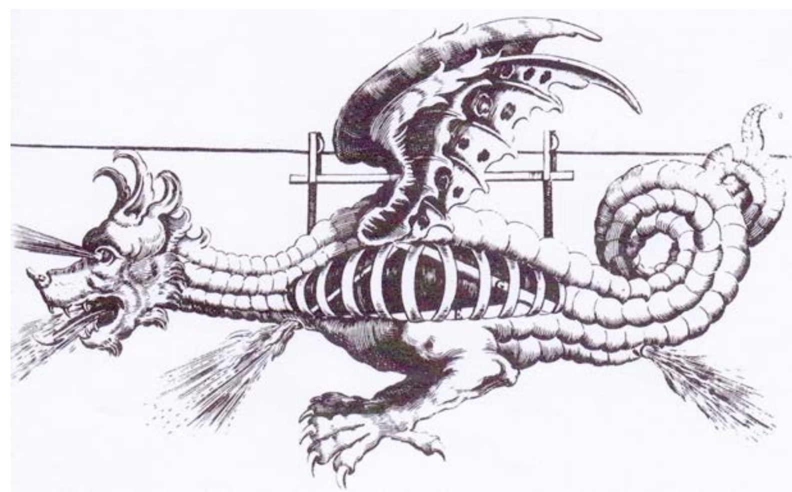

Figure 4.14 Dragon pouring fire from many orifices, running on a line, from John Babington, *Fireworks*.

Figure 4.15 Dragon (at the top left) – perhaps a kite – flying over the Field of the Cloth of Gold in northern France in 1520: from an anonymous painting at Hampton Court Palace. Wikimedia Commons: The Field of the Cloth of Gold.

The tradition of rocket-powered creatures running on lines reached a climax – or maybe one should say a low point – with the principle extended to human performers. On 4 June 1673 in Regensburg, Germany, a local enthusiast Carl Bernoju put on an 'exhibition of pyrotechnical acrobatics'. Bernoju was a surgeon and one might have thought would have been more cautious. But hoping to be a new Icarus, he covered his body with crackers and rockets, fired them and launched himself down a rope, 'looking more like a burning devil than a man'.[59] The engraving of Figure 4.16 shows two points in Bernoju's descent: halfway down the rope, and his flaming remains where he fell to earth.[60]

Basic rocket units were also used in the Renaissance to drive rotating firework devices, something like modern Catherine wheels but often very much larger, the size of cartwheels. Claudio di Lorenzo in his book *The Theatre of Fire* describes a firework show in Naples in the early sixteenth century, featuring characters from the Commedia dell' Arte.[61] This took place on a circular rotating stage driven by rockets. The stage consisted of three concentric rings turning separately, occupied respectively by papier-mâché figures of Pachiana (a version of the serving woman character Colombina), Pulcinella (the English Punch) and a donkey.

Figure 4.16 'Exhibition of pyrotechnical acrobatics' put on by Carl Bernoju in Regensburg, Germany in 1673. Two moments in Bernoju's descent on the wire are illustrated: halfway down, and his remains where he fell to the ground. By permission of the Getty Research Institute, Los Angeles, P950001.

Pachiana, who looms over the others, sprays fire onto Pulcinella, who has a flaming torch under his gown. Meanwhile the donkey, braying continuously, produces what Di Lorenzo coyly calls 'organic emissions' in the form of spurts of coloured fire from his back end. The show culminates with explosions, whistling rockets, cascades of fire and the complete destruction of the puppets.

I have not been able to find any illustrations of such popular shows at this period and maybe they were rarely if ever recorded. However, Giovanni Fontana has a picture of an animated figure that was perhaps intended for an event of the kind (Figure 4.17).[62] This is a *strega infuocata*, a 'flaming witch' with horns, bat wings, clawed feet and tail, spurting fire from her mouth and ears. The arms and wings are moved with strings, and the entire figure slides along rails, shown in the diagram of the supporting structure at the right. Fontana says that there is a spring under her skirt for launching a bomb or an explosive dart, as we can see in the diagram.

Figure 4.17 Design for a *strega infuocata* or 'flaming witch' by Giovanni Fontana, early fifteenth century. The mechanisms for moving the horns and bat wings, and for launching a bomb from under her skirt, are shown diagrammatically at the right. By kind permission of Bayerische Staatsbibliothek, Munich.

A magnetic flying dove

Athanasius Kircher was extremely enthusiastic about automata and showed many in his museum at the Roman College, some of which, one imagines, were among the 'crotchets & devises' mentioned by John Evelyn. The museum's contents are listed in a catalogue made by Giorgio di Sepi in 1678.[63] They included a hydraulic machine with 'a figure vomiting up various liquids for guests to drink', and a crystal goblet 'from one side of which a thirsty bird drinks up water' while on the other side a snake regurgitates the water. Both of these clearly owe much to Hero. Other devices exploited another source of power – magnetism – in typically imaginative Kircherian ways.

The Greek mathematician Archytas, a follower of Pythagoras who lived around 400 BC, is reputed to have built a model dove that could fly. Some have suggested that the bird was powered by a jet of compressed air or steam. Kircher had different ideas.[64] He devised a kind of clock in the form of a tableau in which Archytas himself stands on a little hill holding a wire to which a dove is tethered (Figure 4.18).

Figure 4.18 Magnetic clock designed by Athanasius Kircher, featuring the Greek mathematician Archytas and his flying dove.

Above them is a disc marked with the 24 hours of the day. The dove tells the time by moving to the appropriate position.

The figure of Archytas is made from paper and dried hemp stalk, so that he and the dove are light and easily turned. The dove has metal in its body. Above the clock face is a wheel with a magnet in its rim. The hidden operator turns the wheel and magnet to the appropriate position.[65] The dove follows. The principle is that of the old magnetic toy where a magician figure points to answers to a set of predetermined questions. Any relationship to Archytas's original is of course completely fanciful.

Birds in trees

Besides flying birds, there were many automata featuring birds sitting in trees – like those at the Villa d'Este. The earliest Renaissance garden to feature automated mechanical figures that we know of – before Hero's writings became widely read in Europe – was at Hesdin in northern France.[66] It was built for Robert II, Count of Artois, at the end of the thirteenth century. These 'riotous spectaculars' fell into disrepair in the late fifteenth century and were later destroyed by English soldiers. There are, however, two contemporary descriptions, one by Philip the Good, Duke of Burgundy, the other by Robert's daughter Mahaut, who inherited the garden and had the machinery renovated.

There was a Gallery of Delights, part of which extended onto a bridge over a lake. On the bridge were six groups of fur-covered monkeys, although whether these were automated is unclear. They had horns added when they were repaired, to turn them into devils. Two human figures made of wood spoke to visitors and ordered them about. And in a chapel made of glass called the Gloriette – a word meaning a garden pavilion or birdcage – there was an artificial tree covered with gilded mechanical birds spouting water. This particular detail has suggested to some writers that Robert was inspired by the Islamic gardens that he might have seen during the seven years he spent in Sicily. In particular, the twelfth-century Genoard garden in Palermo had fountains and water games of kinds that are described by several medieval visitors to the East.

Bishop Liutprand of Cremona was sent from Italy to Constantinople on two diplomatic missions in 949 and 968 and reported on the automata that he saw there in the palace of the emperors. There were 'lions, made either of bronze or wood covered with gold, which struck the ground with their tails and roared with open mouth and quivering tongue', and 'a tree of gilded bronze, its branches filled with birds, likewise made of bronze gilded over, and these emitted cries appropriate to their species'.[67] Two caliphs of Baghdad in the ninth and tenth centuries, al-Ma'mun and al-Muqtadir, also had metal trees with gold and silver birds sitting on the branches, which sang and flapped their wings.[68] It seems very probable that their inspiration was in manuscripts of Philo and Hero, which were avidly collected for the caliphs and translated by scholars in Baghdad.

In his *Pneumatics*, Philo illustrates a nice mechanism for making birds' wings move that is not repeated by Hero.[69] A vulture sits on a model mountain on top of a vase that can be filled with water. A rod running down a tube connects the vulture's head and wings to a float. When the float rises as water is poured in, the rod raises the bird's head and extends its wings. When the water runs out again, the movements are reversed. (Philo also has birds that sing, and a simplified version of Hero's owl and birds automaton.)

I have taken the decision to exclude clocks and clockwork from this book; but it is worth mentioning that there were birds and other mechanical creatures driven by clockwork, of considerable sophistication, being built in Europe as early as the fourteenth century, especially in Germany and Switzerland. Many of these were ornaments for church clocks, where mechanical bell ringers (*jacquemarts*) struck the hours and other characters appeared from doorways, moving on turntables. One of the most famous and elaborate of these figures was the mechanical cock installed in Strasbourg Cathedral in 1354. This raised its head, opened its beak and flapped its wings, all the motions actuated by a complex system of rods and levers. It is now in the Museum of Decorative Arts in Strasbourg.

In 1588 the engineer Agostino Ramelli published an encyclopaedic and copiously illustrated book of *Varied and Artificial Machines*, one of which consists of a vase filled with rose branches on which sit birds that sing (Figure 4.19).[70] The design clearly derives from this long Islamic and Heronian tradition. The vase is intended to stand indoors on a dresser. It contains four flutes or whistles of different sizes. Air to sound these flutes is forced in from the next room through a tube, either by a hidden assistant blowing – as shown in the picture – or with bellows. The bottoms of the flutes sit in a container of water, giving the notes a burbling quality. Two tubes lead up to the branches and convey the sounds to the birds' beaks.

Figure 4.19 Design by the engineer Agostino Ramelli from his book of *Varied and Artificial Machines* for a vase of rose branches on which birds sit and sing.

'Theatres of automata' in gardens

Pirro Ligorio's owl and birds fountain provides an example of what we might call the 'fixed automaton tableau' or mini-theatre, in which several figures present a little scene or perform some repeated sequence of actions. These tableaux were installed in gardens, as at Tivoli.

Other designers besides Ligorio used Hero as a source. Giovanni Battista Aleòtti translated the *Pneumatics* into Italian and published it in 1589.[71] He devised four additional 'theorems' of his own and illustrated them with engraved figures. In a copy of the printed book now in the British Library in London, Aleòtti made a large number of further emendations and additions in manuscript, and introduced yet more theorems accompanied by freehand drawings.[72] This extra material was included, with the pictures engraved, in a later edition of 1647.[73]

Aleòtti also changed the title of the volume from *Pneumatics* to *The Science and Art of Properly Regulating Water*, Book Six. This shows that he intended it to form a chapter – under his own name, not Hero's – of his monumental work on hydraulics, which remained in manuscript until the twenty-first century.[74] His introductory summary of the chapter runs as follows: 'In which are demonstrated pleasing things for ornamenting the most noble and magnificent gardens, that can be made artificially with water.'[75]

Among Aleòtti's additions to Hero's text there are some arrangements for raising water with pumps and Archimedean screws. But most are tableaux of automata for gardens or grottoes, all of which are driven by water wheels and the weight of water. This was the obvious choice of motive power, given that water was already being piped throughout villa gardens to feed the fountains. The power supply was therefore continuous and unlimited, and there was no need for the automata to be primed or set in motion by human operators, as is the case with many of Hero's devices.

Thus Aleòtti shows a modified version of Hero's model of Hercules and the dragon, driven by a continuous stream of water, not Hero's closed tank, which would have required refilling for every demonstration.[76] Hercules is made to hit the dragon with a club instead of shooting it with an arrow, so avoiding the need for the bow to be drawn by an operator on each occasion. The dragon both hisses and spits water in return. (The fact that Hero's owl and birds automaton is worked by a continuous supply of water is perhaps one reason why Ligorio selected it for the Villa d'Este.)

A second tableau, more original to Aleòtti but with several Heronian details in its mechanism, consists of a large open-topped water tank that is continuously filled from wineskins carried by four venerable figures representing rivers (Figure 4.20).[77] A Triton swims in the tank and blows on a conch shell.

A third scene depicts a blacksmith's forge and is more complex (Figure 4.21).[78] A waterwheel turns an axle. The axle carries U-shaped prongs that tip levers. These levers in turn move rods that animate the figures of the smith and his apprentices, so that they appear to beat metal on the anvil. The whole system is controlled by counterweight buckets of the type favoured by Hero. Drops of water are made to spurt from the anvil to simulate the sparks made by the smiths'

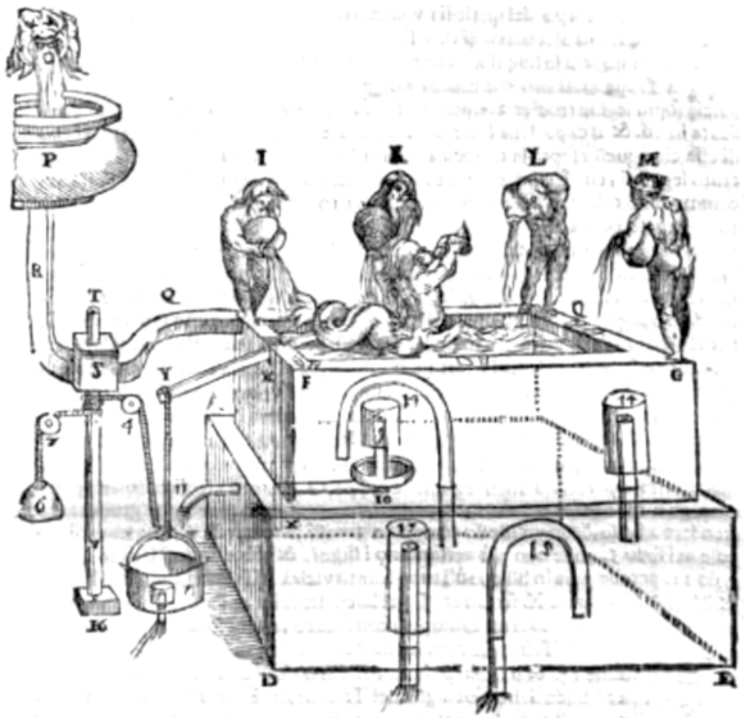

Figure 4.20 Tableau of automated figures by Giovanni Battista Aleòtti. The four men at the corners represent rivers filling the tank from wineskins. A swimming Triton sounds a conch shell.

hammers. The blacksmith's shop became a popular theme for automata and several other designers copied Aleòtti's original.

Some of these may have been just speculative ideas, but others were produced for specific clients. Count Giulio Tiene commissioned architectural works from Aleòtti at the Rocca dei Boiardo Castle in Scandiano near Modena.[79] Tiene was a music lover, and for his gardens Aleòtti suggested a group of three peasant boys, two playing a duet and the third conducting.

In 1590 Aleòtti was working on fountains and automata at the Castellina gardens in Ferrara, for Duke Alfonso II.[80] In a letter to the duke, Aleòtti writes about plans for two scenes at Castellina involving Hercules, one his fight with the dragon, the other in which he chops off the head of a lion.[81] He also describes a version of the owl and birds tableau in one of the freehand drawings inserted into his copy of the 1589 *Pneumatics* (Figure 4.22).[82] The main difference from Hero is that Aleòtti has replaced the owl with a white eagle,

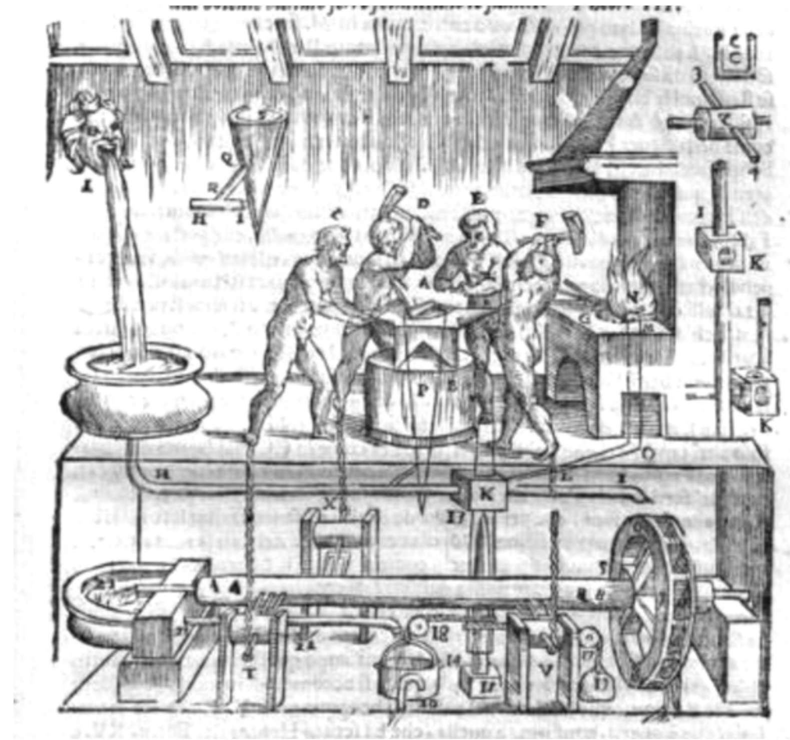

Figure 4.21 A tableau of automated blacksmiths in a forge, designed by Aleòtti. The smiths beat metal with hammers. Drops of water spurt from the anvil to represent sparks.

heraldic symbol of the house of Este. (These Ferrara gardens no longer exist.)

Duke Alfonso was the nephew of Cardinal Ippolito d'Este, the creator of the Villa d'Este at Tivoli, and their respective gardens had features in common. Pirro Ligorio, who worked on the design of the gardens at Tivoli as we have seen, moved in 1569 to Ferrara to work for Alfonso. Both he and Aleòtti were engaged on engineering works to control the flow of the river Po, so it is more than likely that the two men were acquainted.[83] Indeed it seems possible that one of Aleòtti's extra Heronian theorems had a late influence at the Villa d'Este, in a change that Vincenzo Vincenzi, the 'fountaineer' then in charge, contemplated making in the early seventeenth century.

There was a water jet on a path leading to the Rometta fountain, the scale model of ancient Rome – designed by Ligorio – that sprayed visitors automatically when they opened a gate.[84] Vincenzi thought

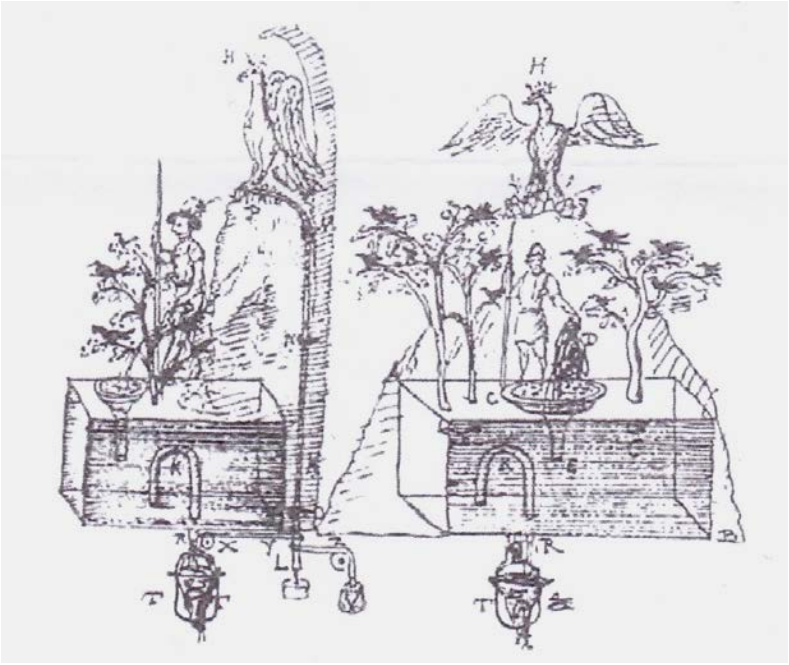

Figure 4.22 A version of Hero's owl and birds automaton, designed by Aleòtti, shown (left) in side view and (right) in front view. Aleòtti has replaced Hero's owl with a white eagle, symbol of the house of Este. Copyright, The British Library Board, from *Spiritali di Herrone*, trans. G. B. Aleòtti (1589) C.112.f.14.

this was too simple and obvious. He proposed a more sophisticated arrangement at the entrance to the lower gardens, in which figures of arquebusiers would be placed in niches on either side of the door, and would squirt water with their weapons at people coming in.[85]

This conceit clearly derives from a design by Aleòtti with two cannon either side of an entrance to a garden (Figure 4.23).[86] Opening the doors makes water fall from the tank above, down long tubes, into the guns' barrels. These expel the air 'with so much fury that they will make a loud report, or rather an explosion like that of Artillery', and shoot water at the terrified visitors.

Mechanical birdsong

In Francis Bacon's utopian fiction *The New Atlantis* of 1627, the Father of the imaginary research centre known as Salomon's House gives an

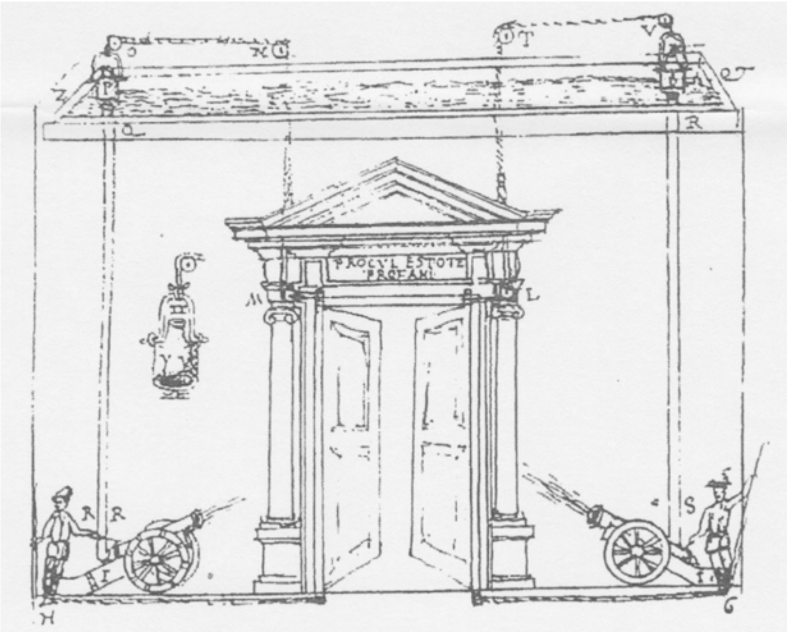

Figure 4.23 A tableau of automated figures designed by Aleòtti, to be placed at the entrance to a garden. Opening the doors makes water fall down the vertical pipes and out of the mouths of the cannon, soaking the waiting visitor. The fall of the water also produces explosive sounds. Copyright, The British Library Board, from *Spiritali di Herrone*, trans. G. B. Aleòtti (1589) C.112.f.14.

outline of that institution's visionary programme for future projects. Among the goals is to 'represent and imitate all Articulate Sounds and Letters, and the Voices and Notes of Beasts and Birds'.[87] But Hero and the designers of Renaissance automata were already doing this. Several of the witnesses who describe machines with singing birds say that it was possible to make out the distinct calls of particular species. Artificial birds were made to produce sounds by the insertion of whistles into their beaks. But how were the songs of particular species imitated?

Hero himself explains in his Theorem 14, 'A bird made to whistle by flowing water'.[88] This is in effect a simplified version of the owl and birds automaton, without the owl. Hero says that if water is poured into the tank, air will be forced out through the pipe that forms the trunk of the tree, to make a noise.

> When the extremity of the pipe dips into water a bubbling sound is heard, and the note of a black-cap [a type of warbler] is produced;

> if no water is near, there will be a whistling only. These sounds are produced through pipes; but the quality of the sounds will vary as the pipes are made more or less fine, or longer, or shorter; and as a larger or smaller portion of the pipe is immersed in the water; so that by this means the distinct notes of many birds can be produced.[89]

Ramelli's vase with birds on a rose tree has its flutes with their ends set in water in the way that Hero describes. Montaigne compared the sounds of the birds at the Villa d'Este with those produced by 'little earthen vessels full of water into which children blow with a mouthpiece'.[90] A second tube in Hero's automaton leads from the closed tank to a little cup of water, to make this kind of bubbling warbling noise.

Hunting small birds for sport and for eating was popular throughout Europe in the Renaissance, and the practice continues in Italy today. As Elizabeth David, the British cookery writer, says in her *Italian Food*: 'Any and every kind of bird, great or small, familiar or strange, is done to death for the fun of the chase and for the benefit of the table.'[91] Hunters have used whistles of varying designs, along the lines indicated by Hero, to imitate the calls of particular species and attract them into the open. There are drawings of a set of these 'calls' – including the cries of other animals besides birds – in a book by John Bate, *The Mysteryes of Nature and Art* of 1634 (Figure 4.24).[92] These are Bate's own designs; he says that similar calls are manufactured in France and come in long white boxes.

John Evelyn mentions in his book on gardening, *Elysium Britannicum*, that he too owned a set of these whistles. 'Such *Calles* as usualy are brought from *Nurnberg*, made by *Nicholas Kren* (a set whereoff we have long had by us) or else by imersing of pipes in the Water, to expresse the warbling of Birds, as the *Nightingalle* & others.'[93]

The key to Bate's drawings explains that his Calls are, in order, for a Kooko and an Oul; a Cock; a Drake; a Bittern; a Hedg-hog; a Levret; a Peacock; a Stag; a Fox; a Plover and a Puppy; small Birds; a Quayl; and a Kyte, Lark and Linnet.[94] (Surely puppies were not hunted?) The typical construction is shown in C and D, the calls of the drake and bittern. A wooden tube is made in two parts that screw together. There is a mouthpiece 'like the mouth of a cornet'. Inside the tube is a brass tongue that vibrates. The sound alters, Bate says, according to the sizes of the tube and tongue. Some sounds can be varied by the ways in which the instruments are blown.

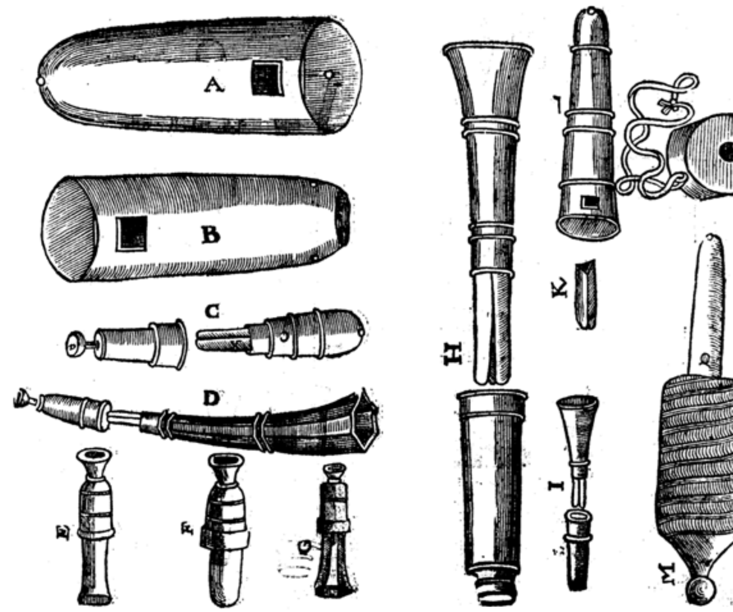

Figure 4.24 'Calls' used by hunters to attract birds and animals into the open, from John Bate, *The Mysteryes of Nature and Art*. The key is as follows: **A** Kooko and Oul; **B** Cock; **C** Drake; **D** Bittern; **E** Hedg-hog; **F** Levret; **G** Peacock; **H** Stag; **I** Fox; **K** Plover and Puppy; **L** Small Birds; **M** Quayl; **N** Kyte, Lark and Linnet.

I do not know whether the artificial birdsong in Renaissance automata was imitated with instruments of exactly these types. But the principles must surely have been similar, especially since designers are likely to have been familiar with Hero's advice on the subject.[95] Where a bird produces a melody as a sequence of two or more notes however, this clearly cannot be reproduced with a simple blast on a single pipe. Bate's calls for the 'kooko', owl and cock (A and B) have fingerholes and are played like little flutes or recorders.

There were nevertheless automatic devices that reproduced complex sustained birdsong in Renaissance gardens, including the song of the cuckoo. The English mathematician and engineer William Bourne mentions these in a book *Inventions or Devises* of 1578 devoted largely to military technology.[96] 'To make birds of mettall to sing very sweetly', he says, one needs to have 'pipes of tinne or other fine mettall to go with bellowes, & the pipes to have stops, and to go with a barrell or other such like devise …' 'By letting the sound or wind of the pipes to passe through or into water … will make a quavering as birds do.' How exactly this was done, I will explain in Chapter 6. Similar machines also provided the means for figures of human musicians to seem to play short melodies on wind instruments – trumpets, flutes or bagpipes.

Automata, serious and frivolous

Natural philosophers since Aristotle have found metaphors in automata and artificial creatures by which to picture the workings of real animal and human bodies. Automata have also played serious if sometimes manipulatively deceitful roles in religion, as indicated perhaps by those devices of Hero's that feature altars and temples. The attitude of the medieval church seems to have been conflicted and contradictory. A tradition of animated religious idols and oracles continued; but at the same time churchmen had misgivings about the blasphemies committed by those builders of automata who were seeking to emulate God's handiwork. From Philo and Hero's theatres onwards, it is nevertheless clear that one of the first roles for automata has been in entertainment. Bernardino Baldi says, in his introduction to Hero, that automata may have had some serious and divine uses, but they have most often been created as *scherzi*.[97] Their prime purpose has, in a word, been *fun*.

This is not, however, completely unthinking amusement. A great part of the pleasure gained from automata is that they are a cause for *wonder*: they require mental effort to try to work out how such surprising motions might be produced, especially when the mechanisms are out of sight.[98] As Baldi puts it, 'The wonder arises from seeing some unusual effect, judged to be impossible, and of which the cause is not known …'[99] It was for this reason that accounts of Renaissance automata in gardens use the word *meraviglie* (marvels); in particular to describe the place that was most thickly populated with artificial creatures, the 'park of marvels' at Pratolino, which we will visit in Chapter 7.

Notes

1 Federico Commandino, *Heronis Alexandrini Spiritalium Liber* (Urbino: 1575), no. 15, p. 52.
2 Woodcroft's figure shows both a U-shaped siphon and a *diabetes*, which would have been redundant. Hero's text says these are alternatives.
3 David R. Coffin, *The Villa d'Este at Tivoli* (Princeton, NJ: Princeton University Press, 1960); and David R. Coffin, *Pirro Ligorio: The Renaissance Artist, Architect and Antiquarian* (Philadelphia: Pennsylvania State University Press, 2004).
4 In an unpublished treatise on the arts, Ligorio says that it is a mistake for 'those who wish to make waterdrawn machines' not to study 'what power the water has with automatic machines which are moved by the striking of wheels, as those of Hero and Philostratus'. Quoted in David Coffin, 'Pirro Ligorio and the Villa d'Este', PhD thesis, Princeton University (1954), pp. 209–10.
5 Michel de Montaigne, *Journal du Voyage de Michel de Montaigne en Italie, par la Suisse et l'Allemagne, en 1580 et 1581*. The manuscript was rediscovered in Montaigne's chateau in 1774, and several editions were published in the nineteenth century. I have used the English translation by W. G. Waters, 3 vols (London: John Murray, 1903), see vol. 2, p. 169.
6 There are several books on automata, robots and mechanical toys covering ancient, medieval and Renaissance examples in the course of wider surveys organised chronologically and by country. The classic texts are A. Chapuis and E. Gélis, *Monde des Automates* (Paris: published by the authors, 1928); and A. Chapuis and E. Droz, *Les Automates* (Neuchatel: Griffon, 1949; English edition New York: Central Book Co., 1958). The latter provides a panoramic coverage from the ancient world to the twentieth century. Mary Hillier's *Automata and Mechanical Toys: An Illustrated History* (London: Jupiter Books, 1976) is a more popular treatment. Scholars have studied the place of automata in the wider history of machines and the theory of mechanics. Two papers with this focus are Derek J. de Solla Price, 'Automata and the Origins of Mechanism and Mechanistic Philosophy', and Silvio A. Bedini, 'The Role of Automata in the History of Technology', *Technology and Culture*, 5/1 (Winter, 1964): 9–23 and 24–42. This line of inquiry is followed into the eighteenth century by Simon Schaffer, 'Enlightened Automata', in William Clark, Jan Golinski and Simon Schaffer (eds), *The Sciences in Enlightened Europe* (Chicago: Chicago University Press, 1999), pp. 126–65. Mark E. Rosheim comes to automata from the perspective of a robotics engineer in *Robot Evolution: The Development of Anthrobotics* (New York: John Wiley, 1994) and *Leonardo's Lost Robots* (Berlin: Springer, 2006). Rosheim has speculated extensively about Leonardo da Vinci's automata, although in places his proposals go some way beyond the evidence. Jessica Riskin in *The Restless Clock: A History of the Centuries-Long Argument over What Makes Living Things Tick* (Chicago and London: University of Chicago Press, 2016) discusses the way in which, since Aristotle, animal and human simulacra have offered philosophers ways in which to understand the workings of the body and brain. Jonathan Sawday looks at the place of machines of several kinds including automata in Renaissance thought and sensibility, in *Engines of the Imagination: Renaissance Culture and the Rise of the Machine* (London and New York: Routledge, 2007). I have learned and borrowed from all these sources, but have taken a different approach again, with special emphasis on Hero and the role of automata in entertainment. In this context, one very helpful paper especially for the classification of automata has been Alexander Marr, 'Understanding Automata in the Late Renaissance', *Journal de la Renaissance*, 2/2 (2004): 205–22. The catalogue of a recent exhibition at the Center for Art and Media Karlsruhe, *Allah's Automata: Artifacts of the Arab-Islamic Renaissance (800–1200)* (Ostfildern: Hatje Cantz, 2015) includes much important material including texts on ancient music machines, cited here in Chapter 6.
7 *Di Herone Alessandrino de gli Automati, overo Machine Se Moventi*, trans. Bernardino Baldi (Venice: Girolamo Porro, 1589). This edition has Baldi's own illustrations.
8 John Wilkins, *Mathematicall Magick: Or, the Wonders that May Be Performed by Mechanical Geometry* (London: Gellibrand, 1648): my references here are to the second edition of 1680. See second book, Chapter 1, '*The Divers Kind of* Automata, *or Self-Movers*', pp. 145–54; Chapter 3, '*Concerning the Fixed* Automata, *Clocks, Spheres, Representing the Heavenly Motions*', pp. 162–78; Chapter 4, '*Of the Moveable and Gradient* Automata', pp. 172–8; and Chapter 6, '*Of the Volant* Automata', pp. 191–9.
9 Wilkins, *Mathematicall Magick*, p. 172.
10 Wilkins, *Mathematicall Magick*, p. 173.
11 Alois M. Nagler, *Theatre Festivals of the Medici 1539–1637* (New Haven, CT, and London: Yale University Press, 1964), p. 20.
12 Nagler, *Theatre Festivals of the Medici*, p. 38.
13 Sebastiano Serlio, *Il Secondo Libro d'Architettura* (Paris: avec privilege du Roy, 1545), p. 70.
14 From the collection of drawings of theatrical machinery in the Biblioteca Palatina in Parma, 'Disegni originali di Machine e di scene teatrale del Secolo XVII'. The drawing is reproduced

by Edward Carrick, 'Theatre Machines in Italy, 1400–1800 – II', *Architectural Review*, 70 (July–December 1931): 31–6 and plates 2 and 3: see 36, fig. 7.

15 Bastiano de' Rossi, *Descrizione del magnificentiss. apparato, e de' maraviglioso intermedi …* (Florence: Giorgio Marescotti, 1585), p. 18r [the printed page numbers are incorrect].

16 Nagler, *Theatre Festivals*, p. 66. Nagler gives the date as 1586, but De' Rossi's *Descrizione* is dated 1585.

17 Pen drawing by an unknown fifteenth-century artist, perhaps from Siena. British Library Add MS 34113, folio 176v.

18 Nagler, *Theatre Festivals*, p. 67 and plate 41.

19 Bengt Dahlbaeck, 'Survivance de la tradition médiévale dans les fêtes Francaises de la Renaissance', in Jean Jacquot (ed.), *Les Fêtes de la Renaissance*, 3 vols (Paris: Editions du Centre Nationale de la Recherche Scientifique, 1973–5), vol. 1, pp. 397–404; see p. 401 and plate 34, Figure 3.

20 Richard Lassels, *Voyage of Italy, or A Compleat Journey through Italy* (Paris: John Starkey, 1670), vol. 1, p. 209.

21 Charles Burney, *Music, Men, and Manners in France and Italy, 1770*, ed. H. Edmund Poole (London: Eulenberg, 1974), p. 93.

22 Roger Savage, 'Checklists for Philostrate', in J. R. Mulryne and E. Goldring (eds), *Court Festivals of the European Renaissance: Art, Politics and Performance* (Aldershot: Ashgate, 2002), pp. 294–307; see p. 299. *Dafne*, arguably the first true opera, was originally performed in Florence in 1598. Gagliano used the same libretto and wrote new music.

23 Quoted in C. MacClintock, *Readings in the History of Music in Performance* (Bloomington: Indiana University Press, 1979), p. 192.

24 Joseph Furttenbach, *Mannhafter Kunstspiegel* (Augsburg: Johann Schultes, 1663), plate following p. 124.

25 Furttenbach, *Mannhafter Kunstspiegel*, p. 245, G. R. Kernodle translation, in Barnard Hewitt (ed.), *Renaissance Stage Documents of Serlio, Sabbattini and Furttenbach* (Miami, FL: University of Miami Press, 1958).

26 Nagler, *Theatre Festivals*, p. 98.

27 Nicola Sabbattini, *Pratica di Fabricar Scene e Machine ne' Teatri* (Ravenna: 1638), English translation by John H. McDowell in Hewitt, *Renaissance Stage,* pp. 142–3.

28 Plato, *Laches. Protagoras. Meno. Euthydemus,* trans. W. R. M. Lamb (Cambridge, MA: Loeb Classical Library, Harvard University Press, 1924), *Meno* 97D, pp. 360–1.

29 *The Iliad of Homer, Rendered into English Prose*, trans. Samuel Butler (London: Longmans, Green and Co., 1898), Book 18, line 370.

30 *Iliad*, Book 18, line 375. Bernardino Baldi (*Di Herone Alessandrino*, p. 5b) says they had wheels, and John Dee in his section on 'Thaumaturgike' in his Preface to *Euclid* also says they had 'secret wheles' (*The Elements of Geometry of the Most Auncient Philosopher EUCLIDE* (London: Iohn Daye, 1570). Both presumably relied on Homer.

31 *Aristotle's De Motu Animalium*, trans. Martha Nussbaum (Princeton, NJ: Princeton University Press, 1985), pp. 42–3; section 701[b] in original. Previous translations of this passage have used the word 'puppets', implying string puppets, to translate αυτοματα; and Nussbaum again uses the words 'automatic puppets'. But there is no Greek word here corresponding to 'puppets'. It is perhaps the mention of cords that has suggested this idea.

32 Giorgio Vasari, *Life* of Leonardo da Vinci in *The Lives of the Artists*, trans. Julia Conway Bondanella and Peter Bondanella (Oxford: Oxford University Press, 1991), pp. 292–3.

33 Gio. Paolo Lomazzo, *Trattato Dell'Arte Della Pittura, Scoltura, et Architettura* (Milan: Paolo Gottardo Pontio, 1535), p. 106.

34 Gio. Paolo Lomazzo, *Idea del Tempio della Pittura* (Milan: Paolo Gottardo Pontio, 1590), p. 17.

35 Michelagnolo Buonarroti, *Descrizione delle Felicissime Nozze della Cristianissima Maestà di Madama MARIA MEDICI Regina di Francia e di Navarra* (Florence: Giorgio Marescotti, 1600), p. 10. The page is reproduced in Pedretti, *Leonardo Architect* (London and New York: Thames and Hudson, 1986), p. 322.

36 Leonardo da Vinci, *Codex Atlanticus*, folio 812r.

37 Pedretti, *Leonardo Architect*, p. 320; Martin Kemp, personal communication.

38 Wilkins, *Mathematicall Magick*, p. 173.

39 Mark Elling Rosheim, *Leonardo's Lost Robots* (Berlin: Springer, 2006), see Chapter II: 'Leonardo's Programmable Automaton and Lion'. Augusto Marinoni gives a history of research on the 'car', including work by Semenza and Canestrini in the 1920s and 1930s, in 'Les machines impossibles de Léonard', in *Léonard de Vinci, Ingénieur et Architecte*, catalogue of an exhibition at the Musée des Beaux-Arts de Montréal (1987), pp. 111–30.

40 Marinoni, 'Les machines impossibles', pp. 123–5; Rosheim, *Leonardo's Lost Robots*, pp. 24–5.

41 Giorgio Canestrini, *Leonardo, Costruttore di Macchine e di Veicoli* (Rome/Milan: Tumminelli, 1939).

42 Rosheim wants his reconstruction to be a 'programmable, mechanical computer-controlled automaton', 'the earliest "computer" in western civilization' (*Leonardo's Lost Robots*, p. 21). Without mentioning Hero, Rosheim wants his vehicle to have all the movements of Hero's mobile theatre, which could equally be described as 'programmable'. But the evidence of Leonardo's sketches hardly supports these notions.

43 Baldi, *Di Herone Alessandrino*, pp. 13a and 13b: translation by Gregorio Astengo.

44 The lobster, sometimes described as a crayfish, is in the Mathematisch-Physikalischer Salon of the Dresden Museum, catalogue number D VII 3. Jessica Riskin (*Restless Clock*, p. 20) says that the creatures were bought by the Prince Elector of Saxony, and that one went forwards, the other backwards – as crayfish often do.

45 Vasari, *Life* of Leonardo in Bondanella translation, p. 296.

46 Leonardo da Vinci, *Codex Atlanticus*, 629bv.

47 Villard de Honnecourt, sketchbook, plate 44, folio 22v: online at fr.wikisource.org/wiki/Carnet_(Villard_de_Honnecourt)/Codex_1.

48 Serlio, *Perspettiva:* Allardyce Nicoll translation, p. 35.

49 Lily B. Campbell, *Scenes and Machines on the English Stage During the Renaissance* (Cambridge: Cambridge University Press, 1923), p. 169.

50 For example Baldi, *Di Herone Alessandrino*, pp. 8b–9a, and Lomazzo, *Trattato Dell'Arte*, p. 106, mention Daedalus' robots and Hephaestus' [Vulcan's] tripods. Other references are to be found in the work of Kircher, Schott, Fludd and Wilkins.

51 Baldi, *Di Herone Alessandrino*, p. 9a.

52 Teller, personal communication.

53 Marina Dmitrieva-Einhorn, 'Ephemeral Ceremonial Architecture in Prague, Vienna and Cracow in the Sixteenth and Early Seventeenth Centuries', in Mulryne and Goldring, *Court Festivals*, pp. 363–90; see p. 374, Figure 19.8.

54 Giovanni Fontana, *Bellicorum instrumentorum liber cum figuris*, ms c.1420, Bavarian State Library, BSB Cod.icon.242, f.37r. The captions to the drawings are in Latin, but further descriptions are enciphered. However, the cipher has been broken: an old key is on the first page of the manuscript. Full Italian versions are given by Eugenio Battisti and Giuseppa Saccaro Battisti, *Le Macchine Cifrate di Giovanni Fontana* (Milan: Arcadia, 1984), see pp. 78 and 125. The manuscript itself is not paginated.

55 For a short account of the life and work of Fontana, see Frank D. Prager, 'Fontana on Fountains: Venetian Hydraulics of 1418', *Physis, Rivista Internazionale di Storia della Scienza*, 13/4 (1971): 341–60.

56 John Babington, *Pyrotechnia or, A Discourse of Artificiall Fire-Works* (London: Thomas Harper and Ralph Man, 1635), p. 38, Figure 10.

57 Jacobius Sylvius, *Francisi Francorum Regis et Henrici Anglorum*, Paris, 1520; translated in Jean Dupebe and Stephen Bamforth, 'Introduction', *Renaissance Studies*, 5/1–2 (1991): 1–47.

58 Andrew Hill, 'A Dragon? A Firework? A Kite?: Seeing, the Stain, and the Field of the Cloth of Gold', CRESC research note (n.d.), online at www.hummedia.manchester.ac.uk.

59 Kevin Salatino, *Incendiary Art: The Representation of Fireworks in Early Modern Europe* (Los Angeles, CA: Getty Research Institute, 1997), p. 41.

60 Exhibition of pyrotechnical acrobatics by Carl Benoju, Regensberg, 4 January 1673: engraving, Getty Research Institute, Brock Firework Collection acc. no. P950001**016.

61 Claudio di Lorenzo, *Il Teatro del Fuoco* (Padua: Franco Muzzio, 1990), p. 50. Di Lorenzo ascribes this story to the Renaissance metallurgist Vannoccio Biringuccio; but I cannot find it in Biringuccio's great book *Pirotechnia* (Venice: Venturino Roffinello, 1540).

62 Fontana, *Bellicorum instrumentorum*, f.63v: see Battisti and Battisti, *Macchine Cifrate*, pp. 96 and 137.

63 See Joscelyn Godwin, *Athanasius Kircher's Theatre of the World* (London and New York: Thames and Hudson, 2009), p. 192. Kircher has illustrations of some of Hero's actual theorems in *Œdipus Æyptiacus*, 3 vols (Rome: 1652–4), for example vol. 2, pp. 333–4.
64 Athanasius Kircher, *Magnes sive De Arte Magnetica* (Rome: Hermanni Scheus, 1641), facing p. 358. This machine is listed in the inventory of Kircher's Museum as 'The dove of Archytas reaching towards a crystalline rotunda and indicating the hours by its free flight': see Godwin, *Theatre of the World*, p. 192.
65 So this is not strictly an automaton.
66 See Elly R. Truitt, 'The Garden of Earthly Delights: Mahaut of Artois and the Automata at Hesdin', *Medieval Feminist Forum*, 46/1 (2010): 74–9; also Alice Welch, 'A Fourteenth-Century Art Patron and Philanthropist, Mahaut, Countess of Artois', in *Of Six Mediaeval Women; to which is added A Note on Mediaeval Gardens* (London: Macmillan, 1913), pp. 113–14.
67 Linda Safran, *Heaven on Earth: Art and the Church in Byzantium* (University Park: Penn State University Press, 1997), p. 30.
68 F. A. Marigny, *Histoire des Arabes sous le Gouvernement des Califes* (Paris: Estienne et Fils, 1750), vol. 3, p. 451; J. I. Reiske, *Abilfedae Annales Moslemici* (Leipzig: 1754), p. 237.
69 Philon de Byzance, *Le Livre des Appareils Pneumatiques et des Machines Hydrauliques*, French translation by Le Baron Carra de Vaux (Paris: Imprimerie Nationale, 1902), section 42; see also section 58. In Philo's owl and birds automaton (section 60) the owl is turned by hand and acts as a kind of a tap.
70 Agostino Ramelli, *Le Diverse et Artificiose Machine* (Paris: published by the author, 1588), parallel French and Italian texts: see Chapter 187, pp. 314v–316r.
71 Gio. Battista Aleòtti, *Gli Artificiosi et Curiosi Moti Spiritale di Herone* (Ferrara: Vittorio Baldini, 1589). Aleòtti also translated but did not publish Philo's *Pneumatics*, according to Madeleine Horn-Monval, 'La grande machinerie théâtrale et ses origines', *Revue de la Société d'Histoire du Théâtre*, 4 (1957): 291–308; see 293–4.
72 British Library classmark C.112.f.14.
73 Giovanni Battista Aleòtti, *Gli Artificiosi et Curiosi Moti Spiritale di Herone* (Bologna: Carlo Zenero, 1647).
74 Giovanni Battista Aleòtti, *Della Scienza et dell'Arte del ben Regolare le Acque*, ed. Massimo Rossi (Modena: Panini, c.2000).
75 Manuscript addition [np] by Aleòtti to *Spiritali di Herone*, British Library copy of 1589 edition C.112.f.14, following the title page: 'Nel quale si dimonstran' alcune piacevolezze le quali ~~per ornamento de i più nobili et sontuosi giardini~~ che si possono fare artificiosamente con l'Acqua.' I have included the words struck out.
76 *Spiritali di Herone*, 1647 Bologna edition, p. 89. Hercules was perhaps chosen to honour Ercole d'Este, Duke of Ferrara.
77 *Spiritali di Herone*, 1647, p. 91.
78 *Spiritali di Herone*, 1647, p. 93.
79 A. G. Keller, 'Pneumatics, Automata and the Vacuum in the Work of Giambattista Aleotti', *British Journal for the History of Science*, 3/4 (1967): 338–47; see p. 346.
80 Oreste Trabucco, *'L'opere stupende dell'arti più ingegnose': La recezione degli* Πνευματικα *di Erone Alessandrino nella cultura italiana del Cinquecento* (Florence: Leo Olschki, 2010), pp. 94–5.
81 Trabucco, *'L'opere stupende dell'arti più ingegnose'*, p. 95. The letter was published by A. Zanoletti, 'Un importante documento aleottiano', *Atti e Memorie della R Deputazione di Storia Patria per l'Emilia e la Romagna*, 1 (1942): 195–205.
82 *Spiritali di Herone*, British Library copy of 1589, edition C.112.f.14, hand drawing inserted on an unnumbered page. This drawing was not printed in later editions.
83 The idea of an acquaintance is suggested by the existence of a manuscript by Ligorio, now in the Bodleian Library in Oxford, into which drawings by Aleòtti are bound; and a printed copy of Vignola's *Regola delli Cinque Ordini d'Architettura* in the Biblioteca Comunale Ariostea in Ferrara, into which drawings and notes by both men are bound.
84 Coffin, *Villa d'Este*, p. 108. See Coffin, *Pirro Ligorio*, p. 190. The jets are shown in action in an engraving by Giovanni Francesco Venturini in Giovanni Battista Falda, *Le Fontane di Roma* (Rome: Gio. Giacomo de Rossi, 1691).
85 Coffin, *Villa d'Este*, p. 107.

86 *Spiritali di Herone*, British Library copy of 1589 edition C.112.f.14, hand drawing inserted on an unnumbered page. This drawing was also not printed in later editions.
87 Sir Francis Bacon, *The New Atlantis*, 1627; reprinted in Henry Morley (ed.), *Ideal Commonwealths* (London: Colonial Press, 1901), p. 134.
88 *The Pneumatics of Hero of Alexandria* (London: MacDonald, and New York: Elsevier, 1971): facsimile of edition by Bennet Woodcroft (London: Taylor, Walton and Maberly, 1851) Theorem 14, pp. 29–30.
89 *Pneumatics of Hero*, p. 30.
90 Montaigne, *Journal*, vol. 2, p. 168.
91 Elizabeth David, *Italian Food* (Harmondsworth: Penguin, 1963), p. 237. The range of species hunted and the numbers killed are more strictly controlled today.
92 John Bate, *The Mysteryes of Nature and Art* (London: R. Bishop for Andrew Crook, 3rd edn, 1654), pp. 73–6, and figures on two unnumbered pages following p. 76. This material is not in the 1634 first edition.
93 John Evelyn, *Elysium Britannicum or The Royal Gardens*, ed. John E. Ingram (Philadelphia: University of Pennsylvania Press, 2000), p. 243.
94 Bate, *Mysteryes*, p. 76.
95 Bate himself is very familiar with Hero's automata and reproduces a number of designs elsewhere in his book.
96 William Bourne, *Inuentions or deuises Very necessary for all generalles and captains* (London: Thomas Woodcock, 1578), p. 99. Bourne also describes a very early type of reflecting telescope and a design for a submarine that was successfully put into practice by Cornelis Drebbel.
97 Baldi, *Di Herone Alessandrino*, p. 5r.
98 This point is made by Hervé Brunon, 'Pratolino: art des jardins et imaginaire de la nature dans l'italie de la seconde moitié du XVI^{e} siècle', Doctoral thesis, Paris 1 Panthéon-Sorbonne (2008), p. 319.
99 Baldi, *Di Herone Alessandrino*, p. 11, left.

Intermezzo: Talking heads

In November 1644 John Evelyn visited the Villa Borghese in Rome. There he found a statue of a 'Satyre which so artificialy express'd an human Voice, with the motion of eyes & head; that would easily affright one who were not prepared for that most extravagant vision'.[1] How did this machine work – assuming it was a machine?

There were statues that reputedly spoke in the ancient world, including the mobile automata built by Daedalus.[2] Others served as oracles in temples. One of these survives. In the 1930s the archaeologist Grégoire Loukianoff discovered a limestone head of the Egyptian god Re-Harmakis, which was later acquired by the Cairo Museum. This has an oval cavity in the back, connecting to a small tube that leads to a concealed opening under the god's right ear. In Loukianoff's account:

> If the priest who was behind the statue, hidden by the great halo crowning it, and by the body of the statue, and so invisible to everyone, approached the cavity and spoke, his voice became modified in the tube and resounded, giving the impression that it was the statue which spoke.[3]

Loukianoff tested all this in practice. At Thebes in Egypt a statue of Memnon made strange noises at sunrise, like the music of a harp or a lyre – although it did not produce intelligible speech.[4] Here there is reliable contemporary testimony, with accounts among others from the historian Tacitus and the geographers Pausanias and Strabo. In the nineteenth century an English traveller, Sir A. Smith, examined the statue and found that the sound occurred at around six in the morning and came not from the mouth but the pedestal of the figure. He concluded that the cause was damp air escaping from crevices in the masonry when heated by the sun.[5] The statue still stands, but today is silent.

This tradition of talking heads persisted into the Middle Ages.[6] Several prominent clerics were involved. The French scholar and teacher Gerbert, who became Pope Sylvester II in the year 999, was said to have used his expertise in alchemy to make a head of metal that answered 'yes' or 'no' in response to questions.[7] In the thirteenth century the English Franciscan Roger Bacon reputedly made a talking head of brass with the help of a colleague. This features in a scene in Robert Greene's comedy of c.1590, *Frier Bacon and Frier Bongay*: the two protagonists sleep while Bacon's assistant Miles plays the drum and the head on the wall says enigmatically 'Time is. Time was. Time is past.'[8] A stage direction follows: 'There is then a flash of lightning and a hand appears, which breaks the Head with a hammer.'

Most famous of these medieval examples was the brass (or perhaps earthenware) head constructed lovingly over a period of 30 years by the Catholic philosopher Albertus Magnus.[9] Like Bacon's head in the play, this was destroyed in moments in a fury by Albertus's pupil Thomas Aquinas. Accounts differ as to Thomas's motive: terror, spite or, perhaps the most convincing, his irritation at the head's endless chattering.[10]

In 1615 Miguel de Cervantes published the second volume of *Don Quixote*.[11] Chapter 62 recounts 'the adventure of the enchanted head'. Don Antonio invites Don Quixote to a secret room where there is no furniture other than a table of jasper with a bust on it, seemingly made of bronze. This bust, says Don Antonio, has been 'fabricated by one of the greatest magicians and wizards the world ever saw, a Pole, I believe by birth'. It has 'the property and virtue of answering whatever questions are put to its ear'. Unfortunately, the statue never says anything on Fridays, and this is a Friday.

However, on the Saturday Don Quixote and other guests are given a demonstration. Quixote asks whether the spell on his beloved Dulcinea will ever be broken and is assured that it will. The voice comes from the bust's mouth, although the lips do not move. All are amazed, with the exception of two friends of Don Antonio, who are in on the secret. Their host has made the head himself from painted wood. It is hollow and contains a speaking tube that connects the throat to another room below. Here a nephew of Don Antonio, 'a smart sharp-witted student', has been told about his uncle's guests in advance and improvises the statue's answers.

Don Quixote was a runaway success and quickly went into several other European languages. Whether or not this was thanks to the book's influence, speaking heads appeared in a number of places soon afterwards, including the Villa Borghese.[12] Nicola Sabbattini describes how a ghostly apparition could be created on the Renaissance stage by clothing an actor in diaphanous robes and giving him a masked artificial head on a pole. This head could be raised and lowered to make the ghost grow or shrink. The mouth of the mask was connected to the actor's mouth with a flexible tube.[13]

When John Evelyn was in Rome he visited Athanasius Kircher, as we learned in the Introduction. Evelyn does not mention seeing talking statues in the museum, but Kircher was another who made experiments with speaking tubes as part of his general fascination with acoustical phenomena. Figure C.1 is from Kircher's book *Universal Music-Making*.[14] He gives this explanation:

> How to construct in any building a cone twisted in a spiral, or a shell-like tube, so that it will render any articulated sounds clearly and distinctly inside a room, no matter how distant from the outside, just as if it were next to the ear, with no one suspecting where it could come from.[15]

There are three of these peculiar twisted tubes in the drawing, all ending in talking heads. The tube at the left carries conversation upwards into a statue in the room above, as in Don Antonio's house. In the upper room at the centre a tube in the left-hand wall conveys sounds that bounce off a curved ceiling and seem to issue from the bust on the right-hand side. Similar devices, says Kircher, could be used by princes to communicate privately at a distance.

Kircher believes mistakenly that helical tubes as in the illustration produce 'some kind of parabola which brings about infinite conglomerations',[16] resulting in amplification of the sound. Despite this confusion he certainly showed a working system of some kind to Queen Christina of Sweden when she visited his museum. This 'Delphic Oracle' took questions whose answers were presumably provided by one of Kircher's assistants, relayed via a tube. Kircher also had an intercom for speaking with the porters and prospective visitors at the entrance to the Jesuit College.[17]

Ten years after seeing the talking satyr in Rome, Evelyn visited Oxford and called on 'the most obliging & universaly Curious' Dr John Wilkins, author of *Mathematicall Magick*.[18] Here Wilkins showed Evelyn

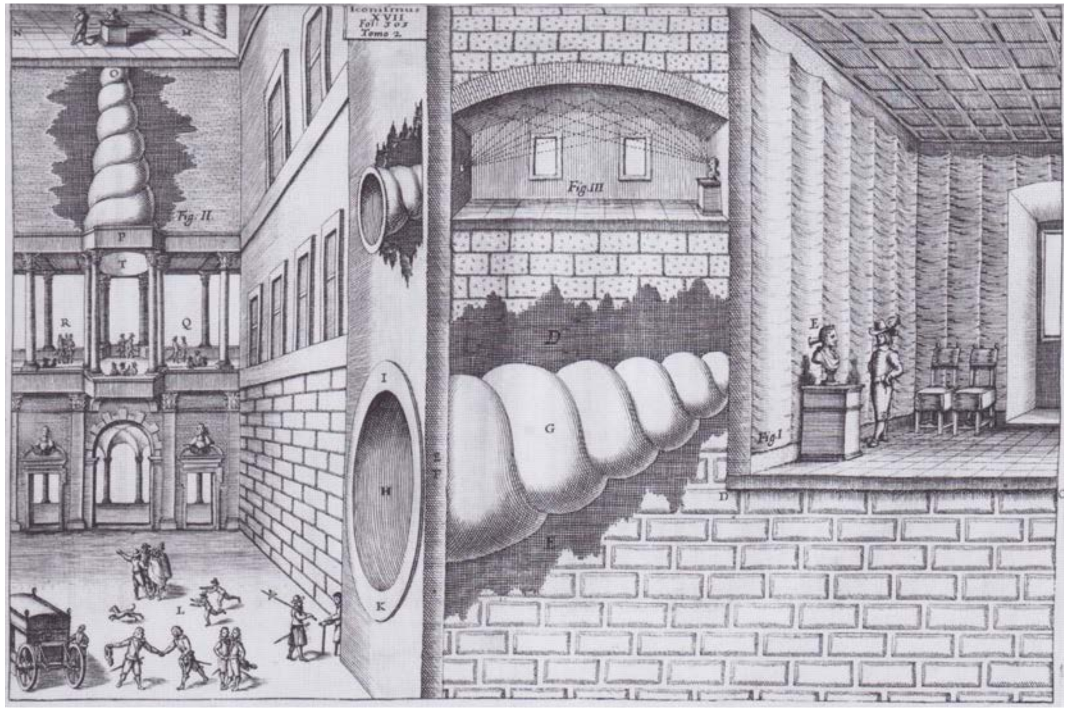

Figure C.1 Athanasius Kircher's spiral speaking tubes, each ending in a talking head, from *Musurgia Universalis,* 1650.

and 'at first' surprised him with a hollow statue, which had a 'long & conceald pipe which went to its mouth'. One of Wilkins's chapters on automata in his book mentions inventions 'which have been able for the utterance of articulate sounds, such as the speaking of certain words'.[19] It is quite possible, Wilkins says, to produce imitations of birdsong mechanically.

> But now about articulate sounds there is much greater difficulty. *Walchius* thinks it possible entirely to preserve the voice, or any words spoken, in a hollow trunk, or pipe, and that this pipe being rightly opened, the words will come out of it in the same order wherein they were spoken. Somewhat like that cold Countrey, where the peoples discourse doth freeze in the air all winter, and may be heard in the next Summer, or at a great thaw.[20]

Does Wilkins have his tongue in his cheek here? As he says, 'this conjecture will need no refutation'. What follows, however, are some suggestive and more serious remarks on the resemblance of certain natural non-human sounds to spoken letter sounds:

> Thus we may note the trembling of water to be like the letter L, the quenching of hot things to the letter Z, the sound of strings, unto the letter Ng, the jirking of a switch the letter Q, &c. By an exact observation of these particulars, it is (perhaps) possible to make a statue speak some words.[21]

In this Wilkins was correct, and prophetic. It was not until the late eighteenth century, however, that any substantial progress was made with mechanical devices for generating artificial speech.[22] Among several experimenters at this time the most successful seem to have been Wolfgang von Kempelen in Vienna and Erasmus Darwin (Charles's grandfather) in Lichfield. Darwin's machine took the form of a wooden mouth and nasal cavity with 'lips of soft leather', operated by pressure of the fingers.[23] The sound was produced by blowing air with a bellows over a stretched ribbon, like the reed of a woodwind instrument. The mouth could pronounce the words 'papa', 'mama', 'map' and 'pam'. Darwin lacked the time to develop it further; but he imagined that 'if built in a gigantic form' it 'might speak so loud as to command an army or instruct a crowd'.[24]

Von Kempelen is known for his spectacularly impressive chess-playing 'automaton' The Turk, later revealed to be a fraud, with a small human chess player concealed inside. But he had other scientific interests in human speech. His talking machine was more elaborate than Darwin's, with a rubber mouth, metal nostrils and an epiglottis. Goethe heard a demonstration and said that it was 'able to say a few childish words very nicely'.[25]

All this is still a long way from supplying the technical means for a convincing Delphic Oracle, however. Going back to our original question, how did the satyr at the Villa Borghese work? The fact that the head and eyes moved is intriguing and indicates some kind of mechanism, at least to create these motions.[26] One theoretical possibility is that this and other talking heads were masks, with real people behind, whose eyes could be seen. The nineteenth-century Scottish scientist David Brewster suggested another option for the speaking: ventriloquism.[27] But we have probably seen enough to draw the most banal conclusion: the voice of the satyr was a remote human voice conveyed through a tube.

Notes

1 *The Diary of John Evelyn*, ed. E. S. De Beer, 6 vols (Oxford: Clarendon Press, 1955), vol. 2, p. 254.
2 Heinrich Cornelius Agrippa von Nettenheim, *Three Books of Occult Philosophy*, trans. John French (London: Gregory Moule, 1651), Second Book, p. 168.
3 Grégoire Loukianoff, 'Une statue parlante ou Oracle du dieu Ré-Harmakhis, *Annales du Service des Antiquités de l'Égypte*, 36 (1936): 187–93.
4 Sir David Brewster, *Letters on Natural Magic*, new edn with additions by J. A. Smith (London: Chatto and Windus, 1883), pp. 291–2.
5 Brewster, *Natural Magic*, p. 292, citing *Revue Encyclopédique* (Paris: 1821), vol. 9, p. 598. Salomon de Caus, in *Les Raisons des Forces Mouvantes* (Paris: Hierosme Droüart, 1624), describes a solar-powered machine of his own invention to imitate the statue of Memnon (see Problem XXXV). More details are given in Chapter 6.
6 See Silvio A. Bedini, 'The Role of Automata in the History of Technology', *Technology and Culture*, 5/1 (1964), pp. 24–42. Bedini gives references (p. 31) to literature on speaking heads constructed by Gerbert, Bacon, Robert Grosseteste and Albertus Magnus.
7 Brewster, *Natural Magic*, p. 226.
8 Robert Greene, *The Honorable Historie of Frier Bacon and Frier Bongay* (London: Edmund White, 1594), Scene XI.
9 See Brewster, *Natural Magic*, p. 226.
10 Brewster, *Natural Magic*, says Thomas was frightened. Alexander Marr ('Understanding Automata in the Late Renaissance', *Journal de la Renaissance*, 2/2 (2004): 205–22: see 205–6) cites three writers giving three different motives: G. P. Lomazzo, that Thomas thought the head was the work of the devil; John Wilkins, that Thomas acted out of spite; and Gabriel Naudé, that 'he could not endure its excess of prating'.
11 Miguel de Cervantes, *Don Quixote de la Mancha* (Madrid: Francisco de Robles, 1615), vol. 2, Chapter 62; English translation by John Ormsby (London: Smith and Elder, 1885).
12 Jessica Riskin, *The Restless Clock: A History of the Centuries-Long Argument over What Makes Living Things Tick* (Chicago and London: University of Chicago Press, 2016), pp. 137–42, gives an entertaining account of talking machines from Don Antonio to the Abbé Mical and beyond.
13 Sabbattini, *Pratica di Fabricar,* McDowell translation in Barnard Hewitt (ed.), *The Renaissance Stage: Documents of Serlio, Sabbattini and Furttenbach* (Miami, FL: University of Miami Press, 1958), p. 176.
14 Athanasius Kircher, *Musurgia Universalis sive Ars Magna Consoni et Dissoni* (Rome: 1650), vol. 2, facing p. 303.
15 Athanasius Kircher, *Musurgia Universalis*, p. 303, translated in Joscelyn Godwin, *Athanasius Kircher's Theatre of the World* (London and New York: Thames and Hudson, 2009), p. 165.
16 Kircher, *Musurgia Universalis*, vol. 2, p. 303, translated by Godwin.
17 Godwin, *Athanasius Kircher*, p. 165.
18 Evelyn, *Diary*, vol. 3, p. 110.
19 John Wilkins, *Mathematicall Magick: Or, the Wonders that May Be Performed by Mechanical Geometry* (London: Gellibrand, 1648, 2nd edn, 1680), vol. 2, p. 177.
20 Wilkins, *Mathematicall Magick*, p. 177. 'Walchius' is possibly the German scholar and alchemist Johannes Walchius Schorndorffensis.
21 Wilkins, *Mathematicall Magick*, p. 178.
22 See Brewster, *Natural Magic*, pp. 267–70, and Mary Hillier, *Automata and Mechanical Toys: An Illustrated History* (London: Jupiter Books, 1976), pp. 51–2 for general accounts. These histories are brought up to the late nineteenth century by David Lindsay, 'Talking Heads', *American Heritage of Invention and Technology*, 13 (Summer 1997): 57–64. See also Theodore Ziolkowski, 'Talking Statues?', *The Modern Languages Review*, 110/4 (2015): 946–68.
23 Erasmus Darwin, *The Temple of Nature, or The Origin of Society* (New York: T. & J. Swords, 1804), pp. 251–2.
24 There are echoes of the Greeks' military 60-mile hydraulis, described in Chapter 6.

25 Hillier, *Automata*, p. 51.
26 As in the grotesque mask called the *Germaul* in the gardens of the Hellbrunn Palace at Salzburg, described in Chapter 7. This swivels its eyes and sticks out its tongue; but it does not speak.
27 Brewster, *Natural Magic*, p. 226.

5
Water in the air

The fountains of ancient Rome

Almost all the 1,200 public fountains of ancient Rome were lost when the city was sacked by the Visigoths and the Vandals. But those few that did survive were to provide inspiration for Renaissance fountain designers. These included three statues of river gods dispensing water who have moved around the city repeatedly, ending up today in the courtyard of the Capitoline Museum. Two of these represent the Tiber and the Nile; the third is known as the Marforio Fountain. In H. V. Morton's words:

> A great river was symbolized by the Romans as a bearded man in the full strength of maturity, naked to the waist, who reclined at ease, one arm resting upon some emblem of the river he represented, the other holding a flowing cornucopia, emblematic of the wealth and fertility created by the fresh water.[1]

The god of the Marforio Fountain, however, grasps a modest conch shell, and the water issues from the mouth of a sea monster.

Two more fountains that remained from the ancient city took less familiar forms. The first was a giant bronze pine cone, La Pigna, some 3 metres tall, now in the courtyard of the Vatican Museum.[2] It was originally gilded, and the water emerged from small holes at the bases of the scales. The second was the Meta Sudans, a tall plain brick structure in the shape of a cone, sited near the Colosseum.[3] Its name translates loosely as 'sweaty turning post': the *metae* were conical markers in the Circus around which the chariots turned.

As in La Pigna, water emerged from holes in the cone's surface and dribbled down; the gladiators are thought to have refreshed themselves from it. The last ruins of the structure were swept away by Mussolini in the 1930s. A number of Renaissance fountains reproduced the 'sweating' or 'weeping' behaviour of La Pigna and the Meta Sudans, as we will see.

Medieval and Renaissance designers also found written accounts in ancient classical and Arabic sources of a variety of forms of miniature fountain, to be installed indoors, perhaps as centrepieces on dining tables.[4] These reduced-scale fountains presumably found favour in the Mediterranean and the Middle East because of the shortage and value of water in those regions. There are elaborate decorative designs from the hands of a number of leading Renaissance artists, including Leonardo, who placed statuettes and bowls with jets on top of classical columns (Figure 5.1).[5]

Figure 5.1 Designs for 'Heronian' table fountains by Leonardo da Vinci, from his notebook now in Windsor, c.1513. Royal Collection Trust: copyright Her Majesty Queen Elizabeth II, 2020.

A simple physics of fountains

The essential principle of all fountains is that water is made to fall from a height. Within this there are different possibilities. Water under pressure can be made to rise from an opening and fall again, like a geyser. Water can be led to fall from an opening or over the edge of a raised surface in columns or sheets, like a waterfall. As the water runs away it can be directed down sloped surfaces and along channels, as in natural streams. All Renaissance and most modern fountains exploit variations on and combinations of these effects.[6] The physics of the waterfall and stream types need little explanation. The geyser presents more complications.

Water can be made to shoot up into the air by various means. It can be done with pumps, as in most modern fountains. Small Renaissance indoor fountains made use of air pressure, the weight of water or even heat to produce spurts or trickles of water. In large outdoor fountains, however, the water was generally brought from a source of supply at some height above the level of the nozzle of the jet. The vertical difference between these levels is the 'head' of water. The water could come from aqueducts, rivers or elevated reservoirs.[7] Figure 5.2 is a fifteenth-century drawing by Mariano di Jacopo, known as Il Taccola, showing the principle diagrammatically.[8] There is a reservoir at high level at the right and a pipe supplying water to the fountain's jet, which reaches up nearly to the level of the reservoir. Between fountain and water source Taccola depicts an A-shaped levelling instrument used in determining the relative heights.

The pressure of the water at the nozzle of a fountain depends on two factors. When the water is at rest, the pressure is related to the weight of water above, which is determined by the height of the head. When the water is allowed to flow from the reservoir, then the pressure is also affected by the way in which the water gains speed as it descends. In terms of modern physics,[9] the water sitting in the reservoir has *potential energy*; that is, the energy possessed by a body (the water) by virtue of its potential to fall under gravity. As the water falls down the pipe, this potential energy is converted to *kinetic energy*, the energy possessed by a body in movement.

When the jet emerges from the vertical nozzle and rises, the kinetic energy is converted back into potential energy as the water loses its speed and falls back. The whole system obeys the law of the conservation of energy: overall – and ignoring several complications – energy

Figure 5.2 Drawing of a fountain by Mariano di Jacopo, known as Il Taccola, fifteenth century, showing water supplied from a reservoir (right) at the height of the fountain's jet. The A-shaped object to the right of the fountain is a surveying instrument for measuring the levels of reservoir and jet. By kind permission of the Biblioteca Nazionale Centrale, Firenze.

is neither gained nor lost. Ideally the geyser rises to the height of the reservoir (as it does in Taccola's drawing). In practice it might fall some way short of the head.

However, this physics was not understood as such in the Renaissance, still less in ancient philosophy. It was only in the eighteenth century that the Swiss mathematician Daniel Bernoulli succeeded in formalising the relationship between water pressure, gravity, height and speed, in an equation that provides the foundation of modern hydrodynamics. Instead the theory of fountains in the sixteenth and seventeenth centuries still rested on Empedocles' conception of the four elements and their inherent tendencies to move in characteristic ways, in particular the tendency of water to find its own level.

This is why, when the first technical treatises on fountain design were written in the seventeenth century, they began with long disquisitions on the elements. Salomon de Caus was a French designer of fountains and automata who visited Italy – probably in the 1590s – and saw its great gardens. The title of his book on these subjects, *The Causes of Moving Forces*, of 1624, refers explicitly to the four elements.[10]

Carlo Fontana, a prolific Baroque architect – with a surname that matches his hydraulic expertise only by coincidence – published his *Most Useful Treatise on Running Waters* in 1696.[11] Fontana had responsibilities for the aqueducts of Rome under several popes, and designed a number of public fountains, some while working for Bernini. I will refer to *Running Waters*, although it only appeared at the very end of the seventeenth century, because it summarises the knowledge acquired by hydraulic and fountain engineers in the previous 200 years. Figure 5.3 is from an early page and shows the concentric realms of fire, air and water around the earthy sphere of the world.[12] Water, Fontana says, circulates through the world, springing from veins in the earth, coming from the sea and returning to the sea, 'as is written in the Sacred Scriptures'.[13]

All this is not to say that Renaissance designers did not know how fountains worked; but their knowledge was empirical rather than theoretical. It was guided by their understanding of the element of water and based in its details on practical experience. Indeed, fountain designers still work to an extent by trial and error today, and build physical models to test their ideas.

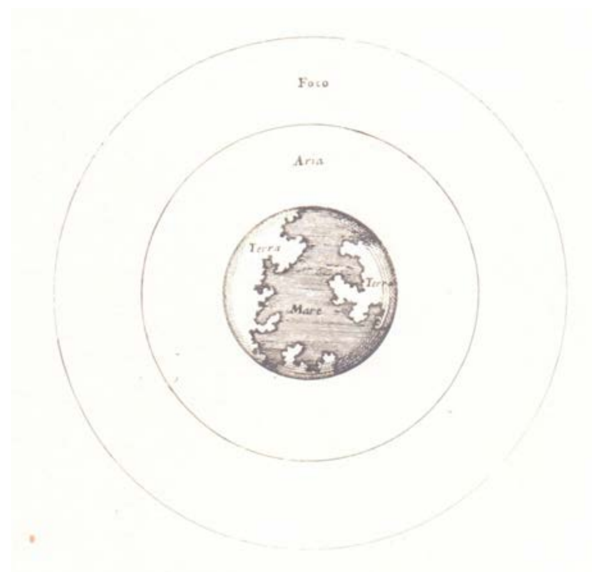

Figure 5.3 The concentric spherical realms of the four elements: Earth ('Terra'), Water ('Mare': the sea), Air ('Aria') and Fire ('Foco'). From Carlo Fontana, *Most Useful Treatise on Running Waters.*

Table fountains and their sources of power

It might in principle have been possible to supply a small moveable fountain for a dining table from an elevated head of water, but the plumbing would have been tricky and unwieldy. Renaissance engineers thought about several other self-contained means for creating jets, finding precedents – as with automata – in the manuscripts of Philo, Hero and their followers in the Islamic word. Alberti, Leonardo and others give detailed descriptions with diagrams.

Hero has a simple device for producing an upward spurt of water from the mouth of a vase using compressed air.[14] Water is introduced to the vase through a tap at the side, and then air is blown in by mouth to raise the pressure of the air above the water. When the top of the vertical tube is opened, water squirts out in a thin jet. De Caus adapts the principle, using a syringe to introduce more water and compress the air.[15] Another possibility, described by Hero, is to heat water to produce a vertical jet of steam. In a further development of these ideas both Hero and, following him, de Caus illustrate devices where water and air are warmed together in metal containers by solar heat, so generating the pressure for powering small fountains.[16]

Hero describes his theorem, numbered 47 in the *Pneumatics*, as 'A fountain which trickles by the action of the sun's rays'.[17] It consists of a sealed metal globe containing air and water, sitting on a pedestal. When the globe is heated by the sun, air pressure forces water out through a tube into an open cup and thence into a closed tank in the pedestal. When the globe cools, the water is sucked back from the tank through a second tube. As the temperature varies between day and night, so the water is moved back and forward between globe and tank. Today this would be known as a thermoscope, an instrument by which the effects of heat are made visible (but not measured, as in a thermometer). The device might seem to an observer innocent of modern physics to be a perpetual motion machine. This is what Leonardo seems to have thought. He was evidently fascinated and drew many variants of Hero's theorem – and a similar device described by Philo – in the *Codex Atlanticus*, the collection of Leonardo's drawings and notes assembled after his death, now in Milan.[18] One of the sketches is labelled 'moto continuo' (continuous movement).

De Caus's version is more complex than Hero's, but the physical principle is identical.[19] In place of Hero's single globe there are four metal tanks containing air and water, exposed to the sun. During the day a small jet is created in the bowl. During the night the water

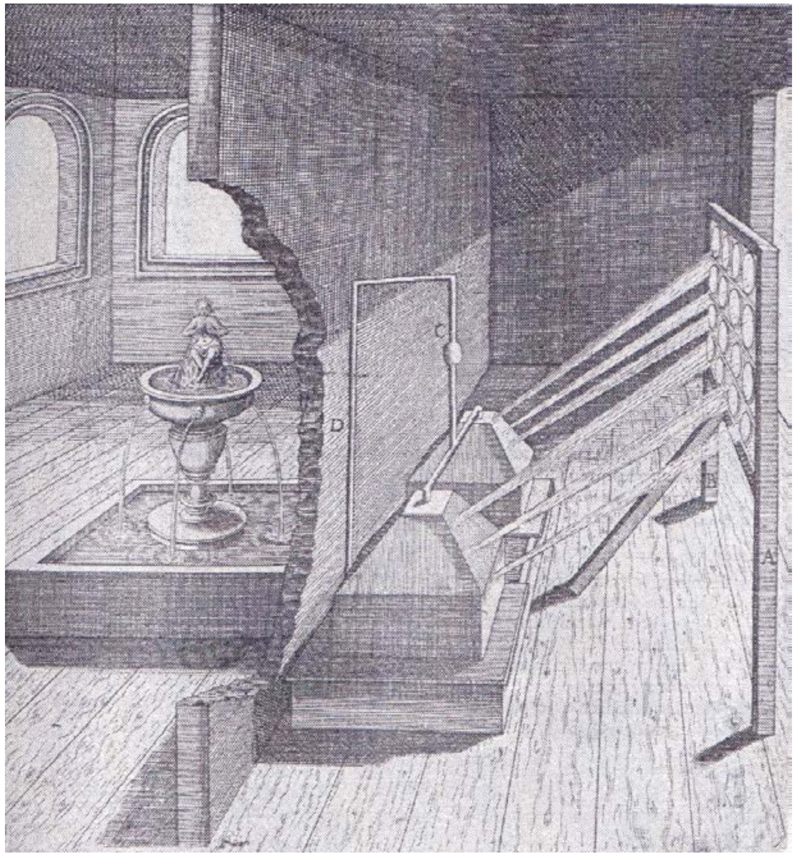

Figure 5.4 Problem XV from Salomon de Caus, *The Causes of Moving Forces* Book I. Sealed metal containers containing air and water are heated by the sun, focused by an array of lenses, to create the water pressure for a small fountain. The overflowing water collects in the pedestal. When the machine cools at night the water is sucked back up into the tanks, in a kind of perpetual motion.

is sucked back from the pedestal into the tanks. De Caus illustrates further elaborations of this design using arrays of glass lenses to focus the sun's rays onto the tanks (Figure 5.4).

None of these ideas was very practical for table ornaments, however; not least because the outflow of water would have been just a brief spurt, a weak dribble or dependent on the sun shining. What was needed was some device that could sustain a decent jet for the duration of a meal or a party.

Some of Hero's automata with singing birds consist of series of stacked tanks containing air and water, connected by siphons and

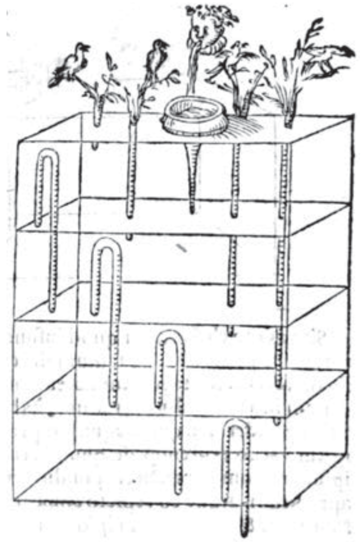

Figure 5.5 Theorem 44 from Hero's *Pneumatics*: 'Notes produced from several Birds in succession, by a Stream of Water.' Air in the tanks is forced through tubes up into the birds' beaks. The same principle could be adapted to produce jets of water instead of air.

straight vertical tubes (Figure 5.5).[20] Each siphon drains the water from one tank to the next below, raising the air pressure in that tank and forcing air up through a vertical tube to the beak of a bird. In this way several birds are made to sing one after the other. The same principle is readily transposed to make the weight of the descending water raise up jets of water instead of air. In his book *Mathematical Games* Alberti explains this in detail.[21]

Three tanks are placed in a stack and joined by openings and tubes (Figure 5.6). I have redrawn Alberti's diagram four times to create an animated sequence of stages in the machine's working. At the start of operation, the middle tank and the upper tank are filled with water. The contents of the top tank are then allowed to flow into the bottom tank. Compressed air passes from the bottom tank to the middle tank, forcing water up to create the fountain.

Leonardo studied several of Philo and Hero's other hydraulic devices – not just their thermoscopes – with great interest. Figure 5.7 shows one of his diagrams of the operation of a Heronian fountain from around 1497, from the first of the Madrid Codices.[22] This corresponds precisely to Alberti's design, which Leonardo had doubtless seen in his own copy of the *Mathematical Games*.

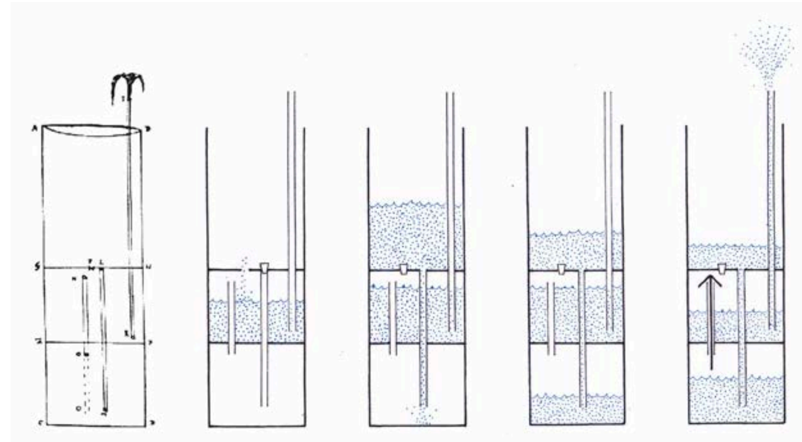

Figure 5.6 Leon Battista Alberti, workings of a fountain, from his book *Mathematical Games*. My diagrams, following Alberti's original, show the sequence of operation. Water (in blue) moves through the tanks, raising the air pressure, which forces water out of the jet at the top. The vertical arrow indicates the flow of air.

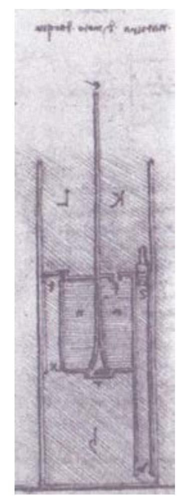

Figure 5.7 Diagram by Leonardo da Vinci for a 'Heronian fountain', c.1497, from the first of the Madrid Codices. This follows Alberti's design of Figure 5.6. Image property of the Biblioteca Nacional de España.

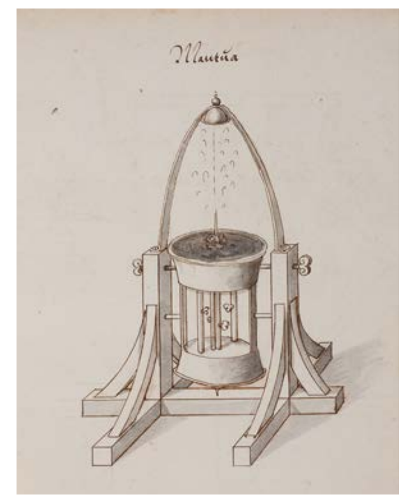

Figure 5.8 Portable fountain drawn by Heinrich Schickhardt on his visit to Mantua, c.1599–1600. It looks as though this operates on principles similar to Alberti's fountain of Figure 5.6 but can be turned upside down on pivots when the upper basin is empty, to reverse the flow and make water flow from a second jet. Stuttgart, Württembergische Landesbibliothek, Cod. hist. qt. 148,b 0071r.

A fountain of this type would only continue to flow until the water in the top tank was exhausted. The German engineer Heinrich Schickhardt toured Italy in 1599–1600 and made a drawing of a portable fountain (Figure 5.8) in Mantua.[23] He gives no written description, but it is reasonably clear that the structure with two basins connected by tubes can rotate on a pivot, and is secured in place by the two keys in the frame. My guess is that this works on something like Alberti's principles, and that there are closed containers below the two basins. When all the water in the top basin has flowed through to the container above the lower basin and the jet from the first nozzle has stopped, the structure is turned over, the flow is reversed and a jet begins to shoot up again from the second nozzle.

The fluid that flowed in these small fountains was not always water. A fountain of wine could continue to recirculate its contents until drained by guests filling their glasses. Figure 5.9 shows a small bronze model from the 1540s by the sculptor and goldsmith Benvenuto Cellini for his full-size figure 'Perseus and the Head of Medusa'.[24] It is thought that this may have been adapted to serve as a table fountain that dispensed wine, no doubt red, flowing from Medusa's severed neck.

Figure 5.9 Small bronze model by Benvenuto Cellini for his sculpture 'Perseus and the Head of Medusa'. It has been suggested that this was used as a table fountain, serving red wine from Medusa's severed neck. Photo courtesy of the Gallerie degli Uffizi, Florence.

'Chalice' fountains with bowls

In large outdoor fountains supplied from heads of water, more complex effects are possible, exploiting more powerful jets. Carlo Fontana's book *Running Waters* explains some of the principles. It is organised as a series of demonstrations with illustrations, rather like Hero's *Pneumatics* after which it was perhaps partly modelled. These are the fruit of field experiments and measurements carried out by Fontana. (De Caus's text is similarly organised as a series of 'Problems'.) Figure 5.10 from Fontana, like Taccola's drawing, shows the relationship of a head of water to the resulting height of a jet. In this case the reservoir is provided by the contents of a decorative vase.[25] The jet rises nearly to the level of the water in the vase.

Figure 5.11 shows a more complicated situation.[26] The fountain at the left must be receiving water from a reservoir (which we do not see) at the height of the top of its central jet. This fills the basin beneath with slow-moving *acqua morta*, or 'dead water'. This dead water acts in turn as a reservoir for lower jets. Water from the basin is taken off in a pipe at *A* and issues in a vertical jet *E*, which achieves the same height as the basin reservoir. Other jets might issue horizontally as Fontana shows, from the pipe junction at *C*. The distance to which these jets

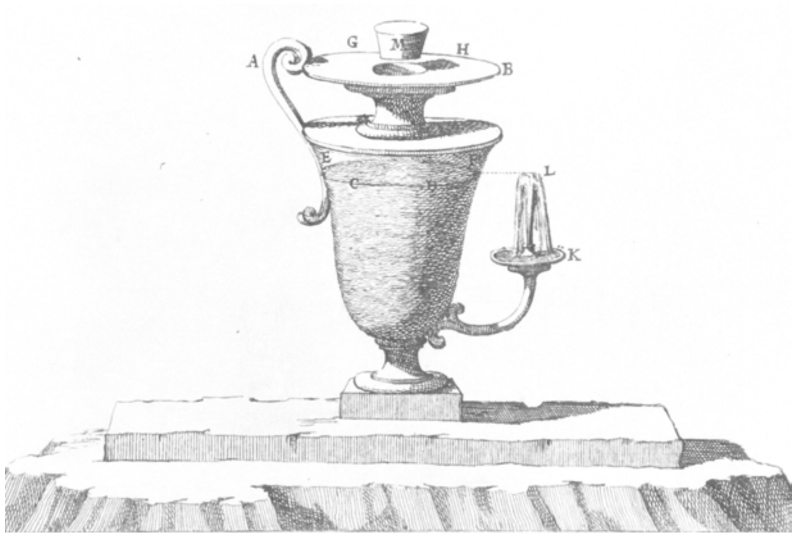

Figure 5.10 A little fountain at *K* is supplied by the water in a vase. The fountain rises to a height *L*, level with the surface *CDEF* of the water in the vase. From Carlo Fontana, *Most Useful Treatise on Running Waters*.

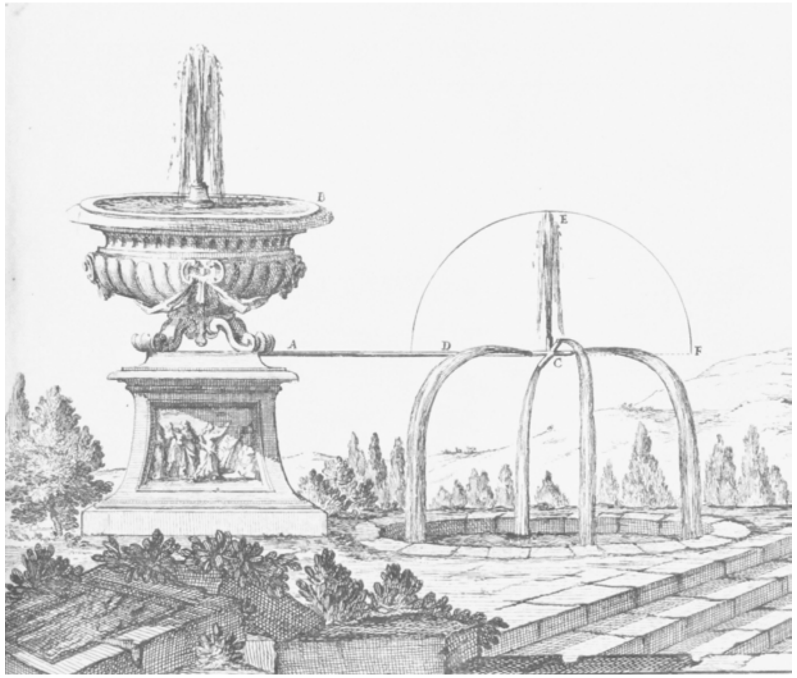

Figure 5.11 The 'dead water' in the pool of a fountain at *B* provides the head of water, via the pipe *AC*, for a jet at *E*, which rises to the height of the pool *B*. Three other jets issue horizontally, to distances equal to the height *CE*. From Carlo Fontana, *Most Useful Treatise on Running Waters.*

extend horizontally is the same as the height to which the jet *E* rises vertically.

These effects are exploited in one of the commonest types of fountain, the so-called chalice or cup (Italian: *tazza*), of which large numbers were built in Italian cities from the start of the sixteenth century. At its simplest the design consists of a single bowl with a central vertical jet. The jet pours water into the bowl, and – in large fountains – the water in the bowl can then overflow into a shallow pool at the foot of the structure. Most public urban fountains, their sculptural decoration notwithstanding, were termini of the civic water supply and served essential utilitarian purposes. In many such chalice fountains, it was common practice to set the main bowl at a height convenient for people to drink or fill jugs or barrels, while the pool at the fountain's base was reserved for animals.

The chalice principle was elaborated in designs with several bowls, one above the other, like cake stands. In France these

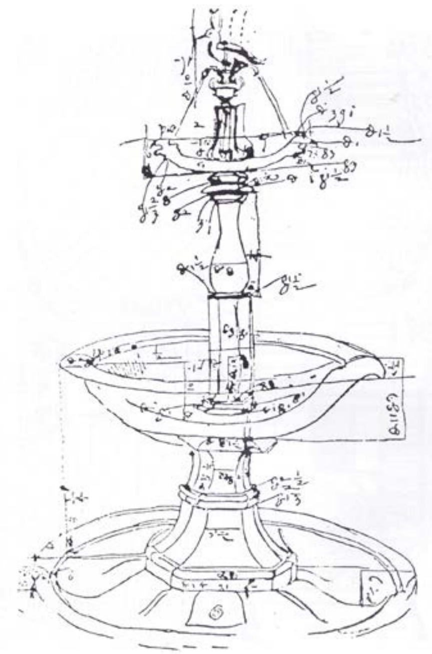

Figure 5.12 Working drawing for a chalice fountain by Baldassare Peruzzi. Gabinetto Disegni e Stampe, Gallerie degli Uffizi, Florence.

were known as *pyramides*. Figure 5.12 shows a working sketch, with dimensions, by Baldassare Peruzzi. The dead water in one bowl is used to create minor jets in a bowl below, as explained by Fontana.

Figure 5.13 shows two such 'cake stand' fountains erected in the Piazza Farnese in Rome in 1627. In each case there are three receptacles one above the other. Those in the middle are huge granite bathtubs recovered from the Baths of Caracalla. Girolamo Rainaldi designed the topmost basins, which are crowned with fleurs de lys, emblem of the Farnese family. See how, on the two lower levels, there are again subsidiary jets supplied from the dead water above. The engraving is by Giovanni Battista Falda, who specialised in depicting fountains. A collection of his pictures, which are highly reliable and full of local detail, was published as *The Fountains of Rome* in 1691.[27]

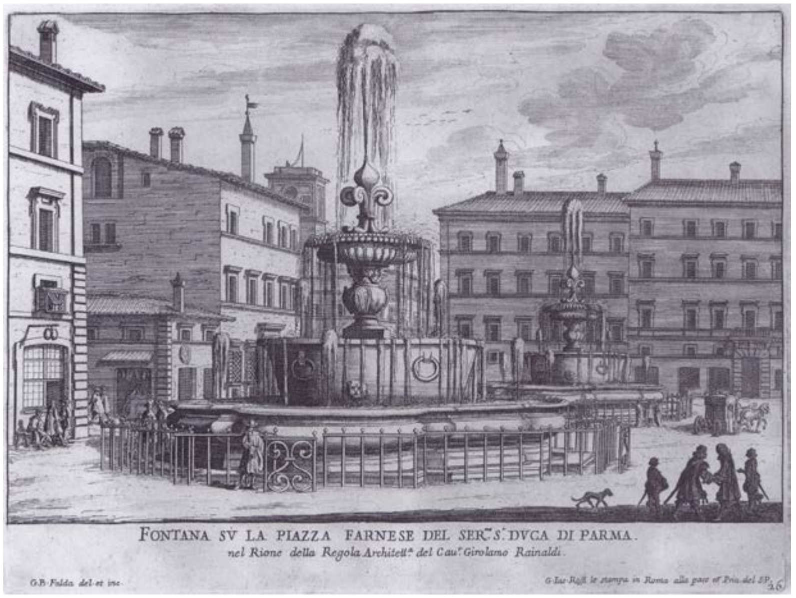

Figure 5.13 A pair of chalice fountains in the Piazza Farnese in Rome, installed in 1627. The middle basins are ancient Roman bathtubs. The upper parts were designed by Girolamo Rainaldi. Engraving by Giovanni Battista Falda.

Measuring the height of water sources, and laying out pipe networks

A large part of the hydraulic engineer's art in ancient Rome and in the Renaissance was in locating sources of water at a distance, at a sufficient elevation, and then surveying the ground over or under which the conduits were to run. Much of Fontana's book is devoted to these subjects. To measure differences in height between different points on the ground a device called a dioptra was used. Hero wrote a complete treatise on this instrument.[28] Vitruvius also mentions it in passing.[29] Aleòtti devotes a chapter of his book on *Hydrology* to a more elaborate multi-purpose surveying instrument of his own invention called the *archimetro*.[30] This incorporated a magnetic compass as well as a dioptra.

The dioptra was the ancestor of the modern theodolite and was used for measuring visual angles between distant objects, and for establishing levels by means of a horizontal bar or sighting tube. The operator could look along the bar or tube at other distant posts with horizontal arms on their tops. Assistants would move these posts up or down until the arms were on the same level as the dioptra. Figure 5.14 is a sketch by Bernardo Buontalenti showing three types of surveying instrument (above) and a surveyor at work (below).[31] Buontalenti, not content to give us just a functional diagram, has put the surveyor to work in a landscape full of charming but irrelevant detail. A simple dioptra is shown at top right. It has two small bottles fixed at the ends of a long tube. The bottles are interconnected by a pipe and are filled with water, perhaps coloured with wine. When the water is at the same level in the two bottles, the apparatus is perfectly horizontal. The observer then sights through the tube.

Buontalenti shows two more aids to surveying. At top left there is an A-shaped level with plumb line like Taccola's. And below the dioptra is a second sighting device in which the observer looks through holes in a cylinder on top of a vertical staff, again with a plumb line to ensure that the staff is vertical. These instruments have been used to survey the profile of the hill at the right with a series of vertical and horizontal measurements (drawn in red) in steps down the slope.

Water might have to be brought over some distance to supply entire towns and cities. By contrast the sites for great villas and gardens built outside Rome and Florence by the cardinals and the Medici grand dukes could be chosen specifically for their abundance of local water, so that the many fountains could be supplied directly. This is what happened for example at the Villa d'Este at Tivoli.[32] The river Aniene flows through the town of Tivoli, where it pours over a series of waterfalls. Cardinal d'Este's hydraulic engineer Curzio Maccarone diverted a part of the river through a 600-metre tunnel, to deliver water at a rate of 17,000 gallons a minute to a great reservoir at the top of the villa's gardens.[33] From here the flow was channelled down the steeply sloping site to the fountains below, the 'dead water' on one level providing the head of water for the level beneath.

A similarly sloping site was selected by Cardinal Gambara for the Villa Lante at Bagnaia near Viterbo, finished in the 1570s at around the same time as the Villa d'Este.[34] Gambara's engineer Tommaso Ghinucci brought a short aqueduct to a reservoir at the top of the site. The fountains of the villa's formal garden all lie on an axis connecting this reservoir, via a series of terraces, to the foot of the hill.

Figure 5.15 shows the pipe network for the gardens of the Villa d'Este, as reconstructed by the historian Carl Lamb.[35] The tunnel from the Aniene enters at upper left. The conduits are shown in broken lines

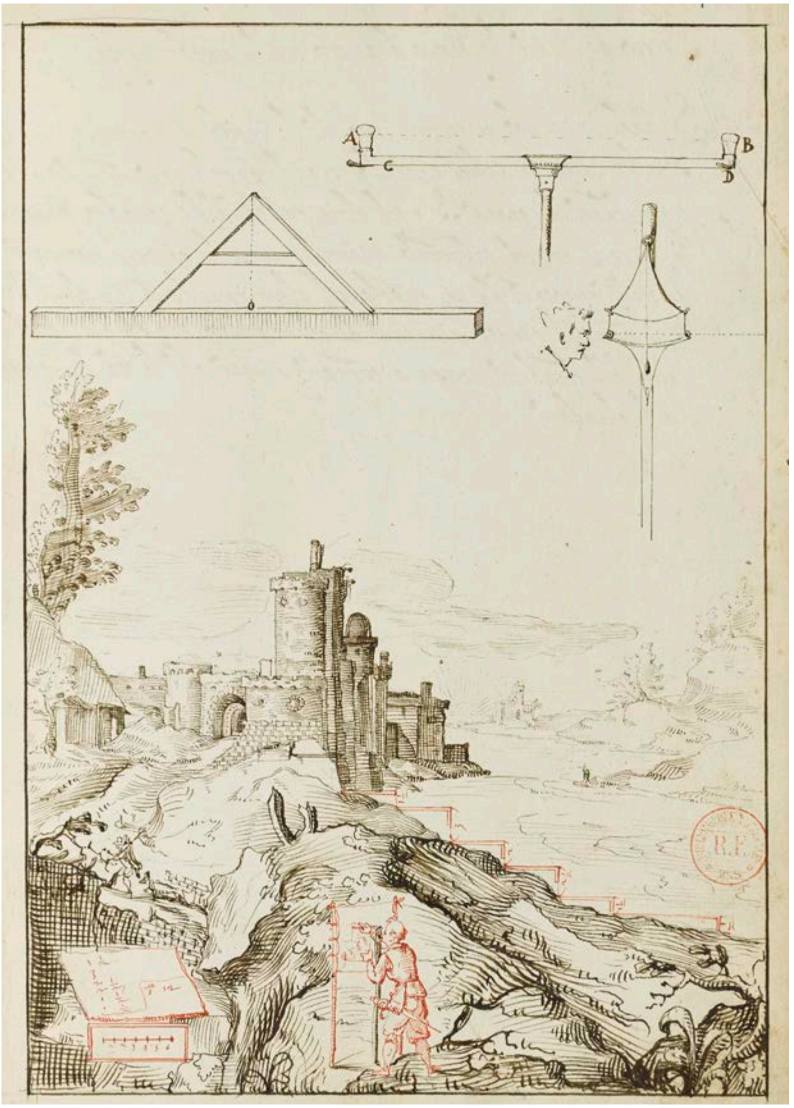

Figure 5.14 Drawing by Bernardo Buontalenti showing an A-shaped level, a dioptra (top right), a second sighting instrument on a vertical staff, and (below) a surveyor at work. The surveyor has measured the profile of the hill at the right with a series of horizontal and vertical measurements stepping down the slope. By permission of the Bibliothèque Nationale, Paris.

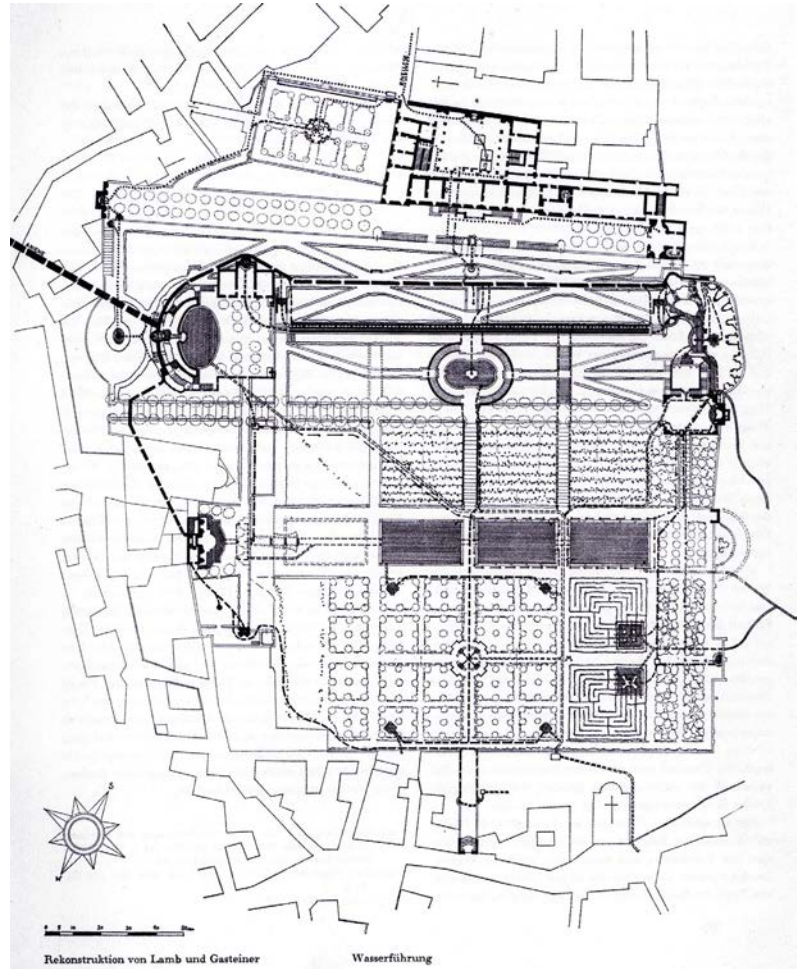

Figure 5.15 Plan of the water distribution system for the gardens of the Villa d'Este at Tivoli. The villa is at the top and the gardens slope down towards the bottom of the page. The conduits are shown in broken lines whose thickness indicates the volume of flow. The water supply from the river Aniene to the main reservoir is at top left. The water flows away into the town at the bottom and the right. Reconstruction by Carl Lamb, *The Villa d'Este at Tivoli: A Contribution to the History of Garden Design.*

and the widths of the lines indicate the volumes of water carried. In this plan the villa is at the top and the garden terraces step down from the top to the bottom. The various fountains and pools are shown in darker shading. The water finally flows away at bottom and right to provide part of the public supply to the town of Tivoli.

Arrangements of jets, basins and cascades

The basic components of fountains – jets, basins, cascades – can be put together in a great variety of different ways. The simplest arrangement is the wall fountain used for drinking, with a single low-speed jet issuing horizontally from the wall, falling into some kind of receptacle. In Renaissance wall fountains the water was often made to spout from the open mouth of a sculpted human face or animal head. Ancient stone baths and sarcophagi were pressed into service for the containers. At the Villa d'Este the same type of modest downward-arching jet is repeated in impressive numbers in the Avenue of a Hundred Fountains. (There are also vertical jets.) The nozzles here are on two levels: each row pours into a long trough. Antoine-Joseph Dezallier, an eighteenth-century writer on gardening, says that French *fontainiers* refer dismissively to these little spouts – so common, he says, in Italian and Spanish gardens – as *pissotières*.[36]

We have already seen examples of chalice fountains. Designers can control the ways in which the water flows over the rims of the bowls to achieve different effects.[37] If the water moves slowly and the stone edge is smooth, the result can be to create an unbroken sheet of free-falling water or *nappe* (French: tablecloth). A groove or 'drip' just under the rim serves to separate the flow from the bowl. A perfect *nappe*, however, is difficult to achieve. Alternatively, by shaping the profile of the bowl's rim and omitting the drip, the overflowing water can be made to cling to the stonework and run over the edge and down the supporting structure. By contrast, a flow that goes rapidly over an edge can break into frantically changing splashing patterns, with the air caught up in the turbulence turning the water white.

Another option for the rim of a bowl is to give it corrugations so that the water spilling over divides into a series of vertical columns. As the modern fountain designer Craig S. Campbell describes: 'fluted, drilled, or notched edges will break the falling water into separate streams that offer a rhythmic pattern of light and dark, with the light reflecting off the individual streams'.[38] In Renaissance fountains this happens where basins are made in the shape of giant scallop shells. Bernini's Triton Fountain in the Piazza Barberini in Rome provides an example (Figure 5.16).[39] A similar but less regular pattern can develop over time as a smooth rim becomes damaged or encrusted with moss and lichen.

Some of the most delightful visual effects are achieved by making falling water crash onto rocks or into pools, or by making 'streams' run

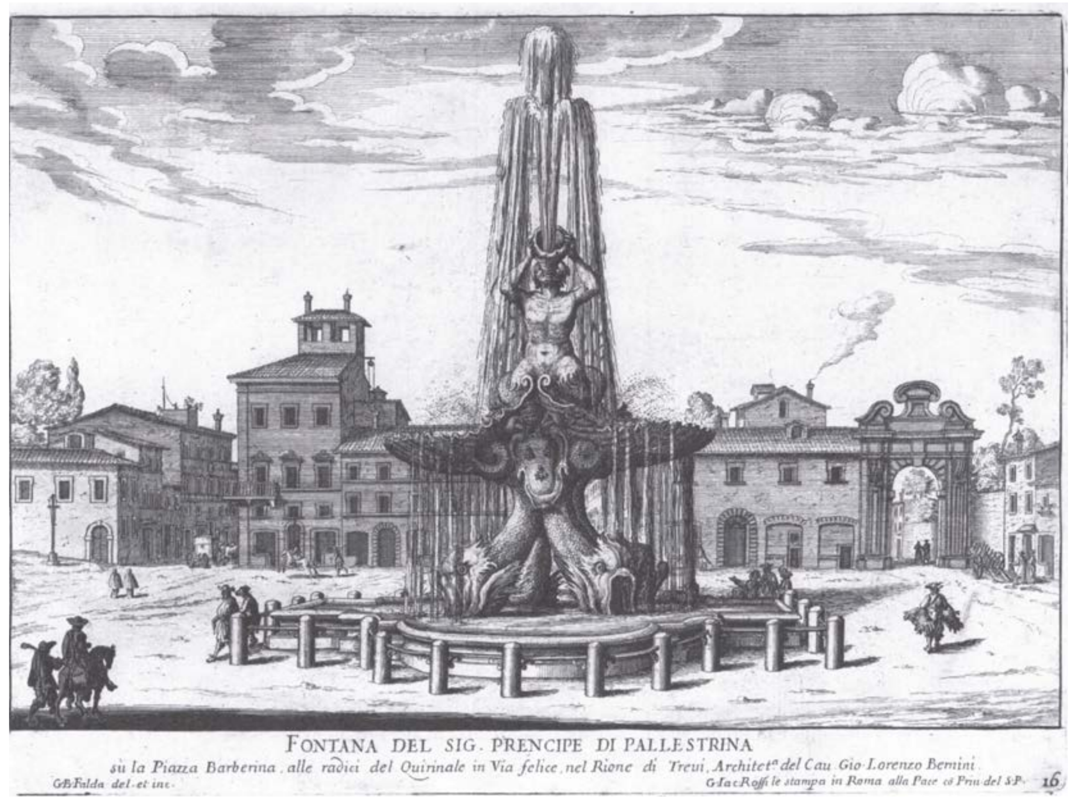

Figure 5.16 The Triton fountain in the Piazza Barberini in Rome, designed by Gian Lorenzo Bernini, c.1642–3. Water falls in columns from indentations in the rim of the scallop shell bowl. Engraving by Giovanni Battista Falda.

over corrugated surfaces such as rough beds of pebbles, so that the water ripples and glitters. All this generates a corresponding repertoire of musical effects. In a letter of 1543 a Sienese writer Claudio Tolomei lists some of the sights and sounds of the 'newly rediscovered ingenious art of making fountains':

> one sees some broken waters that splash downwards among the roughness of the rocks, dividing in several parts, turning white and making a sweet sound; while others fall softly into the gaps between stones, like a river in its bed, making a little murmur. Others rise up into the air as jets, and then when they lose the force to go higher, fall back, and in falling back divide, break into many droplets and descend to earth in the softest of rains, like the

> tears of lovers. Others, carried through the finest of tubes, emerge from numerous orifices on all sides, and falling in the fountain produce the sweetest water music.[40]
>
> So waters are broken, others flowing, those spurting, these whispering, one bubbling, another trembling; and I believe that in the future the art will progress so far, that to these will be added sweating, falls of dew, bladders, gurglings, and many other types.[41]

In Chapter 4 we saw Aleòtti's automaton for an entrance to a garden, with soldiers shooting water and making sounds of gunfire (Figure 4.23). Montaigne described fountains that he visited on his Italian travels giving out similar blasts 'as of cannon shots; elsewhere a more frequent smaller noise as of harquebus shots. This is done by a sudden fall of water into channels; and the air, labouring at the same time to get out, engenders this noise.'[42] Such loud bangs are caused by what would today be called 'water hammer', when a stream of water in a pipe is brought to a sudden halt. As well as gunfire, Renaissance designers used the effect to simulate thunder or the roaring of dragons, as in the Fountain of the Dragons at Tivoli.

Water was directed down steeply sloping surfaces in the Renaissance garden in the 'water staircase'. Where water was plentiful this could take the form of a series of alternating small cascades and pools stepped down a hill, as at the Villa Aldobrandini at Frascati, whose gardens were designed and constructed over 20 years at the start of the seventeenth century by Carlo Maderno and (a different) Giovanni Fontana.[43] Falda depicts this water staircase in Figure 5.17. We see two barley-sugar columns at the summit of the stairs, with jets on top. Water from these jets swirls down the helical channels wrapped around the shafts of the columns and passes on to the cascades. There are staircases for people on either side of the water staircase, with balustrades that consist of series of shallow basins linked one to the next, down which water also moves. Notice the fountain in the foreground of this view in the shape of an eight-pointed star with jets issuing from all eight points.

Water staircases in Italian villas owe a debt to the Moorish gardens of the Generalife Palace in Granada, which date from the fourteenth century.[44] At the Generalife there is a staircase down which people can walk; on the landings there are fountains in basins. Water also runs down channels in the balustrades, which are made from inverted pantiles set in cement. The Venetian ambassador to Spain Andrea Navagero visited Granada and wrote an account of the Generalife's gardens.[45] This was published in Italy in 1563, and Navagero's description is likely to have

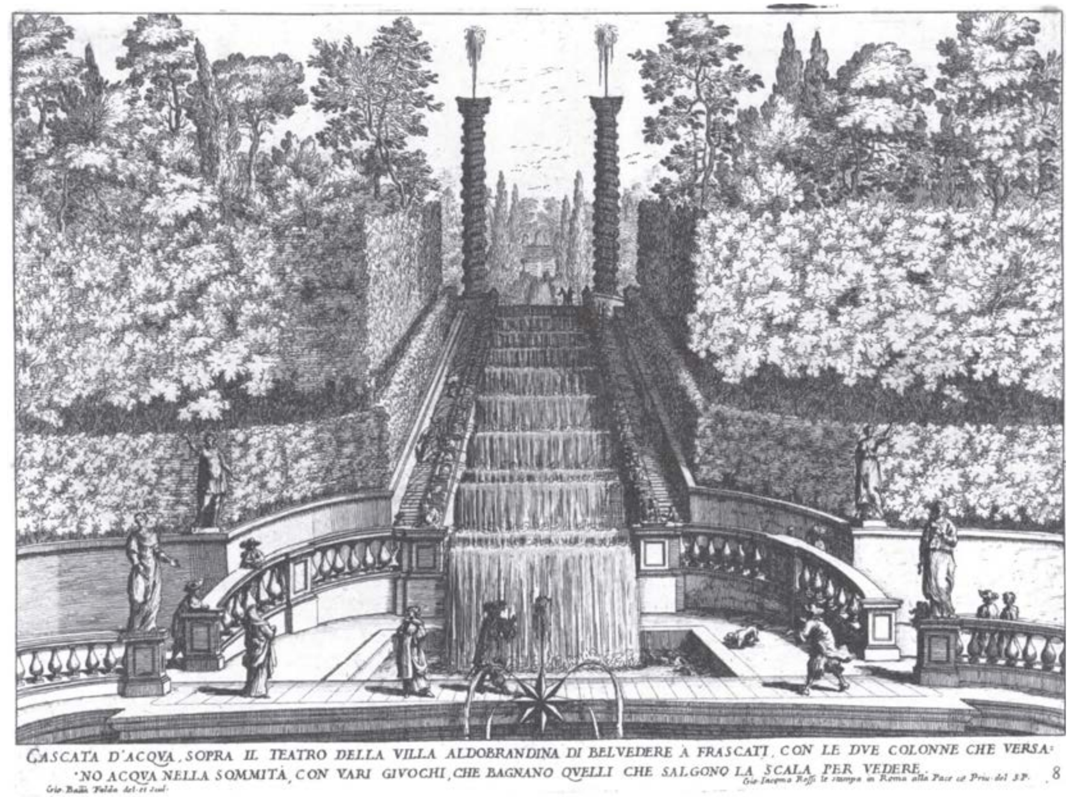

Figure 5.17 Water staircase with pools and cascades at the Villa Aldobrandini in Frascati, early seventeenth century. Visitors climbing the steps on either side are trying to avoid being squirted by 'water jokes'. Engraving by Giovanni Battista Falda.

inspired the design of water staircases at the Villa d'Este, whose gardens were then being planned. The arrangement of the Stairs of the Bubbling Fountains at Tivoli is directly comparable with the Generalife, if more refined in execution. Each has a (dry) flight of stairs, flanked by many small jets in square boxes alternating with little oval pools. The water bubbles from one container to the next. Other staircases flanking the Fountain of the Dragons also had water flowing in their balustrades.

Another comparable type of garden feature using smaller quantities of water was the *catena d'acqua* or 'water chain'. This was a series of shallow interconnecting bowls or trays in line, stepped down an incline, perhaps with (dry) staircases or grassy slopes on either side. Figure 5.18 shows the *catena d'acqua* at the gardens of the Villa Lante at Bagnaia.

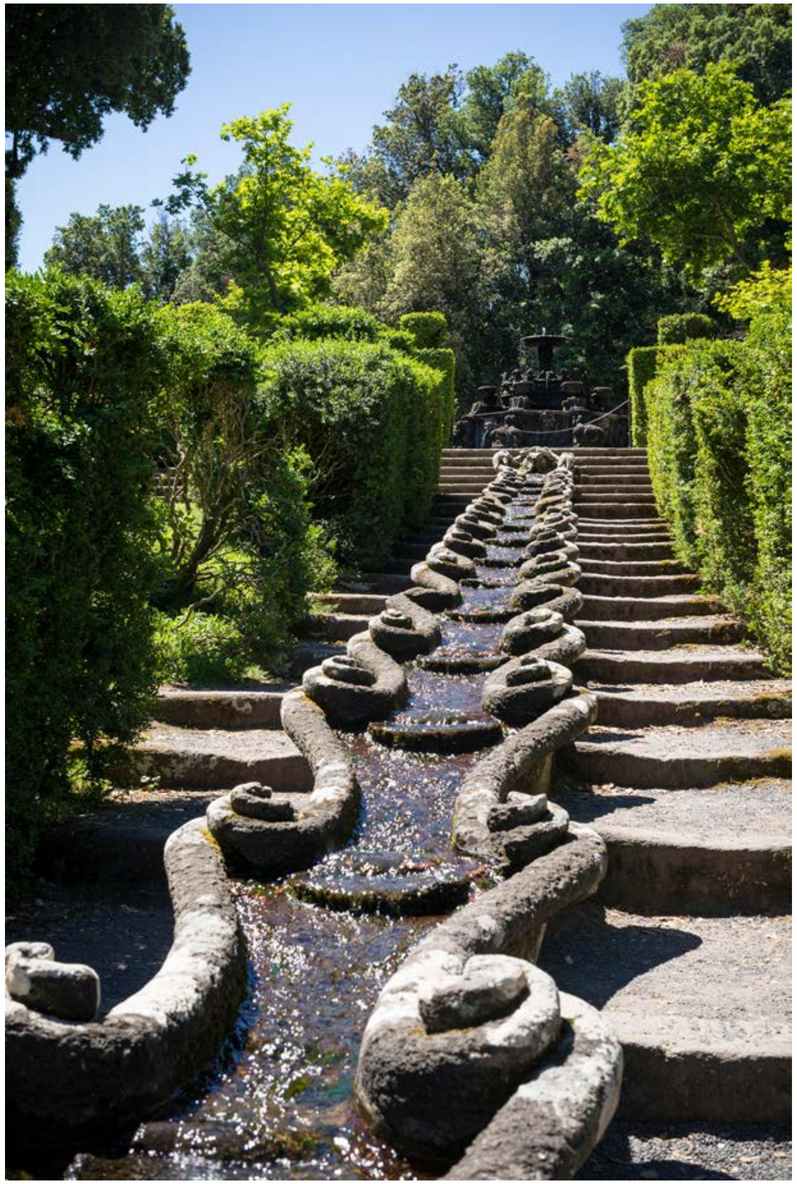

Figure 5.18 The *catena d'acqua* (water chain) at the gardens of the Villa Lante at Bagnaia. The water engineer and fountain designer was Tommaso Ghinucci of Siena. Photo: Alamy.

Figure 5.19 The Piazza Navona in Rome, flooded to create an improvised 'lake'. At the centre is Bernini's Fountain of the Four Rivers with its granite obelisk. Painting by Giovanni Paolo Panini, 1756. Photo: Alamy.

On occasion temporary 'fountains' could be improvised. From the mid-seventeenth century the quantities of water available from the Acqua Paola aqueduct in Rome were so great that, in the heat of the Roman summer, the residents of the Piazza Navona stopped up the drains and flooded the entire square to the depth of a couple of feet. Guests were invited to visit this 'Lago di Piazza Navona' and take supper on the balconies overlooking the lake, while the nobility drove their carriages through the water (Figure 5.19).

Bernardo Buontalenti engineered a similar temporary 'lake' in the courtyard of the Pitti Palace in Florence in May 1589, as part of the same marriage celebrations for which *La Pellegrina* and its *intermezzi* were presented.[46] The purpose was to stage a mock naval battle or *naumachia* between Christians and Turks, of a kind that the ancient Romans put on in the Colosseum. Buontalenti had the walls of the courtyard waterproofed and filled it with water to a depth of a couple of metres. Christian and Turkish ships completely filled the lake, and spectators packed the balconies. There was scenery representing a Turkish castle, and the court was roofed with red cloth.

Giuseppe Pavoni described the sequence of events in his diary.[47] The battle was unevenly matched, with 18 Christian ships and more than a hundred Christian knights against four Turkish galleys and just 14 defenders of the castle. Buontalenti deployed all his skills in pyrotechnics. The Christians launched a bombardment with mortar shells; fireworks burned in the water; there was shouting (in Turkish by the 'Turks') and the sound of trumpets, drums, bagpipes and cymbals. The courtyard filled with smoke. The Christians stormed the fortress and raised their own flag.

We saw how some ancient Roman fountains were made to weep or sweat. At the Villa d'Este two versions of the Meta Sudans, the 'sweaty turning post', were planned for the lower gardens, although they were only finally installed in the seventeenth century. These are not cones like the original, however, but squat ungainly mounds on thick legs whose surfaces are now green with moss and weed. They are built from a variety of travertine marble known as *spugna* (Italian: sponge), which has a porous texture through which the waters of the fountains permeate. In the late sixteenth century, other fountains in the gardens of the great Roman and Florentine villas began to retreat under cover into grottoes. The walls of the grottoes were lined with different kinds of spongy rock, and water was made to seep through, as in the Meta Sudans.

Fountains go indoors in grottoes

The Renaissance grotto was an artificial cave dug into a hillside or constructed within a special-purpose garden building, perhaps disguised externally as a small hill.[48] It carried several layers of reference: to the sacred caves of the ancient world; to the underground chambers of those Roman ruins in which excavations had revealed wall paintings and 'grotesque' decorations, as at Hadrian's Villa near Tivoli; and to the natural caves of the Italian coast. In terms of the four elements, grottoes were places where water from the sea, heated by the sun, was imagined to pass through earth on its way to springs and streams.

Internally the artificial grotto might be given a cavernous form with curving walls and an irregularly domed ceiling. On occasion the structure was deliberately designed to appear as if it was about to collapse. The walls and ceiling were always lined with lumps of some sort of porous rock, either *spugna* (otherwise known as *tartaro*), as in the Meta Sudans; the closely related calcareous *tufa* formed in rivers or springs by mineral-rich waters; or volcanic *pumice* of the kind found around Mount Vesuvius. These rough, knobbly surfaces were then further embellished with seashells, corals, mother-of-pearl and other materials associated with the sea, formed into decorative patterns, pictures or even sculpted figures.

Grotto-like structures were also created as large niches or apses, either indoors in otherwise conventional rooms or in the exterior walls of buildings or garden terraces. There were niches of this kind in the gardens of the Villa d'Este, including one housing a statue of Jupiter, behind the Fountain of the Dragons, whose surface was always dripping wet.[49] This must have been achieved with narrow pipes supplying water from behind the rock.

In Greek mythology grottoes were the haunt of nymphs: minor goddesses of seductive beauty, associated with woods, rivers and springs. Nymphs were celebrated in the ancient Roman nymphaeum, which was a building containing fountains but whose exact purpose remains unclear; it may have served as a museum of sculpture or a theatre. The nymphaeum was recreated in the Renaissance, notably at the Villa Giulia in Rome, where there are fountains, statuary, a lily pond and a grotto with windowless rooms. Like nymphaea, grottoes were cool moist retreats from the summer sun, secluded places for meditation, conversation, dining and informal unbuttoned pleasures. Their fountains could be conveniently supplied with water from cisterns above.

One of the best-known surviving Renaissance grottoes is the Grotta Grande in the Boboli Gardens in Florence, designed by Bernardo Buontalenti and constructed between 1583 and 1593. Set against the encrusted walls of the interior are tableaux featuring human and animal figures made from *spugna* (Figure 5.20). The Grotta houses Michelangelo's four statues of slaves – not as incongruous as might at first seem, given the way these figures are still partly locked into the rock from which they are carved. (The originals are now in the Accademia Gallery in Florence; the statues in the Grotta today are copies.) Buontalenti brought in a little daylight through an oculus in the roof. In this he set a large clear glass fishbowl filled with water containing live fish, through which the light from above filtered and flickered, giving the impression of being in a cavern beneath the sea.

For our story, the grotto is the place where in the late Renaissance the histories of fountains and automata converge. Machinery for automata

Figure 5.20 Interior of the Grotta Grande in the Boboli Gardens in Florence, designed by Bernardo Buontalenti and built between 1583 and 1593. The trees, the figure of the shepherd and his sheep are all covered with the spongy stone called *spugna*. The marble statue embedded in the wall is one of Michelangelo's slaves. Wikimedia Commons, Grotta del buontalenti, prima sala 00 photo by Sailko.

could be hidden behind a grotto's walls. The fragile mechanisms, as well as the delicate painted decoration and shellwork, could be protected from the winter weather – although the constant moisture could still be damaging. Salomon de Caus is one of the key figures in bringing automata and grottoes together. Another is Buontalenti. In the early years of the seventeenth century de Caus built hydraulic machines and fountains for grand estates in Belgium, England and Germany.[50] On his Italian travels he visited the gardens at Pratolino and elsewhere.[51] Among the later 'Problems' in *Moving Forces* he offers a number of designs for fountains and animated figures to be installed in grottoes, some heavily inspired by the examples he had seen in Italy. These take advantage of the flow of water to the grotto fountains to provide power to the machinery.

Figure 5.21 shows a design by de Caus for a 'Machine in which is represented a Neptune, who turns in a circle around a rock, with several

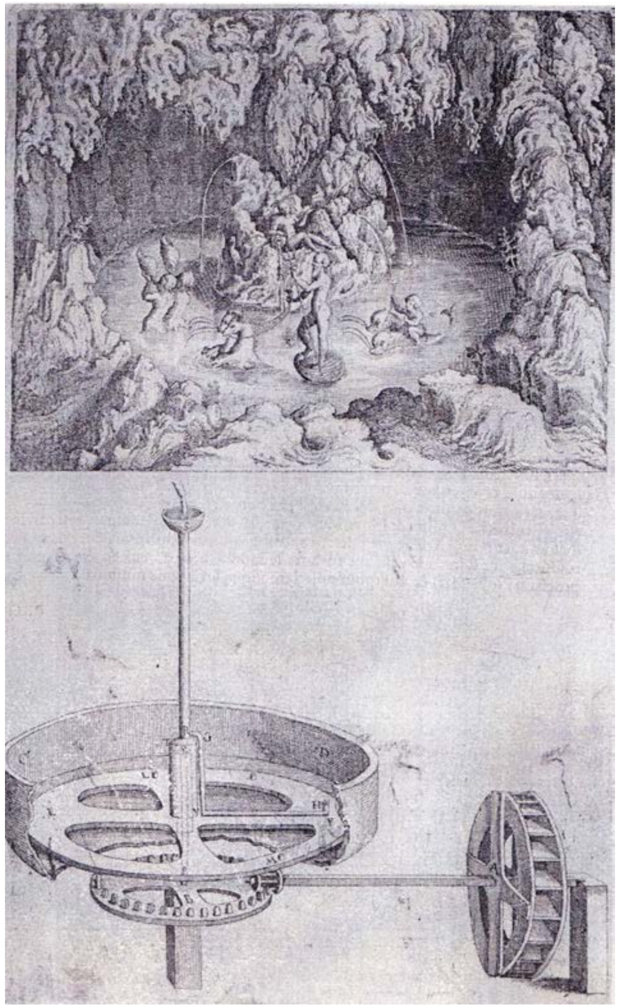

Figure 5.21 Fountain and automata in a grotto designed by Salomon de Caus. Neptune, his Tritons and attendant dolphins circle around a pool. The turntable mechanism sunk in the pool is illustrated below. From *Causes of Moving Forces.*

other figures who shoot out water as they turn'.[52] The view seen by the visitor is shown at the top; the mechanism is explained below. Neptune in his shell-boat is pulled by seahorses and accompanied by dolphins and Tritons blowing on conches. The figures ride on a turntable sunk beneath the water of a pool. The turntable is rotated via a system of gearing by a waterwheel (at the right). The water supply to the jets is brought down the hollow vertical shaft and relayed to the various figures by pipes that radiate out from the centre.

In many sixteenth- and seventeenth-century fountains, the water issued from the bodily orifices of animal and human sculptures – and not just their mouths. There are several examples in the work of Salomon de Caus. He and other fountain designers had been provided with strange and novel models by the anonymous publication in 1499 of the hugely popular romance *Hypnerotomachia Poliphili*.[53] The author is now believed to have been Francesco Colonna and the book's title can be translated as *Poliphilo and his Dream of a Struggle for Love*. Poliphilo spends much of the time in his dream wandering through a wood, where – among various pavilions and statues – he comes upon a series of fountains. The book includes many splendid drawings. In one fountain the three Graces, made of gold, pour streams of water from their breasts, 'like rods of refined silver', onto the heads of harpies below.[54]

Another fountain shown in Figure 5.22 is set in a temple carrying the inscription ΓΕΛΟΙΑΣΤΟΣ (Greek: trickster).[55] Two nymphs hold up a little boy, naked below the waist, who pisses cold water into a hot bath to make it tepid. Poliphilo approaches closer to collect some of the water in a vase. 'No sooner had I set one foot on the step to reach the falling water, than the little Priapus lifted his penis and squirted the freezing water in my hot face, so that I fell back instantly on my knees.' Poliphilo immediately understands the mechanical trick: putting one's weight on the step 'raises the child's instrument' to eye level.

Figure 5.22 A fountain design from Francesco Colonna's romance *Hypnerotomachia Poliphili* [*Poliphilo and his Dream of a Struggle for Love*].

Real fountains were not quite so bizarre or made from such lavish materials, but they did employ similar imagery. Statues of naked women did indeed spurt 'milk' from their nipples. De Caus has a design for a grotto in which a mermaid and merman sit in a pool, he holding a fish that pours water from its mouth, she pouring milk from her breasts.[56] At the Villa d'Este there is a statue of the fertility goddess Diana of the Ephesians, spray arching from her many breasts. One regular feature of royal progresses and entries was the provision of public fountains that flowed with wine. For the entry of Charles V into Paris in 1539 a fountain was erected with a statue of a woman personifying Peace spurting red wine from one breast and white wine from the other.[57] At the entry into Avignon of Cardinal Alessandro Farnese in 1553 a fountain, directly inspired by the *Hypnerotomachia*, had statues of the three Graces, but pouring wine and water from their navels.[58]

Figures in fountains really were designed to provide water for bathing. For another of his grottoes de Caus planned a figure metamorphosed into rock, standing in a pool, with water squirting from the top of his head and from the fingers of both hands (Figure 5.23).[59] One hand provides cold water, the other hot. In front is a Moor who pours water from a jug into a basin in which one may wash one's hands.

The garden historian Elisabeth Blair MacDougall says that in the Renaissance antique statues recovered from excavations were drilled with holes to serve in fountains.[60] A restored female figure was pierced to spurt water from her nipples at the Quirinale Palace in the sixteenth century. Another statue treated in this way formed part of a composition of 'Ganymede with a Swan'. According to MacDougall this was 'probably a replica of the Hellenistic statue type of a boy with a goose, a popular decoration in fountains of this period. A payment to the restorer Cioli, which may refer to this statue, speaks of making his "pincerello" so that he could appear to piss.' 'Genre figures', MacDougall says, 'such as the *putto mingens* [Latin: urinating cherub] were known very early.'[61]

Shaping the spray issuing from nozzles

When John Evelyn visited gardens in Italy, something that specially intrigued him – as mentioned in the Introduction – was how 'jettos' of water could be formed into the shapes of glasses, cups, crowns or fleurs

Figure 5.23 A grotto designed by Salomon de Caus for the Hortus Palatinus in Heidelberg. The figure petrified in the rock supplies water from his fingers, hot from one hand and cold from the other. From *Causes of Moving Forces*.

de lys. How was this done? Designs for fountains with specially shaped jets are found in ancient sources. They are described among other places in a manuscript produced in Baghdad in the ninth century, *The Book of Ingenious Devices*, written by three brothers called the Banū Mūsà (sons of Mūsà).[62] The court of Caliph Al-Ma'mun was a centre of cultural and intellectual brilliance, and the Banū Mūsà were among its leading lights. They worked at the Baghdad 'college of science' known as the House of Wisdom, and had interests in geometry, astronomy, mechanics and music. The House of Wisdom sent emissaries to Byzantium to find and bring back texts by ancient authors, and had translations made into Arabic.

The Book of Ingenious Devices sets out a series of some hundred 'models' with diagrams and explanations.[63] The great majority are cups, vases and other vessels for holding and transferring water or wine, many of them deriving from Philo and Hero. Like their prototypes, these have deceptive and curious properties based on siphons, valves and automatic controls. At the end of the book are eight 'models' for fountains, all variations on one basic idea. The water emerges in jets that are shaped either as simple vertical 'rods' or 'lances', as 'shields' or as 'lilies-of-the-valley'. The Banū Mūsà do not illustrate the shapes, but I imagine the shield would have resembled an inverted shallow cup or a round mushroom cap. I will explain shortly how this was done.

The lily-of-the-valley is more problematic. The real plant has clusters of little bell-shaped blossoms. Did the fountains imitate the shape of one flower or many flowers? The fact that the Banū Mūsà's machinery shows an array of little tubes suggests perhaps the latter. Donald Hill, translator of *The Book of Ingenious Devices*, says that the brothers are not entirely explicit here. Several of the 'models' have means for making more than one kind of jet, the machinery switching periodically and automatically from one shape to another. Philo and Hero have nothing comparable in their *Pneumatics*, and it seems possible that these particular ideas were original to the Banū Mūsà.

Hill says that the Banū Mūsà's works may have passed into Europe, as did other Islamic writings on science and technology, via Spain. I have not found technical descriptions of comparable shaped jets in Renaissance texts earlier than the mid-seventeenth century, even though many working examples are mentioned by travellers such as Montaigne and Evelyn. However, there are some explanations given in an illustrated book published in 1664 by the German engineer Georg Andreas Böckler, who visited Italy, called *Curious New Architecture*.[64] Dezallier covers the subject in the eighteenth century.[65] And since the physics and geometry involved do not change, modern handbooks on fountain design can also throw light on the techniques involved.[66] Most of these effects are created by altering the geometry of the nozzle on a fountain's jet, much as one changes the spray from a garden hose by fitting different attachments.

A plain vertical jet is created with a simple nozzle that narrows into a small round hole at the top. If the stream of water rises very high, it may break up completely into droplets. Another possibility is that water higher up falls back onto the rising column, so that the height of the jet becomes now lower, now taller. If this is not wanted, it can be avoided by setting the pipe at a slight angle to the vertical. If the aperture in the nozzle is formed into a narrow slit, this produces a sheet of water in a flat fan shape. With a smooth enough surface this can act as a mirror. In 1573 Etienne Dupérac engraved a bird's-eye view of the Villa d'Este and its gardens. The key to this picture mentions 'a pavilion with four fountains which spout water in the form of a mirror'.[67]

A French traveller Nicolas Audebert visited Italy from 1574 to 1578 and wrote a journal.[68] In it he mentions a fountain with a statue of Leda and the Swan (the Swan being Jupiter in disguise), which was then also at the Villa d'Este.[69] He describes Leda as holding a vase from which emerged a jet in the form of a sun. This was done by 'having a round sheet of tin in the shape of a sun, applied to the mouth of the vessel without touching it, but sufficiently near that there is left only a little space between … so that the mass of water trying to escape pushes with force against the tin, and is spread out flat all round … and by this means the sun is imitated, which in this context represents Jupiter'.[70] Presumably the tin plate was vertical or near vertical, to create a vertical disc of water issuing from this thin ring-shaped orifice (Figure 5.24a). Georg Böckler gives a picture of a sun fountain (Figure 5.25) that seems to match Audebert's description.[71]

A similar but horizontal ring-shaped opening can be created by placing a horizontal plate over a vertical jet, as in Figure 5.24b. The effect – depending on the water pressure – is to create a thin sheet of water that curves under gravity into the shape of a bell, a mushroom cap or an umbrella. This I suggest is how the Banū Mūsà produced their 'shield'. Figure 5.26 shows an 'umbrella fountain' of this kind designed by Salomon de Caus for the Hortus Palatinus.[72] If instead of a flat plate a conical plug is positioned above the nozzle, again leaving a gap all round (Figure 5.24c), the result will be a sheet in the shape of a trumpet or morning glory flower. Again, Böckler has an illustration (Figure 5.27).[73]

If a nozzle is sunk just below the surface of a pool, the effect is for air to be carried up with the water jet, turning the water white with small bubbles. Many kinds of aerated jets working on this principle are used in modern fountains, but they existed in the Renaissance. Dezallier says that they make jets 'seem bigger and white like snow'.[74] Annibale Caro writing in 1583 describes the effect. Water is piped to a basin where 'it emerges from many holes [beneath the surface], gushes out with force, meets resistance from the water in the pond, and breaking the surface produces beautiful gurgling bubbles, like a natural spring'.[75]

Many small jets can be supplied from one pipe. The pipe can be widened at the end into a flat-topped head with a pattern of slots cut in it – like an attachment for a watering can. Alternatively, a series of small nozzles can be set in the plate, perhaps in a circular pattern. Dezallier shows both options (Figure 5.28).[76] These will produce bouquets of spray or what the French call *gerbes* (wheatsheaves). Another option shown at letter *I* in Dezallier's figure is to split the water flow between two concentric pipes, with the water supplied to them at different pressures. The central jet will then rise higher than the jets from the surrounding ring of small nozzles. Dezallier calls this either a *gerbe* or an *aigrette* (a headdress of feathers or flowers).

Dezallier explains how to make what he calls a *bouillon* (bubble) fountain without a special nozzle but simply by closing the end of a lead pipe into a rounded shape and piercing it with many holes.[77] He does not describe the effect, but I imagine this would produce a sphere of fine spray, something like a dandelion seedhead.

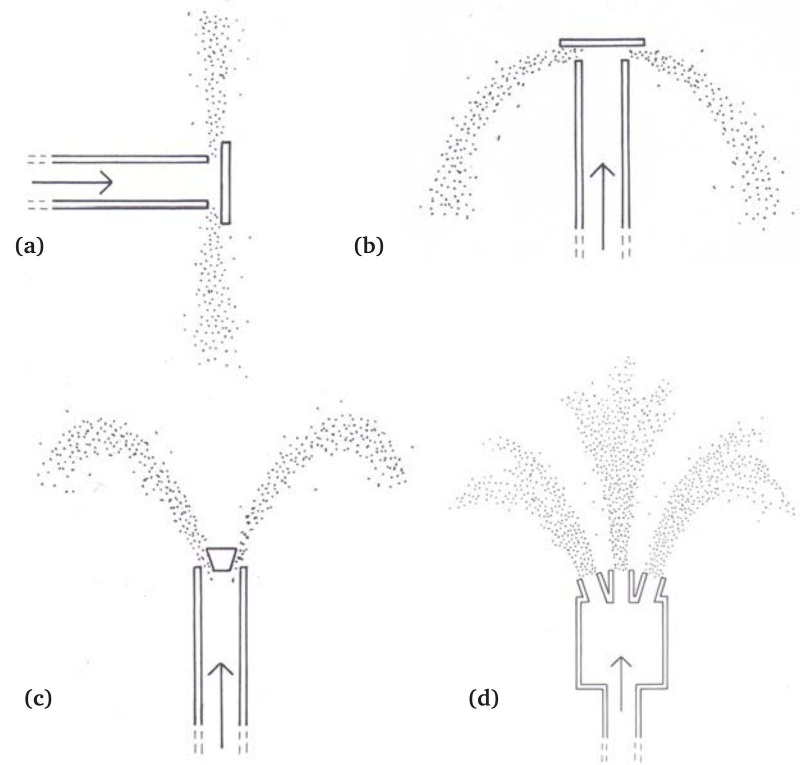

Figure 5.24 Types of attachment and nozzle to produce sprays of water of different shapes: a) A vertical metal disc set against the head of a pipe to produce a 'sun'; (b) as in (a), but with the disc horizontal, producing a 'bell', 'mushroom' or 'umbrella'; (c) a conical plug set in the opening a pipe to produce a 'trumpet' or 'morning glory'; (d) a group of three jets angled to produce a 'fleur-de-lys'.

Figure 5.25 A 'sun' fountain in the form of a vertical disc of water, designed by Georg Böckler, presumably produced with an attachment as in Figure 5.24a. From *New and Curious Architecture*.

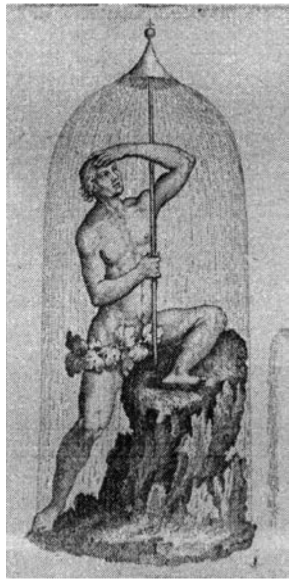

Figure 5.26 An 'umbrella' fountain designed by Salomon de Caus for the Hortus Palatinus in Heidelberg, presumably produced with a disc attachment as in Figure 5.24b. From *Causes of Moving Forces*.

Figure 5.27 A 'morning glory' or 'trumpet' fountain designed by Georg Böckler, presumably produced with a conical plug attachment as in Figure 5.24c. From *New and Curious Architecture*.

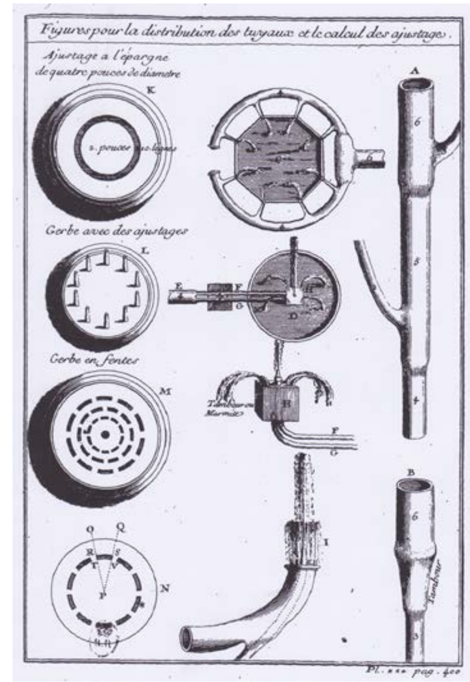

Figure 5.28 Plate from Antoine-Joseph Dezallier d'Argenville's *La Théorie et la Pratique du Jardinage*, showing different ways of making *gerbes* or wheatsheaf sprays: with a ring of nozzles on one head (*L*); with a series of slots in one head (*M*); or with two concentric pipes with several nozzles in the outer ring (*I*).

It is possible to make other patterns by spacing separate pipes and nozzles out at short intervals, say in lines or circles, and angling the jets. For example, at the Villa d'Este there were displays in the shape of fleurs de lys, which feature in the arms of a branch of the Este family.[78] I imagine these might have been made with groups of angled jets in threes as in Figure 5.24d. The openings would be slotted so as to make flat vertical shapes.

If the streams from widely spaced jets set at angles are directed so as to crash in mid-air, they can produce clouds of spray like showers of rain. At the Villa d'Este, thin tubes supported on columns delivered an artificial rain into pools beneath. Nicolas Audebert describes the effects made by these arching jets:

> A rainbow with its spectrum of colours is created very simply by these pipes, by letting the water flow in abundance, thrown out so high that it meets the water from the columns opposite, so making

a semicircle of spray which spreads out in the air; and the sun shines through to make a rainbow – otherwise Iris – just like the real thing.[79]

Montaigne also said of this rainbow at Tivoli that it was 'so marked and so like nature that it in no way falls short of the bow seen in the sky'.[80] Of course the verisimilitude is explained by the fact that the physics of the 'artificial' rainbow are precisely the same as the real rainbow, but the detailed optics were not understood in the sixteenth century.

An allegory of the art of the fountain designer

It is only to be expected that much of the symbolism of Renaissance fountains, as in other periods, should be concentrated on watery and marine themes. In some cases the references are indirect: to the role of water in agriculture as embodied in the person of Pomona, wood nymph turned goddess of fruitful abundance; or the production of wine as personified by Bacchus. In other cases the allusions are more literal. We have seen river gods, seashells, the underwater decoration of grottoes and Neptune with his entourage. Fountains were also designed in the form of boats. Rome has several examples, of which the most unusual is the metal galleon in the Vatican Gardens designed by Jan van Santen. This sails on a pond and shoots water from its cannon, the spray from the jets breaking up into a plausible imitation of smoke.

Are there cases where an entire garden and all its fountains were organised around a single coordinating idea or theme? The question is very vexed and could take us well outside the scope of this chapter. It is made particularly problematic by the fact, as Elisabeth MacDougall emphasises, that 'No written iconographical programs have survived, and indeed there is not much evidence for their existence in the sixteenth century.'[81] As MacDougall points out, essentially the same familiar fountain types were permuted in different combinations in different gardens, suggesting that they were rarely if ever deployed systematically to follow the storyline of some single poem or myth. 'Were there deeper meanings, as many believe there were in the literature and painting decorations of the period? The possibility cannot be excluded, but it seems unlikely.'[82]

Despite MacDougall's doubts, there is one garden I believe that provides an exception. In this instance the unifying theme I would suggest is self-referential: the garden's meaning is to be found in the practical work of the fountain designer and the scientific underpinnings of his art.

No documents of any kind survive relating to the commissioning and design of the Villa Lante and its gardens at Bagnaia, other than a letter from Cardinal Gambara for whom the villa was built, to his colleague Cardinal Farnese at Caprarola, requesting the services of the architect Giacomo Barozzi da Vignola.[83] It is on this slender basis – as well as on stylistic grounds – that the design of the Villa Lante is generally attributed to Vignola. There is no doubt about the identity of the hydraulic engineer: he was Tommaso Ghinucci of Siena. Otherwise historians have only the gardens themselves – which remain largely unchanged – from which to interpret what iconographical meanings, if any, Gambara, Vignola and Ghinucci might have had in mind.

The gardens were begun in around 1568 and are divided into two very different parts. On one side is a *barco*, a wooded hillside once reserved for hunting, which has separate fountains scattered among the trees. Next to the *barco* are formal gardens, shown in Figure 5.29 in Maya Reiner's bird's-eye view.[84] Here the entire layout is symmetrical, with a series of terraces stepping down the hill, disposed about a central axis.[85] There are even two symmetrical casinos – not just one villa building – although these were built at widely separated dates. We can take an imaginary tour, climbing up through the *barco* and descending again through the formal gardens from the top.

Some of the fountains originally in the *barco* have disappeared, but they included a Fountain of the Acorns, a Fountain of the Unicorn and a Fountain of Bacchus, plus others featuring dragons, ducks and a beaver. There is a Fountain of Parnassus, still standing today, which does not, however, take the form of a little hill: here the Muses are set in niches in a curving wall behind a pool with Pegasus at its centre. David Coffin and Claudia Lazzaro-Bruno have argued that what connects these fountains thematically is an evocation of the Golden Age before the destruction of the Deluge.[86] In those days, men lived on acorns and honey, and according to Virgil the rivers flowed with wine. Dragons, who never slept, guarded this paradise. Life was peaceful, pure and untainted. 'It was believed that unicorns could purify water of poison with their horns.'[87] All this seems convincing, although it is hard to bring the other assorted animals into this scheme.

Moving across to the formal gardens, at the very top of the hill is the Grotto of the Flood, where water emerges from the rocks. On

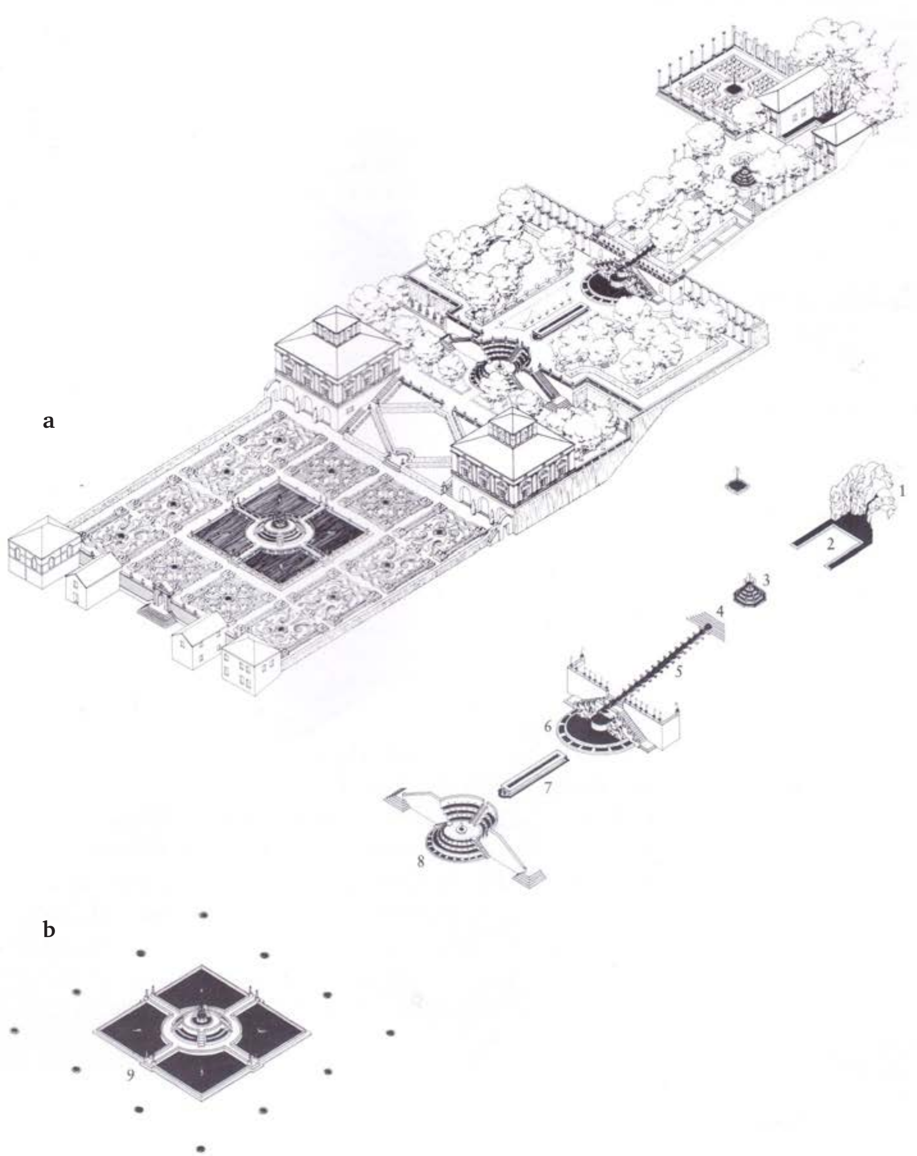

Figure 5.29 Bird's-eye (isometric) view of the formal gardens at the Villa Lante at Bagnaia, drawn by Maya Reiner: (a) the gardens as a whole; (b) the fountains and pools shown separately – 1) Grotto of the Flood, 2) lawn between the Houses of the Muses, 3) Dolphin Fountain, 4) cascade, 5) *catena d'acqua*, 6) fountain with river gods and statues of Pomona and Flora, 7) Cardinal Gambara's dining table, 8) *Cavea* or Fountain of the Lights, 9) Parterres and pools with boats. The architect is thought to have been Giacomo Baruzzi da Vignola and the hydraulic engineer was Tommaso Ghinucci. By kind permission of Maya Reiner.

either side are two pavilions, the Rooms of the Muses, who are depicted in murals in the interiors. Small pipes run under the eaves of these buildings, punctured with small holes from which thin arcs of water gently fall. Next in sequence down the hill is a chalice fountain in an octagonal pool, the Fountain of the Dolphins. This was originally covered with a wooden canopy that was sculpted and painted to look like coral.

Running down the slope from this level is a *catena d'acqua*, a water chain, with the head and claws of a crayfish at the top and its legs at the bottom (Figure 5.18). This is a pun on the name of Cardinal Gambara whose arms sported a crayfish (Italian: *gambero*). The water chain flows on into a semicircular pool flanked by river gods representing the Tiber and the Arno. In two niches are statues of Flora and Pomona, goddesses of flowers and fruit. In front is a grassy terrace.

The water from the pool reappears at the centre of this lawn, running in a channel down the centre of a long stone table (Figure 5.30). This is where the cardinal would have entertained his guests to al fresco meals. Bottles of wine would have been set to cool in the trough of water, and dishes laden with food could have been floated along. This table perhaps had its inspiration in a description by the classical writer Pliny the Younger in his *Letters* of a dining room at his Tuscan villa. This

Figure 5.30 Cardinal Gambara's stone dining table at the Villa Lante, with water running down the centre. Either side of the cascade beyond are the gods of the Tiber and the Arno. Wikimedia Commons: Jardins da Villa Lante en Bagnaia.

Figure 5.31 The *Cavea* or Fountain of the Lights at the Villa Lante, with jets to imitate the flames of lamps. Photo: Charles Latham/Country Life Picture Library.

had a 'graceful marble basin' on which the lighter dishes 'formed into the shapes of little boats and birds, float on the surface and travel round and round'.[88]

The outdoor dining room is separated from the next terrace by a fountain known either as the *Cavea* (auditorium) or the Fountain of the Lights. It has a series of semicircular steps like theatre benches, along which are set out many small jets issuing from cups in the form of Roman oil lamps (Figure 5.31). Finally, at the foot of the garden is a formal layout of parterres in squares surrounding four square pools, each with a stone boat 'floating' in the middle (Figure 5.32). Originally there were three human figures in each boat, trumpeters and arquebusiers, all of them shooting water from their instruments and firearms. At the very centre was a *guglia sudante*, a 'sweating obelisk', modelled closely after the Meta Sudans. According to Montaigne, this had jets that rose in height while others diminished.[89] Perhaps they were controlled by mechanisms similar to those on the Banū Mūsà's fountains.

Both Coffin and Lazzaro-Bruno identify the theme of the formal gardens as the relationship between nature and art. This can hardly be

Figure 5.32 Parterres and pools at the Villa Lante, with figures in boats. Originally there was a *guglia sudante* or 'sweating obelisk' at the centre. Wikimedia Commons: Bagnaia Villa Lante 06.

argued with. Many features of the layout can certainly be seen in these terms, including some subtle touches. For instance, the formal gardens are surrounded by wild woods, in which the nearest trees become organised into lines, which are in turn picked up in lines of classical columns, transforming nature by stages into art. But this broad idea does not get us very much further, since almost all gardens could be given this interpretation.

I see the gardens of the Villa Lante rather as a masterclass in the fountain designer's art. There are three interlocking themes, the first of which is the variety of possible forms of fountain. There is an example here of almost every standard type that we have seen so far. There is a Parnassus, a cascade, a grotto, a chalice, a *catena d'acqua*, river gods, a *meta sudans* and boats floating in pools. This catalogue of archetypal fountains is connected by two larger meditations on the nature of water. The first has to do with water as one of the four elements; the second with the long route that water takes through the world. These after all are the subjects with which two leading seventeenth-century texts on fountains and hydraulics – those of de Caus and Fontana – begin.

The element of Water combines with Air to create water vapour, clouds and rain. This is the meaning of the 'rain' that falls from the roofs of the Rooms of the Muses at the top of the hill. Water, as rain or carried by streams and rivers, mixes with Earth to create the damp fertile soil in which plants and flowers flourish and can be cultivated in the warming Fire of the sun. This is why the two ancient Etruscan river gods preside over the central grassy terrace, along with Pomona and Flora. The cardinal enjoys the fruits of the earth conferred by these goddesses, as well as the pleasures of wine, here at his dining table. Finally, Water is transformed into Fire in the Fountain of the Lights. The little jets glitter in the light 'like silver candles in a chandelier', as Curzio Ardizio described them in 1598.[90] Perhaps their drifting spray might be imagined as smoke.

At the same time the movement of the water through the gardens from the top of the hill to the bottom reproduces the movement of water from the mountains to the sea, finding its own level. Rain at the very highest point, from the roofs of the Rooms of the Muses, collects into a stream that gathers strength and speeds down the water chain, and by the middle terrace has become a river – either the Tiber or the Arno. This river finally reaches the sea of pools in the lowest parterres, with their complement of boats.

There is one apparent difficulty in this neat picture, which is the Fountain of the Dolphins near the top of the hill, between the 'rain' and the 'stream'. With its marine creatures and coral decorations, there can be no doubt of the association of this fountain with the sea. This seems to be out of place. There are I believe two explanations. The Flood brought the Golden Age to an end; and it is the Grotto of the Flood that separates the two parts of the gardens at the Villa Lante. The wooded park, the *barco*, corresponds to the Golden Age, the formal gardens to the Ages that followed. The Fountain of the Dolphins is part of the drama of the Flood. Ovid in the *Metamorphoses* says that during the Deluge the sea rose and 'dolphins took possession of the woods, and dashed against high branches, shaking the oak trees as they knocked against them'.[91]

But there is a second meaning relating to water's journey through the world. Classical philosophers knew that water was evaporated from the sea by the heat of the sun and was carried in clouds to fall as rain on high ground. But, living in the drier parts of Europe, they could not believe that this was sufficient to supply the flow of all streams and rivers. They did not, that is to say, believe in the completeness of what today is called the hydrological cycle.[92] They imagined that, as well as rain, water was somehow channelled directly through the earth from the sea to the high slopes of mountains. Fontana explains this supposed mechanism: solar heat penetrates underground and drives water vapour upwards to grottoes, caverns and the bowels of the earth. 'The cold of those places condenses the vapours and turns them into torrents.'[93] So this is why, in Fontana's world view, we find seawater rising through the earth to grottoes and springs at the tops of hills, as it does metaphorically at the Villa Lante.

Notes

1 H. V. Morton, *The Fountains of Rome* (London: The Connoisseur and Michael Joseph, 1970); first published as *The Waters of Rome* (1966), p. 151.
2 Morton, *Fountains of Rome*, pp. 202–5.
3 Morton, *Fountains of Rome*, p. 47.
4 A number of these are discussed, with illustrations, in Marco Dezzi Bardeschi, 'Le Fonti degli Automi di Pratolino' and Alessandro Vezzosi, 'Pratolino d'Avanguardie *Fonti d'Ingegni Stupori e Controveleni*', in Alessandro Vezzosi (ed.), *La Fonte delle Fonti: Iconologia degli Artifizi d'Acqua* (Florence: Alinea, 1985), pp. 13–24 and 49–67. Giovanni Fontana, *Bellicorum instrumentorum liber cum figuris*, ms c.1420, Bavarian State Library, BSB Cod.icon.242, f.37r, includes several intriguing pictures of what seem to be small or table fountains (22v/23r, 28v, 31r, 46v/47r, 59v/59r, 62v/63r), some derived directly from the Islamic scholar Al-Kindi. But, disappointingly, he refers readers for explanations to Al-Kindi (whose manuscript is lost), or reverts to writing gobbledegook, perhaps to protect his own inventions.
5 Leonardo da Vinci, Royal Collection Windsor, RCIN 912690 and RCIN 912691, c.1512.
6 There is no modern book to my knowledge on the technicalities of Renaissance fountains. However, a few details are to be found scattered in a number of works on garden history, in particular Elisabeth Blair MacDougall's two edited volumes, *Fons Sapientiae: Renaissance Garden Fountains* and *Fountains, Statues and Flowers* (Washington, DC: Dumbarton Oaks Research Library and Collection, for Harvard University Press, 1978 and 1994); and John Dixon Hunt's *Garden and Grove: The Italian Renaissance Garden in the English Imagination 1600–1750* (Princeton, NJ: Princeton University Press, 1986). A nice general history with many illustrations is given by Marilyn Simmes (ed.), *Fountains, Splash and Spectacle: Water and Design from the Renaissance to the Present* (New York: Rizzoli, 1998).
7 A rare example of a pump used to provide water to a sixteenth-century fountain is described by Katherine Rinne in *The Waters of Rome: Aqueducts, Fountains and the Birth of the Baroque City* (New Haven, CT, and London: Yale University Press, 2010), pp. 111–15. This was a Parnassus fountain in the gardens of Cardinal Ricci. The pump was driven by a waterwheel in the flow of an aqueduct, the Acqua Vergine.
8 Mariano di Jacopo (Il Taccola), *Liber tertius de ingeneis ac edifitiis non usitatis*, Codice Palatino 766 folio 2v, Biblioteca Nazionale, Florence, fifteenth century: facsimile version ed. J. H. Beck (Milan: Il Polifilo, 1969).
9 A brief overview of the principles of fluid mechanics as they relate to fountain design, and of the evolution of the understanding of hydraulics in the Renaissance, is given by

Craig S. Campbell, *Water in Landscape Architecture* (New York: Van Nostrand Reinhold, 1978), pp. 71–3.

10 Salomon de Caus, *Les Raisons des Forces Mouvantes, Avec diverse Machines tant utiles que plaisantes; Ausquelles sont adjoints plusieurs desseins de Grotes & Fontaines* (Paris: Hierosme Droüart, 1624). The book is only paginated in part, and by spreads, so my references are to the numbering of the 'Problems'. These numbers start again in each of the three Books.)

11 Carlo Fontana, *Utilissimo Trattato dell' Acque Correnti*, 2 vols (Rome: Gio. Francesco Buagni, 1696). Marisa Tabarrini has shown that Fontana's book owes a large debt to a manuscript of 1642 by Vincenzo della Greca: see 'An Unpublished Treatise on Waters by Vincenzo della Greca: A Source of Carlo Fontana's "Utilissimo Trattato Delle Acque Correnti"', in Robert Carvais et al. (eds), *Nuts and Bolts of Construction History*, vol. 1 (Paris: Picard, 2012), pp. 629–34.

12 Fontana, *Acque Correnti*, p. 3.

13 Fontana, *Acque Correnti*, p. 3.

14 *The Pneumatics of Hero of Alexandria* (London: MacDonald, and New York: Elsevier, 1971): facsimile of edition by Bennet Woodcroft (London: Taylor, Walton and Maberly, 1851) Theorem 42, p. 65.

15 De Caus, *Forces Mouvantes*, Book I, Problem IX.

16 De Caus, *Forces Mouvantes*, Book I, Problems XIII, XIIII and XV.

17 *Pneumatics of Hero*, Theorem 47, p. 69.

18 Leonardo da Vinci, *Codex Atlanticus*, folio 1113, r,v.

19 De Caus, *Forces Mouvantes*, Book I, Problem XIII. Figure 5.4 shows Book I, Problem XV.

20 *Pneumatics of Hero,* Theorem 44, p. 67.

21 Leon Battista Alberti, *Ex ludis rerum mathematicarum*, ms written 1450–2, Biblioteca Nazionale, Florence; English translation in Kim Williams (ed.), *The Mathematical Works of Leon Battista Alberti* (Basel: Birkhäuser, 2010), pp. 9–140; see pp. 26–9.

22 Leonardo da Vinci, Madrid MS I, c.1497–1500, f.115r. This page of the digital version of the Codex online (leonardo.bne.es) at the National Library of Spain links to a nice video animation of the fountain in action.

23 Heinrich Schickhardt, *Zweite italienische Reise*, ms1600, Cod. Hist. 4, 148; Württembergische Landesbibliothek, Stuttgart. There are four notebooks. This drawing is in the book digitised as Zweite Reise_urn_nbn_de_bsz_24-bsz3114809777, sheet 71r.

24 Benvenuto Cellini, bronze table fountain in the form of a statue of Perseus with the head of Medusa, 1540s: Museo Nazionale del Bargello, Florence.

25 Fontana, *Acque Correnti*, p. 89.

26 Fontana, *Acque Correnti*, p. 105.

27 Giovanni Battista Falda, *Le Fontane di Roma* (Rome: Gio. Giacomo de Rossi, 1691). Different sources give different publication dates, including 1675. The book is a collection of engravings. Those in Parts 1 and 2 are by Giovanni Battista Falda; those of the Roman villas in Part 3 and the Villa d'Este in Part 4 by Giovanni Francesco Venturini. Falda's work is discussed by Maurizio Gargano, 'Villas, Gardens and Fountains of Rome: The Etchings of Giovanni Battista Falda', in Monique Mosser and Georges Teyssot (eds), *The History of Garden Design: The Western Tradition from the Renaissance to the Present Day* (London: Thames and Hudson, 1991), pp. 166–8.

28 Hero, *Dioptra*. The book mentions a lunar eclipse in AD 62, and so can be dated (as can Hero himself) to the first century. Manuscript copies are held in the Austrian National Library in Vienna and the Bibliothèque Nationale in Paris.

29 Vitruvius, *De Architectura* [*The Ten Books on Architecture*], trans. Ingrid D. Rowland (Cambridge: Cambridge University Press, 1999), p. 103; however, Vitruvius gives no description.

30 Giovanni Battista Aleòtti, *Hidrologia*, changed later to *Delle Scienze et dell'Arte del Ben Regolare le Acque*, ms; ed. Massimo Rossi (Ferrara: Franco Cosimo Panini, 2000), p. 714. See also Fabrizio I Apollonio, 'Giovan Battista Aleotti (1546–1636)', in Michela Cigola (ed.), *Distinguished Figures in Descriptive Geometry and Its Applications for Mechanism Science* (Cham: Springer, 2016), pp. 181–200; see pp. 195–6.

31 Bernardo Buontalenti, *Disegni (a penna e acquerelli) d'architettura*, Bibliothèque Nationale, Paris, ms ITAL 1292, p. 17.

32 For general histories and descriptions see David R. Coffin, *The Villa d'Este at Tivoli* (Princeton, NJ: Princeton University Press, 1960), and David Dernie, *The Villa d'Este at Tivoli* (London: AD Academy Editions, 1996).

33 Campbell, *Water in Landscape Architecture*, p. 35. The upper terraces were supplied by an earlier and smaller source in the Rivellese spring.

34 See Claudia Lazzaro-Bruno, 'The Villa Lante at Bagnaia: An Allegory of Art and Nature', *The Art Bulletin*, 59/4 (1977): 553–60; and David R. Coffin, *The Villa in the Life of Renaissance Rome* (Princeton, NJ: Princeton University Press, 1979), pp. 340–60.

35 Carl Lamb, *Die Villa d'Este in Tivoli: Ein Beitrag zur Geschichte der Gartenkunst* (Munich: Prestel Verlag, 1966), p. 39: 'Wasserführung'. It is not clear from Lamb's text what the thicknesses of the lines in the diagram mean; I have made my own interpretation.

36 Antoine-Joseph Dezallier d'Argenville, *La Théorie et la Pratique du Jardinage*, 4th edn (Paris: Pierre-Jean Mariette, 1747), note p. 389. The author is given on the title page only as 'M.*** de l'Académie Royal des Sciences de Montpellier'.

37 See E. Byron McCulley, 'Water – Pools and Fountains', in Jot D. Carpenter (ed.), *Handbook of Landscape Architectural Construction* (Washington, DC: Landscape Architecture Foundation, 1976), pp. 479–98; in particular pp. 488–90.

38 Campbell, *Water in Landscape Architecture*, p. 98.

39 Engraving by Falda, *Fontane di Roma*, Book I, plate 16.

40 Claudio Tolomei, letter to Giambattista Grimaldi, 26 July 1543, quoted in full in MacDougall, *Fons Sapientiae*, Introduction, pp. 12–14; see p. 13. My translation.

41 MacDougall, *Fons Sapientiae*, p. 13. I am uncertain about the word 'bladders' (*veschighe*).

42 Michel de Montaigne, *Journal du Voyage de Michel de Montaigne en Italie, par la Suisse et l'Allemagne, en 1580 et 1581*. English translation by W. G. Waters, 3 vols (London: John Murray, 1903), vol. 2, p. 169. Montaigne describes the gardens at the Villa d'Este in some detail, although he does say that accounts can also be found in books and 'public paintings': see Coffin, *Villa d'Este*, p. 127.

43 Not to be confused with Giovanni Fontana, the fifteenth-century author of *Bellicorum Instrumentorum Liber*.

44 See Charles W. Moore, William J. Mitchell and William Turnbull Jr, *The Poetics of Gardens* (Cambridge, MA: MIT Press, 1988), pp. 195–8, in particular the isometric drawings of the gardens on pp. 196–7.

45 Andrea Navagero, *Il Viaggio fatto in Spagna et in Francia* (Venice: 1563), see p. 20 for mention of the Generalife and its water staircase. For the possible influence on the Villa d'Este, see Coffin, *Villa in the Life*, p. 327.

46 Kevin Salatino, *Incendiary Art: The Representation of Fireworks in Early Modern Europe* (Los Angeles, CA: Getty Research Institute, 1997), p. 45.

47 Giuseppe Pavoni, *Diario descritto delle feste celebrate nelle solennissime nozze delli serenissimi sposi, il. Sig. Don Ferdinando Medici, & la Sig. Donna Christina di Loreno Gran Duchi di Toscana … 15 di Maggio, MDLXXXIX* (Bologna: Giovanni Rossi, 1589), pp. 40–3.

48 For a comprehensive historical account see Naomi Miller, *Heavenly Caves: Reflections on the Garden Grotto* (London: George Allen and Unwin, 1982). For Renaissance grottoes in particular see Philippe Morel, *Les Grottes Maniéristes en Italie au XVIe Siècle* (Paris: Macula, 1998).

49 Dernie, *Villa d'Este*, p. 41.

50 Luke Morgan, *Nature as Model: Salomon de Caus and Early Seventeenth-Century Landscape Design* (Philadelphia: University of Pennsylvania Press, 2007).

51 Morgan, *Nature as Model*, pp. 42–5.

52 De Caus, *Raisons des Forces Mouvantes*, Book I, Problem XXVII. The relevant page here is mislabelled 'Livre second'.

53 Anon. [thought to be Francesco Colonna], *Hypnerotomachia Poliphili* (Venice: Aldus Manutius, 1499); trans. Joscelyn Godwin as *The Strife of Love in a Dream* (London and New York: Thames and Hudson, 1999).

54 Anon., *Hypnerotomachia Poliphili*, pp. 89–90 in Godwin translation. (The original is not paginated.)

55 Anon., *Hypnerotomachia Poliphili*, pp. 84–5 in Godwin translation.

56 De Caus, *Forces Mouvantes*, Book II, Problem I.
57 R. J. Knecht, 'Charles V's Journey through France, 1539–40', in J. R. Mulryne and E. Goldring (eds), *Court Festivals of the European Renaissance: Art, Politics and Performance* (Aldershot: Ashgate, 2002), pp. 153–70; see p. 159.
58 Richard Cooper, 'Court Festival and Triumphal Entries under Henri II', in Mulryne and Golding, *Court Festivals*, pp. 51–75; see p. 59.
59 De Caus, *Forces Mouvantes*, Book II, Problem XXIIII.
60 MacDougall, *Fountains, Statues and Flowers*, p. 30.
61 MacDougall, *Fountains, Statues and Flowers*, p. 65.
62 *The Book of Ingenious Devices* (Kitāb al-Hiyal) by the Banū [sons of] Mūsà bin Shākir, trans. and annotated by Donald R. Hill (Dordrecht: Reidel, 1979), pp. 3–5; also Abdy Williams, *Story of the Organ* (London: Walter Scott, and New York: Scribner's, 1903), p. 87.
63 Banū Mūsà, *Book of Ingenious Devices*.
64 Georg Andreas Böckler, *Architectura Curiosa Nova* (Nuremberg: Impensis Pauli Fürsten, 1664).
65 Dezallier, *Jardinage*, pp. 395–401.
66 Campbell, *Water in Landscape Architecture*, pp. 62–4; McCulley, 'Water – Pools and Fountains', pp. 98–100; C. Douglas Aurand, *Fountains and Pools: Construction Guidelines and Specifications* (Mesa, AZ: PDA Publishers, 1986), pp. 214–17.
67 Coffin, *The Villa d'Este*, p. 37. The fountains were in the enclosed Secret Garden on the east side of the villa.
68 The unsigned manuscript is in the British Library (Lansdowne MS. 720). Audebert stayed at the Villa d'Este in late 1576 or early 1577: see R. W. Lightbown, 'Nicolas Audebert and the Villa d'Este', *Journal of the Warburg and Courtauld Institutes*, 27 (1964): 164–90.
69 The statue is now in the Borghese collection in Rome.
70 Quoted in Lightbown, 'Nicolas Audebert', p. 172: my translation.
71 Böckler, *Architectura Curiosa*, Book 2, Figure 63.
72 De Caus, *Forces Mouvantes*, Book II, Problem XXVIII.
73 Böckler, *Architectura Curiosa*, Book 2, Figure 55.
74 Dezallier, *Jardinage*, p. 398.
75 Quoted in Hervé Brunon, 'Pratolino: art des jardins et imaginaire de la nature dans l'italie de la seconde moitié du XVIe siècle', Doctoral thesis, Paris 1 Panthéon-Sorbonne (2008), p. 858, entry in Glossary under 'Bollore'.
76 Dezallier, *Jardinage*, p. 395 and plate facing p. 400.
77 Dezallier, *Jardinage*, p. 397.
78 In the Oval Fountain: see Coffin, *Villa d'Este*, p. 38.
79 Quoted in Lightbown, 'Nicolas Audebert', p. 183: my translation.
80 Montaigne, *Journal*, vol. 2, p. 170.
81 MacDougall, *Fountains*, p. 89.
82 MacDougall, *Fountains*, p. 125.
83 Coffin, *Villa in the Life*, p. 340.
84 From Moore et al., *Poetics of Gardens*, p. 145.
85 The symmetry is no longer absolutely complete: of two enclosed parterres behind the Rooms of the Muses only one remains.
86 Coffin, *Villa in the Life*, pp. 340–61; Lazzaro-Bruno, 'The Villa Lante': 553–60. See also Bruno Adorni, 'The Villa Lante at Bagnaia', in Mosser and Teyssot (eds), *History of Garden Design*, pp. 91–5.
87 Lazzaro-Bruno, 'The Villa Lante': 555.
88 Pliny the Younger, *Letters*, Book V, Number vi, to Domitius Apollinaris; trans. J. B. Firth (London: Walter Scott, 1900).
89 Montaigne, *Journal*, vol. 3, p. 347. An obelisk mentioned by Montaigne is no longer there. It was replaced by Cardinal Montalto with statues of four youths holding the cardinal's device of three hills.
90 Curzio Ardizio wrote an account of a visit to the Villa Lante by Pope Clement VIII in 1598, when there were fireworks with animals spitting flames, towers on fire and the night turning to a new day: see J. A. F. Orbaan, *Documenti sul Barocco in Roma* (Rome: Biblioteca Valicelliana, 1920), p. 475.
91 Ovid, *Metamorphoses*, trans. Mary M. Innes (Harmondsworth: Penguin, 1955), 'The Flood', p. 37.
92 The idea that streams and rivers are supplied by rain alone is sometimes attributed to Bernard Palissy in the late sixteenth century; but this conception of the complete hydrological cycle was only generally accepted by scientists in the early nineteenth century.
93 Fontana, *Utilissimo Trattato*, p. 11.

Intermezzo: Surprise soakings

One specialised type of fountain that provided much innocent (and not so innocent) fun was the *gioco d'acqua* or water joke. This was a small jet concealed in a pavement or a seat that squirted upwards without warning. Another possibility was for the jet to be hidden in some object or statue in which an unwary visitor might be interested, which would then spray his face and body. Several of the great Italian villas of the sixteenth century featured *giochi d'acqua*, as did gardens elsewhere in Europe. Touring travellers found them most amusing and wrote long and enthusiastic descriptions.

On his tour of Italy in 1581 Montaigne visited the Villa La Petraia, one of the Medici villas near Florence.[1] His secretary describes what happened in the garden, where the party

> encountered a very humorous experience, for, as they were walking about therein and marking its curiosities, the gardener for a certain purpose withdrew, and while they stood gazing at some marble statues, there sprang up and under their feet and between their legs an infinite number of tiny jets of water, so that they resembled exactly drops of rain, and with this they were sprinkled all over.[2]

The gardener was controlling the flow of water from a secret vantage point 'two hundred paces distant'. By adjusting the tap he could make the jets go higher or lower.

In other gardens the jets came up from the ground to form a palisade around the victims, so that they were trapped and could only get out by breaking through the water. The French visitor Nicolas Audebert

described a *gioco* of this kind at the Villa d'Este in Tivoli, where he stayed in the late 1570s.[3] In the 'Secret Garden' there was a pavilion with fountains in the corners that threw up spray to form large flat 'mirrors' – as explained in Chapter 5. When people stopped in the centre of the pavilion to admire their own reflections, jets rose from the floor to a height of 3 or 4 feet in an interlaced pattern to make a 'very ingenious and beautiful compartment' in which the visitors were enclosed. The 'engineering' of most of these jokes was of the simplest: concealed members of the garden staff kept watch on the visitors' movements and turned the taps on and off. A few, however, were triggered automatically, as were Aleòtti's cannon for the gates to the Villa d'Este (Figure 4.23).

In some of the pictures of fountains made by Francesco Venturini, published in 1691 along with engravings by G. B. Falda, we can see visitors being subjected to these kinds of indignities. Figure D.1 shows the scene at the Fountain of the Sleeping Venus in the gardens of the Villa d'Este, near the water organ.[4] The *giochi* in front of the fountain have just been turned on, and men, women and a frisky dog are running away. One of the men has escaped around the corner only to be soaked from on high by a pissing putto.

In 1659 Francis Mortoft visited the gardens of the Villa Montalto in Rome with a group of friends.[5] Their guide encouraged them to have a game of bowls, but when they took the bowls from the box 'wee drew water in our faces, which made us have little desire to play at that time'. Later the guide showed them a tap with which they could, he said, wet others, but instead 'wee threw water on ourselves, so with much laughing at these mistakes wee tooke one more sprinkling and departed'. One can imagine a real pleasure in being soaked in a Roman summer, but Mortoft was there in January.

Sometimes the visitor could actually control the direction of a jet. Mortoft and friends went on in March to the Villa Mondragone in Frascati, where they found:

> Among other pretty devices … a Jetteau of Leather, which casts up the water extreame high and with great force, and which may be turned any way one pleases to wett any person that stands within sight of it, the experience of which I too much tried, being forced to creepe up close to a wall to hinder the pleasure that Mr Hare took in wetting mee, and yet all would not doe.[6]

An engraving by Giovanni Battista Falda shows the very scene at the Villa Mondragone (Figure D.2).[7] Like Mortoft and Hare, two

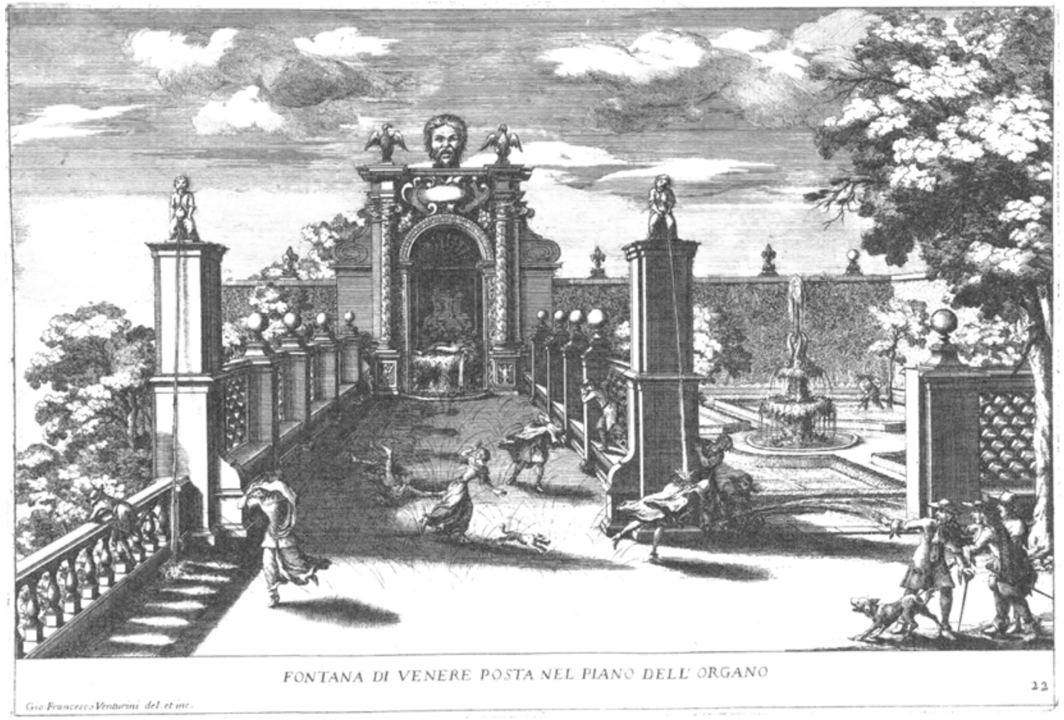

Figure D.1 Engraving by Francesco Venturini of the Fountain of the Sleeping Venus in the gardens of the Villa d'Este at Tivoli, from *The Fountains of Rome* (1691). Jets of water are starting to squirt from the pavement.

gentlemen are having a water fight with the steerable jets from opposite sides of a fountain and pool.

The competitive virility of Mortoft's account becomes all the more explicit in a description of the same fountain by an eighteenth-century French visitor, Charles de Brosse:

> The ceremony started at Villa Mondragone around a – shall we say: polypriapic – basin … Its whole balustrade was fitted with a number of leather hoses, the thickness of a man's leg, with copper nozzles. Laxly curved in an indolent attitude they lay until we turned a cock. Now the air compressed by water swelled their hollow bodies, the charming gents became more and more erect and began – how does Rabelais put it – to shoot fresh water tirelessly.[8]

A comparably salacious tone, together with a mild sadism, creeps into some accounts of how women were surprised with these water sprays.

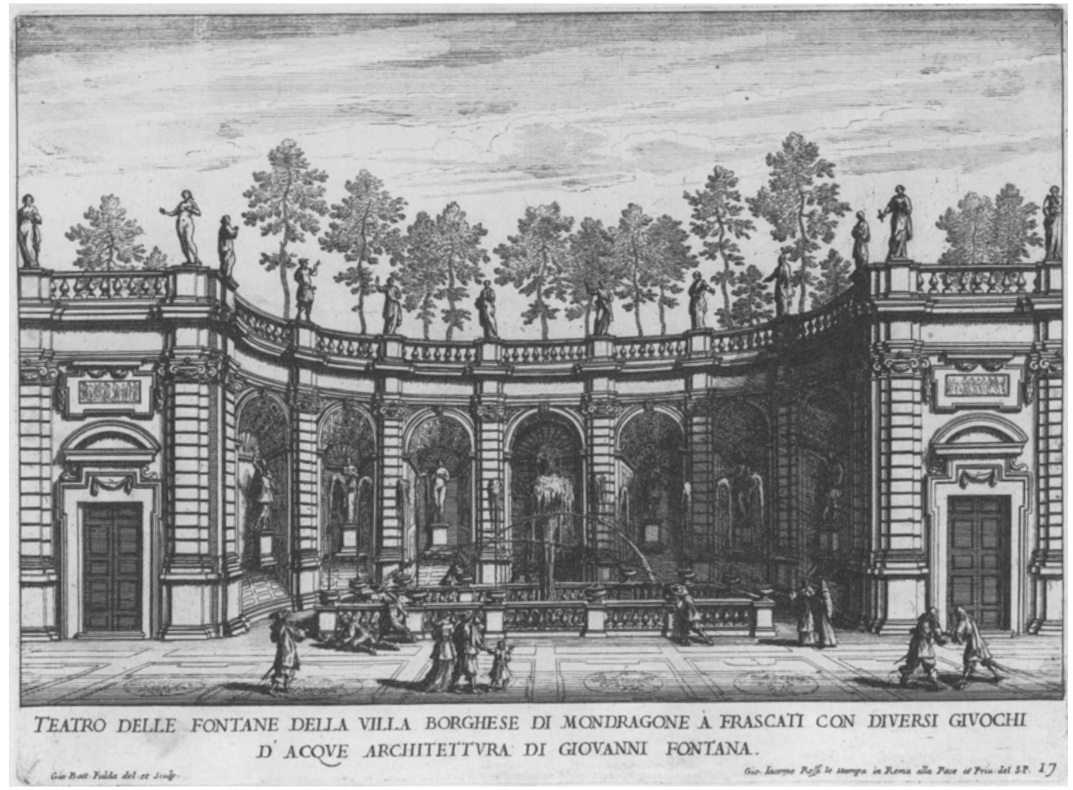

Figure D.2 Engraving by Giovanni Battista Falda of the Water Theatre at the Villa Mondragone at Frascati, designed by Giovanni Fontana, from *The Fountains of Rome* (1691). Two gentlemen are having a water fight with steerable leather hoses.

When Montaigne was in Augsburg in 1580 he visited one of the summer residences of the Fugger banking family.[9] In the garden there were two large fishponds with a space between them, floored with planks. Little brass taps were hidden beneath the planks. 'Thus at any time when ladies may go to divert themselves by seeing the fish play about the pond, it needs only the letting go a certain spring to make every tap aforesaid send a jet of water straight upward to the height of a man, and drench the petticoats and cool the thighs of the ladies.'

Some of the most elaborate water jokes – or *jeux d'eau* in this case – were installed by Cardinal Richelieu in the 1630s at his château at Rueil near Paris.[10] The games were in a garden grotto, probably designed by Richelieu's architect Jacques Lemercier. Here the Cardinal's guests could control not just the directions but the shapes of the sprays.

Élie Brackenhoffer, a traveller from Strasbourg on a Grand Tour, made a visit to Rueil in the 1640s and wrote a detailed description.[11] The grotto building was octagonal, decorated with sculptures, mirrors and 'coagulations'.

> In four of the corners there are satyrs, in the other four nymphs, all of them full height, charmingly constructed from seashells and snail shells; each figure makes a strange gesture with the hand, now putting a finger on the thigh, now on the mouth, while with the other hand he lifts his penis in the air, from which the water spurts; all this is rendered with the greatest realism. On four of the sides are beautiful *fountains* with fine oval basins; three marble figures stand by each fountain, also pouring water from their genitals. On the other four sides are benches to which one can withdraw when all the jets in the grotto are playing. In the middle stands an octagonal marble table, on which one can play all kinds of games, and can make all kinds of shapes in water; by pressing on the instrument or tube coming from the centre of the table, for example lilies, cups, flowers, glasses, moons, stars and *parasols*.[12]

The 'instrument' must somehow have allowed the player to change the effective form of the nozzle on the central jet to produce these different shapes of spray, as we saw in the designs of fountains generally. One can imagine two possibilities. There might have been a stock of different nozzles provided. This is what Evelyn found in a grotto at the Villa Borghese in Rome in 1644. Here there were 'artificial raines, & sundry shapes of Vessells, Flowers &c: which is effected by changing the heads of the Fountaines'.[13] Alternatively, the participant might have been able to squeeze a flexible tube or put his finger over its mouth. The games at Rueil were so much enjoyed that the excitement could get out of hand. Another traveller, Lodewijck Huygens, said that when he visited in 1655, gentlemen were required to leave their swords outside the grotto.[14] It might also have been wise for them to leave most of their clothes.

Notes

1 Michel de Montaigne, *Journal du Voyage de Michel de Montaigne en Italie, par la Suisse et l'Allemagne, en 1580 et 1581*, English trans. W. G. Waters, 3 vols (London: John Murray, 1903), vol. 2, pp. 55–6. This section is written by Montaigne's secretary. Elsewhere Montaigne takes over in the first person.

2 Montaigne, *Journal*, p. 56.

3 R. W. Lightbown, 'Nicolas Audebert and the Villa d'Este', *Journal of the Warburg and Courtauld Institutes*, 27 (1964): pp. 164–90. The relevant section of Audebert's manuscript is reproduced in this paper: see pp. 189–90. H. V. Morton, *Fountains of Rome* (London: The Connoisseur and Michael Joseph, 1970); first published as *The Waters of Rome* (1966), p. 144, describes being imprisoned by jets – which were still working in the 1960s – in the Quirinal Gardens in Rome.

4 Giovanni Battista Falda, *Le Fontane di Roma* (Rome: Gio. Giacomo de Rossi, 1691), Part 4, Plate 22, 'Fontana di Venere posta nel Piano dell'Organo' – that is, close to the water organ.

5 Francis Mortoft, *Francis Mortoft: His Book, Being his travels through France and Italy, 1658–59*, ed. Malcolm Letts (London: The Hakluyt Society, 1925), p. 115. Little is known otherwise about Mortoft.

6 Mortoft, *Francis Mortoft*, p. 154.

7 Falda, *Fontane di Roma*, Part 2, Plate 17, 'Teatro delle Fontane della Villa Borghese di Mondragone a Frascati con diversi giuochi d'acque. Architettura di Giovanni Fontana'.

8 Quoted in Carl L. Franck, *The Villas of Frascati, 1550–1750* (London: Tiranti, 1966), p. 65, from *Le Président de Brosses en Italie: lettres familieres écrites d'Italie en 1739 et 1740* (Paris: Didier, 1836). The translation is at several removes from the original.

9 Montaigne, *Journal*, vol. 1, pp. 140–1.

10 Kenneth Woodbridge, 'The Architectural Adornment of Cardinal Richelieu's Garden at Reuil', in Monique Mosser and Georges Teyssot (eds), *The History of Garden Design: The Western Tradition from the Renaissance to the Present Day* (London: Thames and Hudson, 1991), pp. 169–71; see p. 169.

11 Élie Brackenhoffer, *Voyage de Paris en Italie 1644–1646*, trans. Henry Lehr (Paris: Berger-Levrault, 1927). Brackenhoffer's original manuscript, in the Musée Historique de Strasbourg, is in German.

12 Brackenhoffer, *Voyage de Paris*, p. 40; my translation from Lehr.

13 *The Diary of John Evelyn*, ed. E. S. De Beer, 6 vols (Oxford: Clarendon Press, 1955), vol. 2, p. 252.

14 See H. L. Brugmans, 'Châteaux et jardins de l'Ile de France d'après un journal de voyage de 1655', *Gazette des Beaux Arts*, 18 (1937): 93–114; see 111–12. Lodewijck Huygens was the son of the diplomat Constantijn Huygens and the brother of the physicist Christiaan Huygens. He says that the water jet in the grotto at Rueil could take the form of a sun, a star, rain or hail.

6

Artificial music

The hydraulic organ at the Villa d'Este

One of the most admired ornaments of the gardens at the Villa d'Este, and one of the earliest to be completed, was a water-powered pipe organ that played automatically, without an organist (Figure 6.1). The designer was a Frenchman Luc Leclerc assisted by his nephew Claude Venard.[1] (Leclerc also built the automaton of the owl and birds.) The instrument was ready when Pope Gregory XIII visited in the 1570s: he was so pleased that he wanted to hear it play 'twice and thrice again'. Other visitors 'could not believe that this organ played by itself … they rather thought there was somebody inside'.[2]

Some further acoustic effects accompanied the music. Three little birds sang and five trumpets played 'according to the method of Hero'.[3] Michel de Montaigne heard the artificial song of these birds when he visited the villa in 1581.[4] And when the organ recital ended, the operator pulled on a rope to open a sluice and release all the water that powered the organ, in a great rush, making a thunderous roar underground and throwing up spray 'to the height of two lances'. In the midst of the noise and splashing a stone Triton played raucously on a trumpet – presumably also powered by compressed air. Towards the end, the sound of the water was more of a gargling murmur, gradually dying away.

David Dernie describes the original setting of the organ and the impression it must have created:

> the upper portion of its west-facing façade was a resplendent wall of marble, glass, gold and mirror mosaic, gathering a domain of

Figure 6.1 The water-powered pipe organ of the Villa d'Este in Tivoli. The architectural setting was only completed in the seventeenth century. The pipes are visible in the central window. Wikimedia Commons: Fontana dell'Organo 01.

> light and harmonious music; below, were dark generative caves filled with half-formed sounds. The musical Water Organ was ingeniously manipulated to create the illusion of a continuity between light and dark, Heaven and earth. The sun-filled space of the organ gave out the heavenly music of Apollo.[5]

This organ at the Villa d'Este was followed over the next 150 years by a number of similar automatic instruments in the gardens of great Italian villas and palaces.[6] In the 1580s Buontalenti was at work on the park and villa at Pratolino, which featured two water organs. In 1598 Cardinal d'Este himself oversaw the installation of another instrument – of which more shortly – at the Palazzo Quirinale in Rome. Four others were built later in Rome, Ferrara, Frascati and Naples.

The hydraulis: an ancient music machine

These Renaissance organs were the distant descendants of a type of organ-like instrument, played in many venues in the ancient world. The Greek name for the instrument was ὑδραυλος or *hydraulos*, the Latin *hydraulus*. Modern usage is hydraulis. Both Hero and Vitruvius give descriptions. It was invented by Ctesibios, who lived in the fourth or third century BC. Ctesibios is thought to have been the first head of the Museum of Alexandria where Hero worked four centuries later. Unfortunately, all Ctesibios' writings are lost, including a summary of his research known in Latin as the *Memorabilia*. Vitruvius, however, names Ctesibios as the inventor of the hydraulis, and probably derived his own account from one of Ctesibios' manuscripts.

Vitruvius tells us that Ctesibios started his working life in his father's barber's shop. 'Greatly surpassing the rest in his ingenuity and his great industry, he is said to have delighted in clever inventions … for example, he wanted a mirror to hang in his father's shop in such a way that when it was lowered and then raised again, a hidden cord pulled a counterweight.'[7] The counterweight on this cord rose and fell through a tube, compressing the air and making a whistling sound. This convinced Ctesibios that air was a substance through which force could be applied. The most influential and widely adopted of Ctesibios' hydraulic inventions was a type of pump that bears his name, in use throughout the Mediterranean for raising water. Vitruvius gives a description of this pump in his tenth book.[8] (Vitruvius also mentions in passing that Ctesibios devised 'blackbirds singing by means of waterworks, and *angobatae* [hydraulic automata] and figures that drink or move'.)

The earliest origins of the pipe organ are lost in prehistory, but it seems reasonable to imagine that it was evolved from an instrument consisting of a set of pipes – like panpipes – blown with air from a bag or bellows.[9] There would have been a basic problem, however. If the air was pumped manually the pressure would not have been constant; and if this supply was connected directly to the pipes, their sound would have wavered. When the pressure in a pipe is too high the note rises in pitch, and can even 'overblow', sounding an octave above its fundamental note.[10] In modern pipe organs the air pressure inside a 'wind chest' is kept constant by means of weights or springs. Ctesibios solved the problem in a different way. He introduced a method of stabilising the air pressure using water. This was the key feature of the hydraulis, hence its name.

Figure 6.2 shows a drawing of a hydraulis from Hero's *Pneumatics*, labelled as an 'Altar Organ blown by Manual Labour'.[11] This has a tank containing water at bottom right, under the organ pipes, labelled *ABCD*.

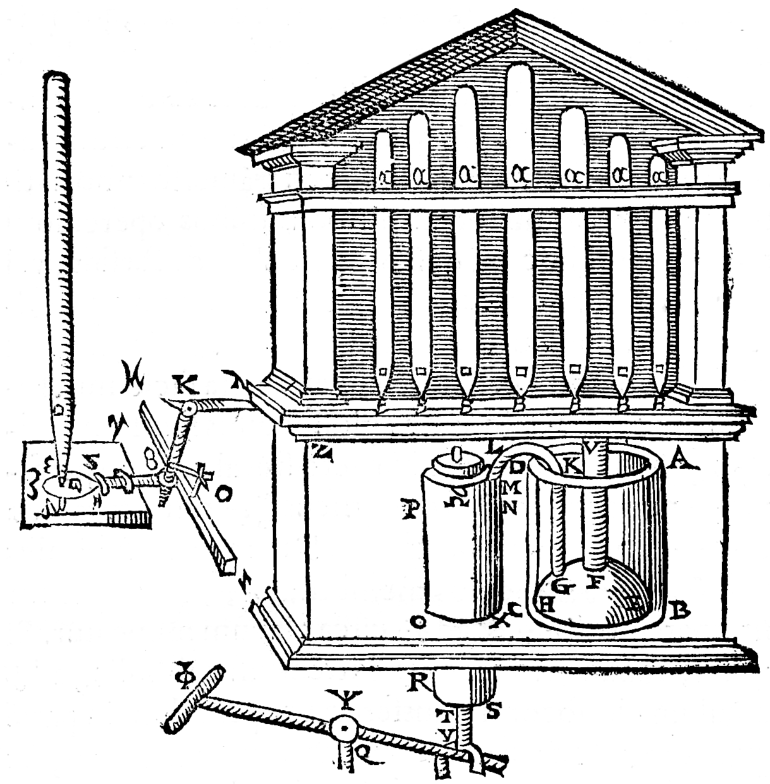

Figure 6.2 Theorem 76 from Hero's *Pneumatics*: 'An altar organ [a hydraulis] blown by manual labour'. The water tank *ABCD* is at lower right. Inside the tank is the inverted bell *HE*. The pipe *FV* carries compressed air to the wind chest above. At the left is a detail of one of the levers connecting the keys to valves on the organ pipes.

Standing in the tank is an inverted bell *HE*, with its open mouth below the water level. Air is compressed with a hand pump (at bottom left) and introduced via tubes into the bell. A tube *FV* carries the air from the top of the bell to a wind chest, which in turn supplies the organ pipes. The notes are sounded – as in a modern organ – with a keyboard. Levers connect the keys to sliders, which allow air to pass or not to the pipes. One lever is shown in detail at the left of Hero's figure.

The important point is that the water in the tank serves to keep the air at constant pressure. If the air pressure in the bell drops too low the water rises, and if the pressure rises too high the water falls. Hero has a second theorem showing another instrument, similar to Figure 6.2, but in which the air is compressed with a pump driven by a windmill.[12]

The hydraulis became very popular and was used in private and public entertainments of many kinds. A large organ with many pipes and several slaves working the pumps could produce very loud music. The Romans, who enjoyed noise, used the hydraulis to accompany gladiatorial contests: images of the instrument appear on *contorniates*, the medals struck to honour the victors in the games. Several Roman emperors were accomplished performers, including Heliogabalus and his successor Alexander Severus. According to C. F. Abdy Williams in *The Story of the Organ*,

> The emperor Nero, who had a mania for exhibiting himself as an actor or singer in the public games appears, towards the end of his short life, to have been attracted to the hydraulus; for Suetonius tells us that when he was being hunted to death by his enemies, he vowed that if he escaped them he would enter the public contests as a player on the hydraulus, the choriaula, and the bagpipes.[13]

The Greeks saw the potential of the hydraulis for creating high-volume sound in military applications of the machine. A treatise survives in Arabic whose elusive author is named as Mauristos, who seems to have been a friend of Philo.[14] This describes 'the great Organ, nicknamed the "Capacious Mouth with the Loud Voice". And this is because its sound carries sixty miles.' The machine was for summoning troops to battle from over large areas and for terrifying the enemy. It was to be worked by as many as 60 men standing on pedestals and pumping. The air bags for the pumps were to be made from whole buffalo hides. 'And the men who will blow will have their ears stuffed with cotton, and covered over in wax, in order that their senses may not depart and that they may not be injured in the ears.'[15]

In the 1880s the Reverend F. W. Galpin built a half-size working hydraulis based on classical texts.[16] He gave a recital of 'original Delphic hymns' on the instrument, accompanied by voice and *kithara* (the ancient Greek lyre) at the Fishmongers' Hall in London. Galpin remarks on a slight unsteadiness in the sound of his instrument – despite the stabilising reservoir – 'owing to the impossibility of keeping the water [pressure] absolutely at a fixed point'.[17] This, he says, gives a 'peculiar piquancy' that might explain the instrument's 'immense popularity'. In 1992 a more or less complete hydraulis with 19 bronze pipes was excavated in fragments in the Greek city of Dion near Mount Olympus. It has been reassembled and is on show today in the Dion Archaeological Museum.[18]

Enthusiasm continued well into the Middle Ages. According to the historian Éginhard, Louis the Pious, King of Aquitaine, had a hydraulis built in 826 at Aix-la-Chapelle by 'a Venetian priest named George'. 'This organ was so ravishing that a woman lost her life from the transports of delight it caused; it could imitate thunder, the lyre and the cymbal …'[19] After this the hydraulis seems to have been abandoned in favour of types of organ more comparable to the modern instrument. However, it emerged again in a new form in the automatic organs of the sixteenth century.

The Renaissance designers of these instruments certainly learned about the hydraulis from Hero, and from Vitruvius' description in the *Ten Books*.[20] The latter's account is difficult to follow, however. One has the impression that Vitruvius was not entirely sure himself of what he was writing about. Sixteenth- and seventeenth-century scholars tried to work out exactly what he was saying, but with varying degrees of confidence and success. Their engineer contemporaries were nevertheless able to create new machines in which the air pressure was again controlled with water and the music of the organ was recorded and played automatically. Let us look in more detail at how they achieved this.

How the Renaissance water organ worked

For the organ at Tivoli we have a full description by the French traveller Nicolas Audebert whom we encountered in Chapter 5, and who stayed at the Villa d'Este in late 1576 or early 1577. Audebert was probably shown the machine's workings by Leclerc's assistant Claude Venard, who was by then keeper of the fountains.[21] This was a special privilege: usually the mechanism was kept secret from visitors to preserve its mystery. There is also a technical sketch by Venard from a manuscript of 1576 that shows most of the machine, although not the organ pipes (Figure 6.3).[22]

One further contemporary account has only recently been published.[23] This comes in the Italian translation of Hero's *Pneumatics* commissioned by Bernardo Buontalenti from Oreste Vannocci Biringucci, which was finished in 1582 but never printed. At the end of this manuscript, following Hero's theorems on the hydraulis, Biringucci – perhaps at Buontalenti's request – added a detailed description of the organ at Tivoli. From these three sources – Audebert, Venard and Biringucci – we can reconstruct the Villa d'Este organ, many of whose features were copied in later instruments.

We can also make comparisons with some much more detailed working drawings of very similar designs of hydraulic organ published by Salomon de Caus in *Causes of Moving Forces*.[24] On his trip to Italy in the 1590s De Caus visited Pratolino where the organs installed under

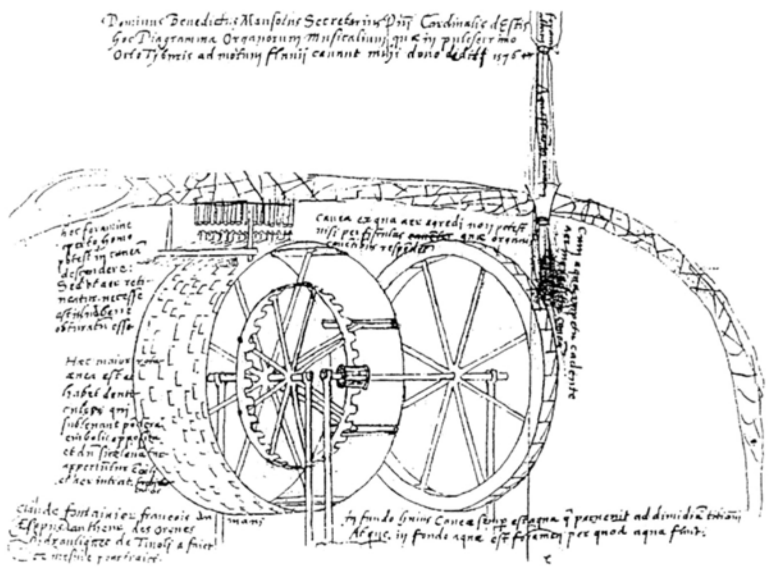

Figure 6.3 Drawing by Claude Venard of the mechanism of the water organ at the Villa d'Este in Tivoli, showing the water/air supply through the vertical tube at the right and the pinned cylinder at the left. The organ pipes are out of view above the roof (shown hatched) of the aeolic chamber.

Buontalenti's direction were then in operation. De Caus might also have seen the instrument at the Villa d'Este. He therefore gained much of his knowledge of their design from Italian examples.[25]

Three reasons why 'water organs' were so called

The organ pipes themselves are the most familiar part of these machines. The instrument at Tivoli had 22 cylindrical pipes of graduated sizes, visible through a window-like opening (see Figure 6.1). As in all organs, these were sounded by air passing through tubes into the bases of the pipes. In the normal instrument and in the ancient hydraulis the compressed air is provided by bellows or pumps, worked either by hand or mechanically. The Renaissance organs used a different method: the air was compressed by the weight of water. At Tivoli a supply of water mixed with air was channelled down a long vertical tube into a chamber where the air was contained.

There are three separate reasons for referring to these Italian instruments as 'hydraulic' or 'water organs'. This is the first: *air was compressed by pouring aerated water down a long pipe*.

Audebert describes a vaulted airtight room beneath the organ pipes, into which he was allowed to descend by ladder through a manhole. The hole was normally closed with a tight-fitting stone slab.[26] This wind reservoir or 'aeolic chamber' was excavated from the rock. The curving roof is shown crosshatched in Venard's drawing. During operation of the organ the chamber was partly filled with water from the top through the vertical tube. The tube had a gate on top whose shape caused the water to become agitated, so that it took up air bubbles as it entered. The lower end of the tube appears at the top right of Venard's sketch, with water pouring from it. There was a reservoir above and behind the organ, from which the tube descended.[27]

Biringucci gives a full description of this tube and its functioning – although the diagrams to which he refers are missing from his manuscript.[28] As he says, 'It is therefore clear that the jumps and disjunctions [the turbulence] of the water … capture and push the air into the channel …' He adds 'The description of this contrivance will not just be useful for the description of the organ but for innumerable other things, which however should not be described here.' What 'other things' might Biringucci have been alluding to?

Oreste Vannocci Biringucci was the nephew of Vannoccio Biringuccio, who was one of the leading figures in Renaissance metallurgy and published an important book on metals and their production, *Working with Fire*, in 1550.[29] In the book, among many other topics, Biringuccio discusses the smelting of metal ores in furnaces. From the sixteenth century onwards devices called trompes were used in such furnaces as well as in industrial kilns in Spain and Italy. A trompe had a tall tube into the top of which a mixture of water and air was introduced. The compressed air issuing from the bottom of the tube was used to increase the wind to the furnace, to create the very high temperatures needed. It seems then that Oreste was alluding to metalworking, his uncle's field of expertise.[30]

In 1629 the engineer and architect Giovanni Branca published a book entitled *Le Machine*, which consisted of a series of drawings with brief explanatory texts.[31] Two successive figures show a blacksmith's furnace blown with a *spiritale*, or trompe, and a pipe organ supplied with air in exactly the same way (Figure 6.4). As Branca says, the mechanism is identical.

Going back to Tivoli: the water that poured into the aeolic chamber via the vertical pipe escaped again through a tube at the bottom of the chamber. The room was filled with water to about half or two-thirds of its volume, keeping the air above compressed. Sluice gates operated with ropes were used to control the flow of water in and out. There was a series of small tubes in the vault leading to the organ pipes above, kept closed by valves. Venard shows these at top left, just under the roof.

The chamber thus contained a continuous supply of compressed air with which to sound the pipes. But it had another critical

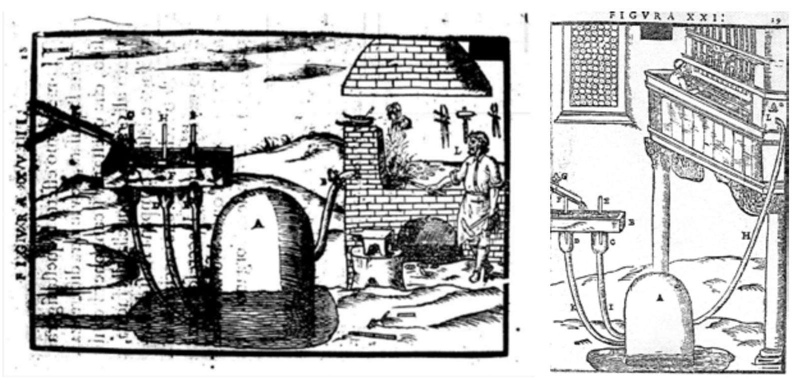

Figure 6.4 Designs by Giovanni Branca for a blacksmith's furnace (left) and a water organ (right). An air/water mixture is supplied through vertical tubes or trompes to compress the air in both cases.

function. The water in the chamber served to keep the air supply at constant pressure, just as the water tank and bell controlled the pressure of the air in the hydraulis. This is the second reason for the description 'water organ': *the air pressure was stabilised by water pressure*.

The final component of the Villa d'Este machine was the apparatus by which the music was recorded, and the valves on the tubes to the organ pipes were opened and shut. This consisted of a large rotating cylinder with pins and fins around the circumference, like the mechanism of a musical box but enormously magnified. We see this on the left of Venard's drawing (Figure 6.3). According to Audebert the drum was made of sheet iron and was about 1.5 metres in diameter and 1 metre wide.[32]

For each organ pipe there was a lever resting on the drum, which was raised by each pin as it passed, opening the corresponding valve and letting air flow to the pipe above. The valves took the form of solid cones fitting inside conical openings: withdrawing the cone allowed the air to pass.[33] Pins on the drum produced short notes; elongated fins produced extended notes.[34] The drum was turned slowly by an iron waterwheel, driven by the stream falling from above. Here is the third reason for calling these 'hydraulic organs': *they were powered by water*.

In 1601 Giovanni Battista della Porta – who built the camera obscura 'cinema' – published *Three Books on Pneumatics*, based very closely on Hero. Della Porta includes a drawing that again shows the workings of the organ at Tivoli (Figure 6.5).[35] All the mechanical elements described so far are represented here, if rather crudely. Della Porta shows the aeolic chamber schematically as a rectangle enclosing all the machinery. See how the air/water mixture enters at top right and excess water leaves at bottom left.

Salomon de Caus gives more detail of the design of a typical musical drum. Figure 6.6 is from de Caus's book and shows a large pinned cylinder turned by a waterwheel.[36] Figure 6.7 gives a close-up of the pins and fins on the drum.[37] In this design, unlike at Tivoli, the protrusions strike the keys on a keyboard, which in turn open the valves and sound the pipes. See how the surface of the cylinder is gridded up, with lines around the circumference corresponding to each organ key, and lines along the length of the drum marking the lapse of time as the drum turns. The garden automata that reproduced complex birdsong, described in Chapter 4, had the sounds recorded using the same method, but on smaller drums with just a few pins.

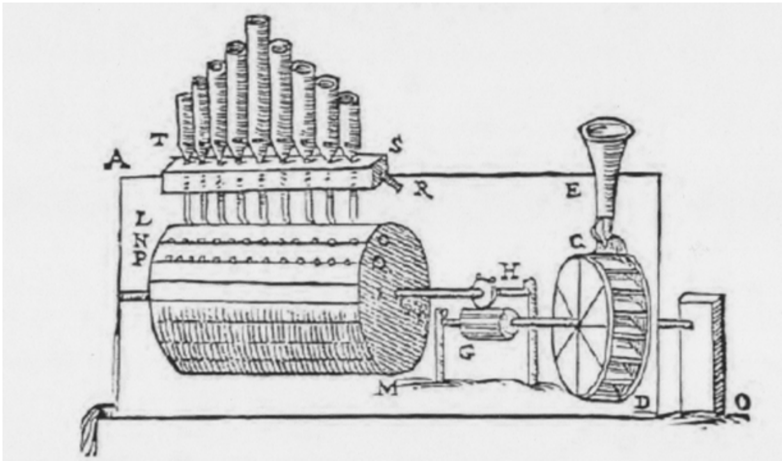

Figure 6.5 Drawing by Giovanni Battista della Porta of the mechanism of the water organ at the Villa d'Este, from his *Pneumatics* of 1601. The aeolic chamber is shown as a rectangle surrounding the other components.

In Figure 6.7 we see six bars, each divided into eight parts. De Caus says that the pins and fins should all strike the keys with equal force, with the exception of the semiquavers, which are sixteen to the bar and should not strike quite so hard.[38] De Caus's drum is made of well-seasoned oak and is about 1.7 metres in diameter. The pins are of hardwood or copper.

It is clear that de Caus's design is much more solidly engineered than the Tivoli organ, perhaps because of the collective experience that must have been gained in building such instruments over the intervening half-century. The entire machine at Tivoli was inside the air reservoir, the aeolic chamber. Because it was made of iron, the water would have rusted the metal. In fact the instrument was vandalised and ruined in 1582, and was rebuilt in the early seventeenth century.

In de Caus's drawings, the aeolic chamber by contrast is shown as a masonry structure the size of a small room built above ground, separate from the rest of the organ.[39] This would have allowed the machinery to be kept dry and easily accessible. In another drawing de Caus shows the organ pipes separated from the rest of the machine by a thick wall, so that the audience would not hear the sounds of the rushing water and the grinding of the gearwheels.[40]

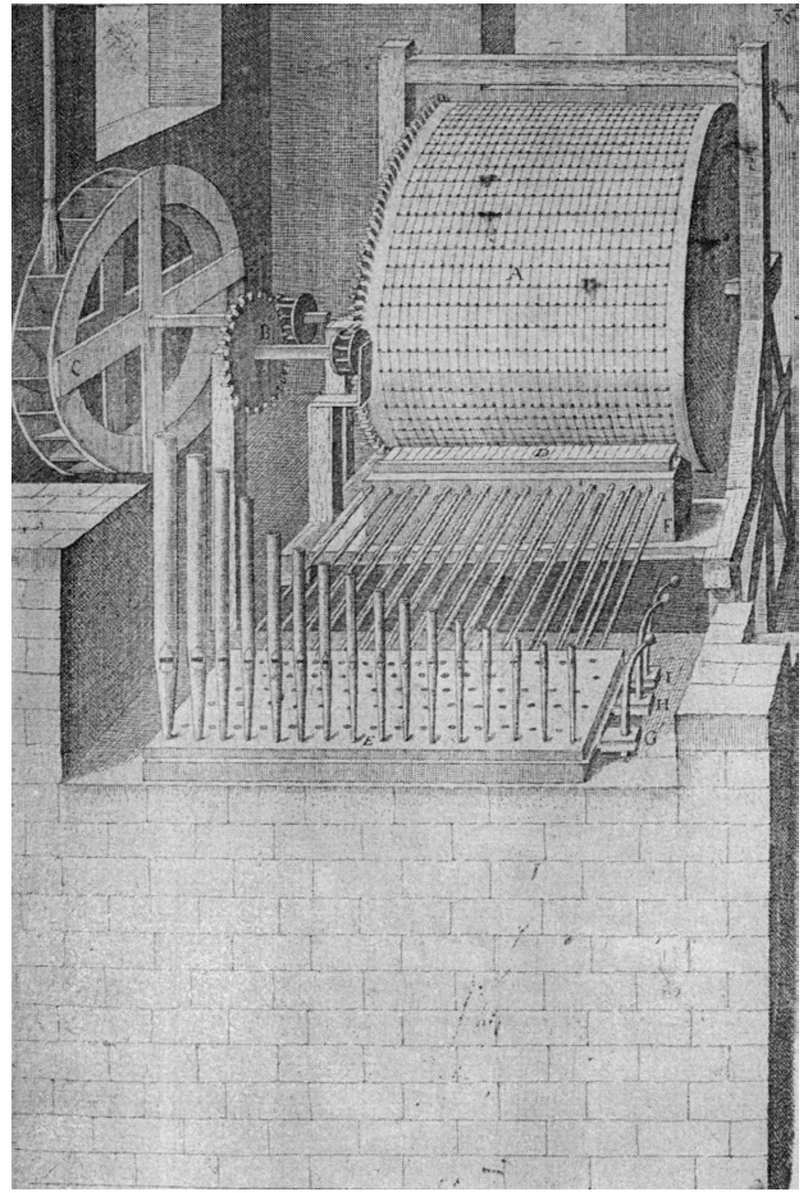

Figure 6.6 Pinned musical cylinder for a water organ, turned by a waterwheel, from Salomon de Caus, *Causes of Moving Forces*.

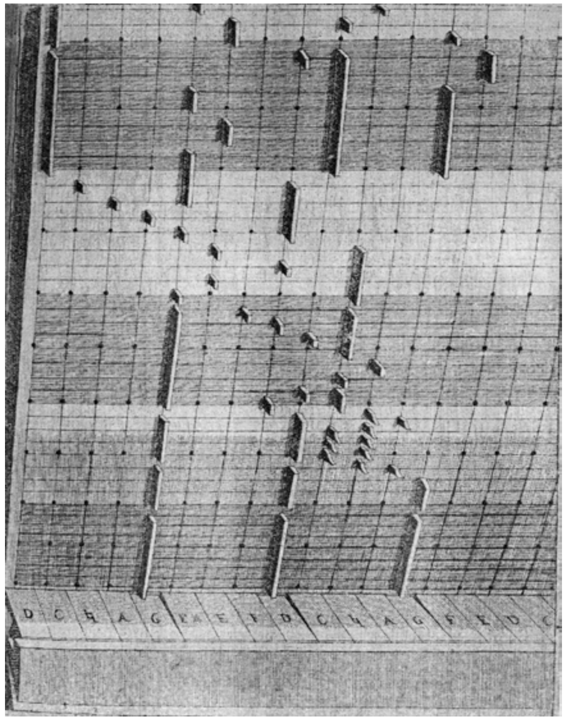

Figure 6.7 Close-up of the pinned cylinder of Figure 6.6 from de Caus, *Causes of Moving Forces*. As the drum rotates the pins and fins depress keys on the keyboard, sounding the respective organ pipes. The pins produce short notes and the fins produce longer notes. Notice the grid of holes into which pins can be fitted.

The water organ at the Palazzo Quirinale

In the late sixteenth century the Palazzo Quirinale in Rome was being extended by Pope Clemente VIII and became the palace of the popes from 1593. Today it is the official residence of the President of Italy. Clemente had put Cardinal d'Este, the client for the Tivoli organ, in charge of works on the Quirinale gardens.[41] D'Este acquired two neighbouring vineyards and supervised the construction of a *nicchione* – a giant niche or apse-shaped structure in the side of the hill beneath the palace, like a grotto, with a water organ at its centre. The architect was Ottavio Mascherino and the hydraulic engineer was Giovanni Fontana. The organ was designed by Luca Blasi and completed in around 1598. We met the German engineer Heinrich Schickhardt briefly in Chapter 5, in connection with a fountain that he

saw in Mantua. In 1599 Schickhardt visited the Palazzo Quirinale and wrote in his diary: 'in the interior of the nicchione there is an organ with four registers [rows of pipes], powered by water, artistically designed'.[42]

The *nicchione* was decorated with paintings and bas-reliefs of Biblical scenes including episodes from the life of Moses, surrounded with mosaics, seashells, pumice and spongy encrustations in typical grotto style (Figure 6.8). Plane trees were planted to give shade, and the pope liked to sit out there on summer evenings. Official deputations were received in the *nicchione*, including in 1601 the Persian ambassador, who might have been reminded of the gardens of his own country.[43] The *nicchione* survives today, largely unchanged but not quite so peaceful: on the terrace above is the presidential helipad.

Little is known about Blasi's instrument, other than the fact that like Tivoli it had extra musical accompaniments. According to Schickhardt there were automatic trombones (*Busonen*) and a row of singing birds. These 'trombones' were perhaps the trumpets blown by two cupids who still sit on rocks below the organ pipes today. However, the Quirinale organ was extensively rebuilt in 1647–8, and we have much more information about this reconstruction. This is because Athanasius Kircher directed the works and gives details in his book *Universal Music-Making*.[44] The engineer Matteo Marione provided Kircher with professional backup.

There is a long section in Kircher's book devoted to automatic water organs generally. Kircher is not overly concerned about technical minutiae – no doubt leaving those at the Quirinale to Marione – with two exceptions. He writes at length about the process of notating the pinned cylinder, and shows methods for laying out the patterns of notes on squared-up sheets of paper, in readiness for transfer to the drum (Figure 6.9). Patrick Feaster, a modern expert on the recording of music, has scanned Kircher's charts digitally, and has written a computer program that deciphers the notes and plays them via a synthesiser.[45] One can just hear the ghostly echoes of Kircher's pieces. Feaster calls this 'palaeospectrophony' (ancient graphic sound).

Kircher also goes into some detail about different configurations for the aeolic chamber. One design in particular seems to have been the principal innovation at the Quirinale (Figure 6.10).[46] This is much smaller than the cave-like room at Tivoli. It is made of metal in a cylindrical shape, 1.5 metres tall, with hemispherical ends. The

Figure 6.8 The *nicchione* or giant niche at the Palazzo Quirinale in Rome, with the water organ at its centre, photographed in 1927. The seated cupids were missing their trumpets at this time. Photo from the Cinecittà Luce archive.

water/air mixture enters through the tube at the right and the water exits through the tube at the bottom. Meanwhile the compressed air is taken off at the top. The two sieve-like diaphragms are to stop dirt and splashes of water reaching the top of the chamber.

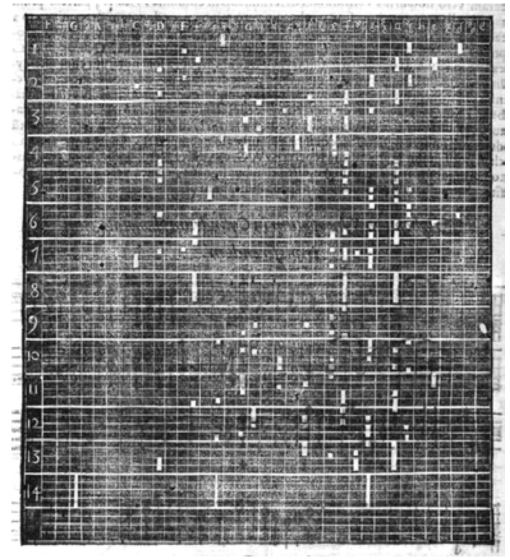

Figure 6.9 Patterns of notes laid out on squared paper for transfer to a pinned musical cylinder, from Athanasius Kircher, *Universal Music-Making*.

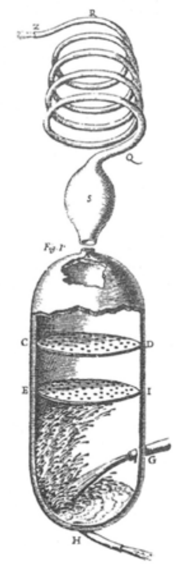

Figure 6.10 Design of aeolic chamber for the organ at the Palazzo Quirinale, from Kircher, *Universal Music-Making*. The water/air mixture enters at the right, and the compressed air is taken off at the top. The diaphragms are to remove dirt and moisture from the air going to the organ pipes.

Kircher devotes much more space in his book to the potential for the water organ to drive automated animals and human figures who play wind instruments using the compressed air supply or are set in motion by wires linked to levers tripped by the musical cylinder. Figure 6.11 shows a pair of linked water organs, illustrated by Kircher, that share the same air supply.[47] The female figure behind the smaller instrument in the grotto to the right represents the nymph Echo, who was condemned by Zeus' wife Hera to repeat forever the last few words spoken to her. Presumably the second organ in Kircher's design likewise echoes the musical phrases played by the first, but more softly and with a suitable time delay. Some conventional pipe organs incorporate sets of pipes enclosed in boxes to give a comparable faraway echo effect. The caption in Greek at the foot of Kircher's drawing reads 'Pan, the harmonious god, Echo to whom he gives all things.'

Kircher must have got the idea from de Caus, who shows a very similar 'Design for a nymph who plays the Organ, to which Echo responds' in *Moving Forces*.[48] Again de Caus has two organs in adjoining caves. Kircher was particularly fascinated by the acoustics of echoes. In *Universal Music-Making* he mentions buildings with remarkable echoes, and shows several possible ways of modifying the reverberation of sound with different geometrical arrangements of walls.[49]

In a second organ design Kircher includes a group of dancers on a turntable, a cherub beating time and a group of blacksmiths hammering metal on an anvil.[50] The gyrating dancers resemble those in Hero's similar 'theorem', whose turntable was driven by jets of hot air. Here, however, the turntable is driven directly off the musical cylinder. The blacksmiths' forge is surely inspired by Aleòtti's design, illustrated in Figure 4.21. The smiths are giant one-eyed Cyclops, supervised by Vulcan, the god of metalworking. Kircher's allusion here is to the legend that the mathematician Pythagoras first understood the basis of musical harmony when listening to the sounds of blacksmiths' hammers.

However, few members of this gallery of robotic figures appear to have found their way into the rebuilt organ at the Palazzo Quirinale. Kaspar Schott, Kircher's friend and assistant, mentions only chirruping birds.[51] Schott's account is confirmed by G. A. Sabelli, who visited the gardens in 1680 and said 'There were organs, which played by the force of water, and an infinite number of little marble birds that were also made to sing by water, and other very curious things, like Moses, the Muses, and statues of several Emperors.'[52] But Sabelli makes no reference to Pan, Echo or Vulcan. In the eighteenth century a group of life-size stone statues representing the Forge of Vulcan was installed

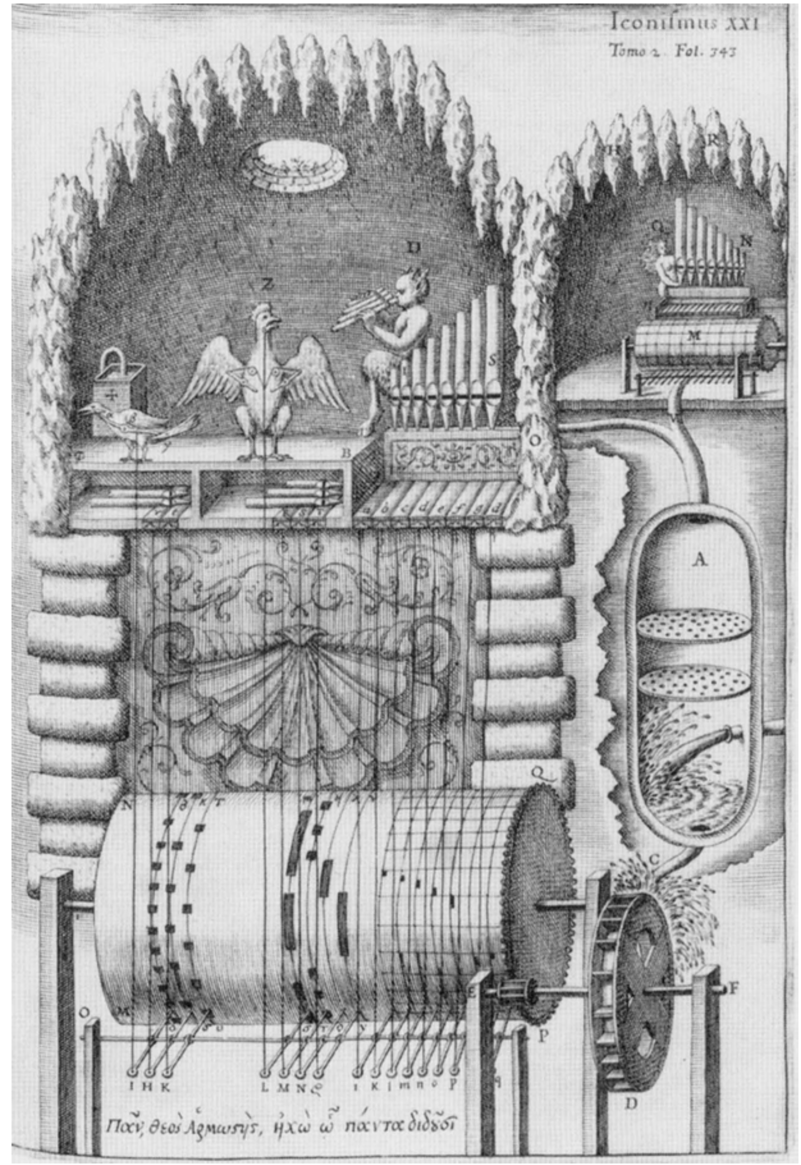

Figure 6.11 Two linked water organs designed by Kircher. The nymph in the small grotto at upper right is Echo, and her small organ, one imagines, repeats the notes played on the large organ below, more softly and with a slight delay. Various automata are driven off the pinned cylinder including singing birds and Pan playing his pipes.

in one of the wings of the *nicchione*. They are still there; but they do not move.

Of the eight Italian organs built in gardens, villas or grottoes, six have since disappeared. The instruments at the Villa d'Este and the Quirinale have suffered many vicissitudes and have been repaired and resurrected on several occasions. Both of them have been restored to working order in recent decades, however, and can be seen and heard in action today.[53]

Cornelis Drebbel's solar-powered harpsichords

Salomon de Caus, despite his expertise and enthusiasm, never got to construct a water organ himself.[54] From about 1611 he was in London, in the service of Henry Prince of Wales – son of King James I – whom he had previously been tutoring in perspective.[55] At around the same time Henry also employed the prodigious Dutch inventor Cornelis Drebbel, who among many marvels was able to change the colours of his clothes in an instant, as we saw in 'Moving pictures'. De Caus and Drebbel worked alongside each other.[56] In writings on Drebbel there are occasional references to the fact that he too designed automatic musical machines and actually built one or more instruments.[57] These played themselves by the action of the sun's rays. Some commentators pass quickly over this idea, as if it is too absurd to contemplate; but the machines certainly existed.

In 1610 the Duke of Württemberg-Mömpelgard made a state visit to King James. Another member of the mission, Hans Jacob Wurmsser von Vendenheym, recorded the duke's programme.[58] On 30 April they attended a performance of Shakespeare's *Othello* at the Globe Theatre. The following day they went to Eltham Palace, where Drebbel had his laboratory, 'to see the perpetual motion'. 'We also saw there virginals which played of themselves.' Tantalisingly, Von Vendenheym says nothing more.

Drebbel himself gives a slightly fuller account in two letters written to King James in 1613.[59] In his words, 'when the sun appears, firstly the curtains and cover of the harpsichord open up; then it plays music, as long as the radiance of the sun lasts, while indeed it stops if the sun goes down or is hidden behind the clouds'. However, Drebbel was not happy with his results: the instrument 'produced a despicable sound'. Had he been able to complete the work to his satisfaction, however, 'it would have been regarded as one of the miracles of the world'.

It is not so easy to guess the secrets of the mechanism. How could it have drawn power from the heat of the sun? The biographer of Drebbel, Gerrit Tierie, says that the workings 'involved the expansion of a certain volume of air by warming'.[60] This is confirmed by Constantijn Huygens, who travelled to London at the time and knew Drebbel well. Huygens says that the upper part of the instrument was designed 'in such a way that it would lift itself up when the sunlight shone on the wall of the building, even if it was merely a dim sunbeam. Undoubtedly he used the movement that emerges when water is being heated to achieve this.'[61]

Von Vendenheym refers in passing to Drebbel's 'perpetual motion', which became very celebrated. We know this was an elaborate form of thermoscope, of the kind described in Chapter 5, almost certainly inspired by Philo or Hero.[62] A coloured liquid moved continuously inside a glass ring when a metal globe at the centre was heated by the sun. Drebbel built several decorative versions of this strange and beautiful instrument for courts and collectors across Europe.

It seems likely therefore that Drebbel's harpsichords had something in common with his perpetual motions, as well as with the solar-powered fountains illustrated by de Caus in *Moving Forces* (see Figure 5.4) – designs with which Drebbel must have been familiar. Still more relevant is a machine by de Caus 'to make an organ or organ pipes sound, every time the sun is at its height, without any other principle of movement than the heat of the sun, and water' (Figure 6.12).[63] The metal box on which the sunshine falls is at the top. The pressure of the heated air causes water to flow from this box via a siphon, the weight of which moves levers and cords that open the water supply to the waterwheel and set the machine in motion. The instrument is therefore water-powered, not strictly solar-powered. Perhaps Drebbel's mechanical harpsichord was similar, with the solar heat just providing an on–off switch.

Some 40 years later Athanasius Kircher offered an explanation for the sounds that came at dawn from the Egyptian 'talking' statue of Memnon (Figure 6.13). Kircher imagines a Heronian device with a closed tank heated by the sun. This sends hot air up a tube to turn a little wheel with plectrums attached, which pluck stretched strings 'like those of a harpsichord'.[64] Is it possible that Drebbel's instrument had some comparable rotating cylinder equipped with plectrums? In any case it would only have played – as he says – when it was sunny in Eltham.

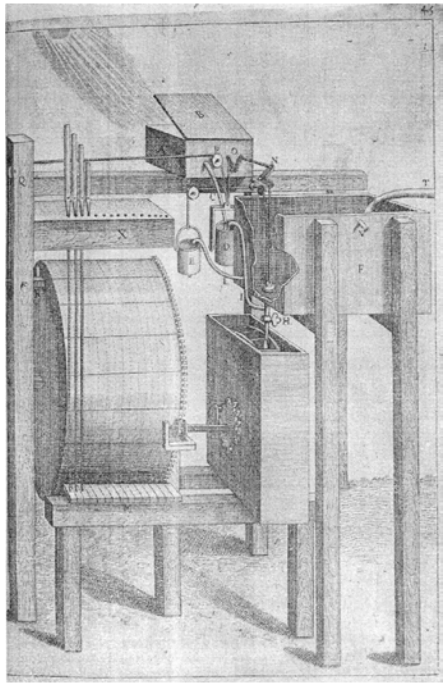

Figure 6.12 Design by Salomon de Caus for a machine to make organ pipes sound by the heat of the sun and water; from *Causes of Moving Forces*.

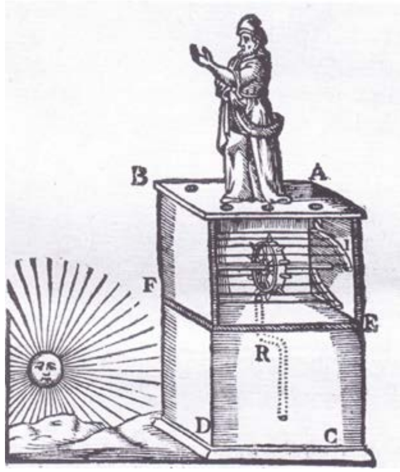

Figure 6.13 A machine designed by Kircher to imitate the ancient Egyptian statue of Memnon that made strange sounds when the sun shone on it. In Kircher's 'explanation', air heated by the sun turns a wheel carrying quills, which ping the strings to make musical notes.

The antecedents of the Renaissance water organ

When Luc Leclerc built the first automatic water organ in Italy, he brought together three components that had separate previous histories. These were the trompe for supplying air under pressure, the aeolic chamber for regulating the pressure level and the pinned cylinder for recording the music. The trompe, as we have seen, came from industrial furnaces. The method of regulating the air pressure was derived from the hydraulis.

Daniele Barbaro studied Vitruvius' rather enigmatic account of the hydraulis, and published a drawing, showing all the main parts, in his translation of the *Ten Books*.[65] A century later Athanasius Kircher published another conjectural reconstruction, again based on Vitruvius' account, in *Universal Music-Making*.[66] However, Kircher confessed that he had not fully understood the purpose of the water, perhaps baffled by Vitruvius' text. He wondered whether it was to impart a pleasing tremolo to the music. This might seem surprising, given Kircher's detailed discussion in his own book of the hydraulic engineering of the Renaissance organs. In fact he never really explained how the air pressure was regulated in those instruments either. But Luc Leclerc and Kircher's engineer Matteo Marione must have understood.

Then there is the pinned cylinder on which the music is recorded. For the origin of this mechanism, we need to look elsewhere, but there are large gaps in the history. One other type of musical instrument that was automated, in the century before the first Italian water organs, was the carillon, or set of bells played from a keyboard.[67]

The carillon differs from the normal peal of church bells in having more bells and striking them with hammers from the outside, rather than with clappers on the inside. Carillons became popular in the fifteenth century in the Low Countries and Germany, where they were installed in church towers and town halls. As Henry Heathcote Statham remarks, 'this bell-music has had its special development in flat countries, where its loud and travelling sounds are heard with far more effect and at far greater distance than in hilly districts'.[68]

In early manual carillons the hammers were moved directly by the keys on a keyboard. Because the hammers were heavy and the keys were set far apart, the playing of the instrument was not a matter of delicate fingerwork, more an exercise in physical strength. The player stripped to his underwear and wore thick leather gloves to protect his

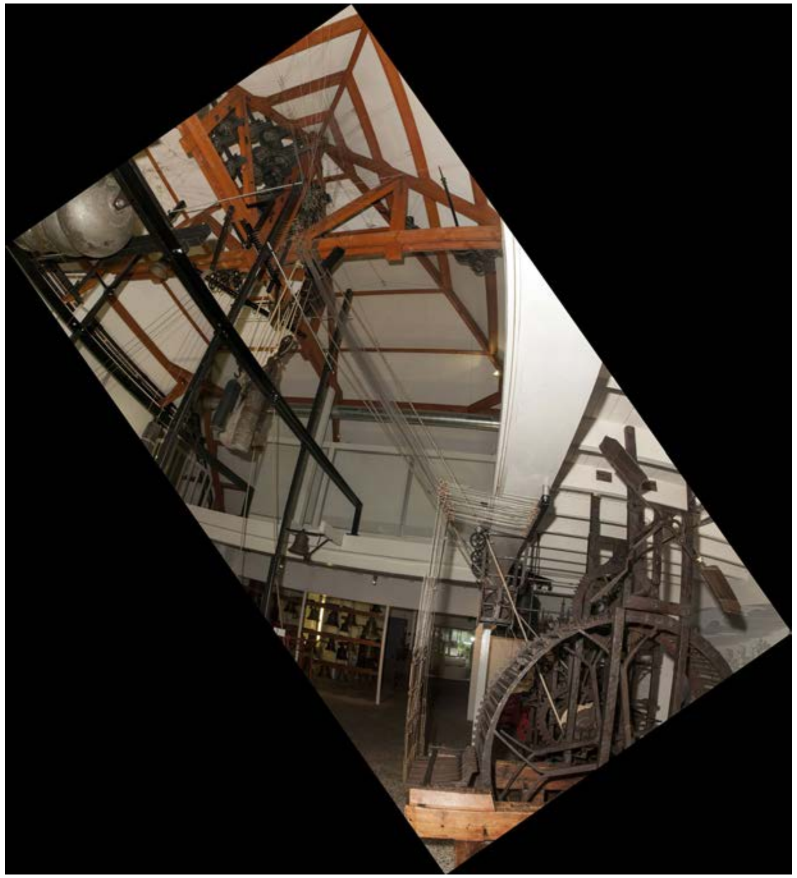

Figure 6.14 A Dutch carillon made in 1635 for a church in Hattem, Gelderland. The pinned cylinder is at bottom right. The wires connect to hammers that strike the bells above. By kind permission of Museum Klok & Peel, Asten, and C. van der Ven.

hands. When pinned cylinders were introduced, these too had to be made large and heavy to do the same job.

Figure 6.14 shows the cylinder of a Dutch carillon dating from 1635 in the Klok & Peel Museum in Asten, Holland.[69] The pinned cylinder is at the right and the wires connect to the hammers and bells above. The water organs adopted these big cylinders, despite the fact that much less power was needed to move organ keys. (On the other hand, the larger the diameter of a cylinder, the longer the piece of music that could be recorded on it.) The cylinder of the automatic carillon was turned by a weight descending the tower in which it was housed. There is, however, a much more remote ancestor of the pinned cylinders of the Renaissance carillons and organs to be found in the Islamic scientific culture of the Middle Ages.

The Banū Mūsà's automated flautist

The Banū Mūsà's ninth-century *Book of Ingenious Devices* contains no 'models' for musical instruments, even though the brothers had strong interests in music. A separate manuscript of theirs, however, miraculously preserved in a library in Beirut and translated into English in the 1930s by Henry George Farmer, describes 'The Instrument Which Plays by Itself'.[70] Although there are references to diagrams, these are missing from the Beirut copy, but the text is sufficiently detailed that Farmer and others have been able to make drawings. René Khawam has made a translation into French and has analysed the mechanism in detail.[71] Mona Sanjakdar Chaarani has also made a reconstruction.[72]

The machine described by the Banū Mūsà is not an organ: it plays a simple flute or reed pipe with nine holes. The holes are closed and opened with stoppers. The air is compressed by water in an arrangement with close similarities to the hydraulis, but having two aeolic chambers instead of one, both supplying air to the flute.[73] These are filled alternately with water from a tank above, to compress the air (Figure 6.15). The music is recorded on a cylinder with teeth corresponding to eight of the holes in the flute. These teeth move levers and stoppers in the same way as the water organs. (In his translation Khawam refers not to teeth but to 'indentations' in the drum. One can imagine that the ends of the levers would then dip down into these indentations.)

The cylinder is rotated by a waterwheel that can be controlled to turn faster or slower, appropriate to the tempo of the music. For a machine to play two tunes, the cylinder can be made double length. When the first tune is finished, the barrel is moved along its axle automatically to play the second piece, like a ninth-century jukebox. The Banū Mūsà describe how the whole machine may be concealed inside an automaton musician figure, whose moveable fingers are linked to the levers that open and close the stoppers and so seem to play the flute.

There are two ways of recording the music on the cylinder. The first is to count out the beats and notes and mark corresponding positions where pins are to be inserted (or indentations made) in the same way as in the Italian organs, as explained by de Caus and Kircher. The most

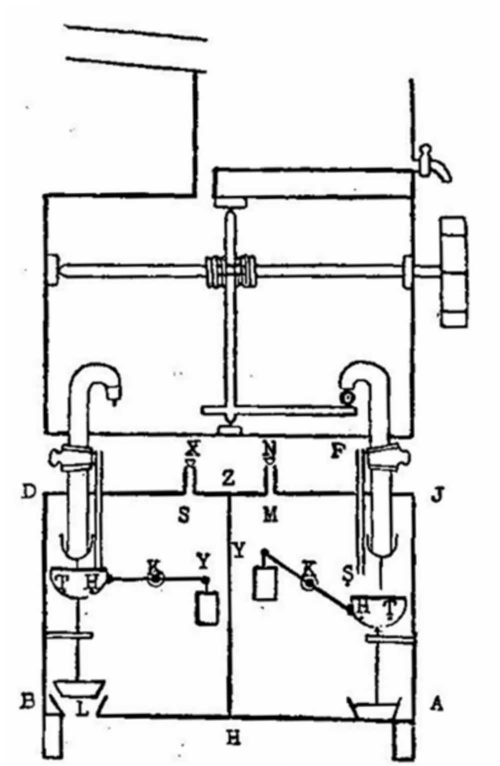

Figure 6.15 Diagram by Henry George Farmer of the hydraulic part of the Banū Mūsà's automated flute player, built in Baghdad in the ninth century. The mechanism to compress the air resembles a hydraulis, but with a water tank above, and two aeolic chambers below, which operate alternately. The compressed air flows to the flute via the tubes *X* and *N* at the tops of the aeolic chambers. The music is recorded on a pinned cylinder (see Figure 6.16).

astounding part of the Banū Mūsà manuscript, however, describes a second method of recording. This is done by covering a cylinder with black wax 'like that which the Byzantines make, and which they smear upon the slates in elementary schools, in order that everything that is marked in it may be impressed upon it'.[74] The wax-covered drum is then rotated slowly by a waterwheel.

A lever is mounted on each hole on the flute, whose other end hovers just above the surface of the turning wax cylinder. A real human flautist has his fingers tied with strings to these levers, so that, as he plays, the free ends of the levers scrape on, or are lifted above, the wax surface. 'And the drum continues going round evenly as we have said, and [each] lever impresses the value of [each] note on the wax on

the surface of that drum.'[75] Here is Edison's phonograph with its wax recording cylinder, anticipated by a thousand years!

Khawam says that the Banū Mūsà made the cylinders that played the music from earthenware. It would be easier to cut grooves in these than fix teeth or pegs. If there were indeed 'indentations' in the pottery, the resemblance to a gramophone or phonograph record would be even closer. But the Banū Mūsà do not say how the musical recording was transferred from the wax cylinder to the earthenware cylinder.

In 2015 Liang Zhipeng of the Berlin University of the Arts built a working reconstruction of this part of the Banū Mūsà machine for an exhibition of 'Allah's Automata'.[76] Figure 6.16 shows, at the left, the method by which the human flute player records a tune and, at the right, the flute being played automatically by the musical cylinder. (The cylinder in this version is turned by an electric motor and an electric pump supplies air to blow the flute. The hydraulic parts were modelled separately by computer.)

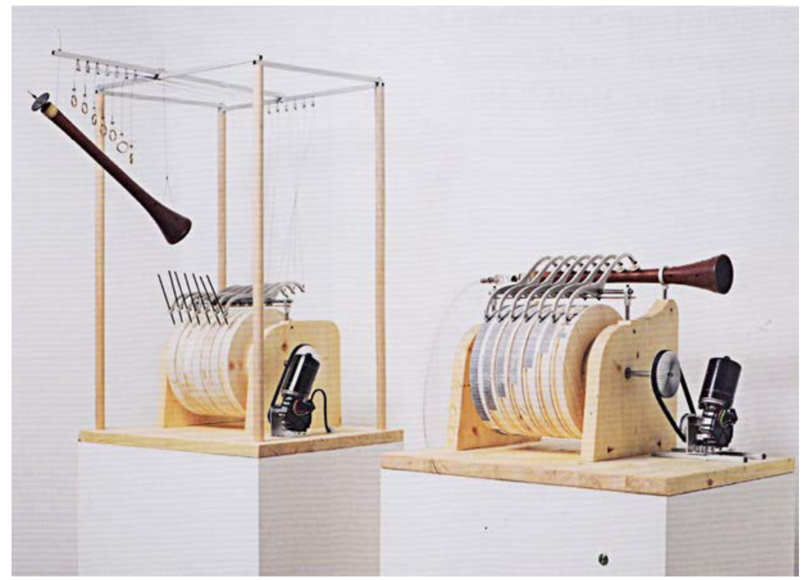

Figure 6.16 Reconstruction of parts of the Banū Mūsà's flute machine by Liang Zhipeng and a group at the Berlin University of the Arts supervised by Alberto de Campo: at the left the method by which a human flute player records a tune, and at the right the flute being played automatically by the musical cylinder. The traces made on the cylinder are milled to create indentations. The hydraulic apparatus is not shown. By kind permission of Liang Zhipeng and Alberto de Campo.

Giovanni Fontana and his 'clock works'

Did knowledge of the Banū Mūsà's flute-player and its mechanism find its circuitous way to the designers of the garden organs of the sixteenth century? I believe we can locate two points in a possible line of intellectual and technical connection in the persons of two Italian engineers working a hundred years and more before Leclerc built his instrument at the Villa d'Este. The first is Giovanni Fontana. In Fontana's *Book of Military Machines* there are drawings of a hydraulis (Figure 6.17) and an automatic self-playing organ (Figure 6.18). The pictures might seem crude and naïve, but they repay detailed study. Fontana's Latin caption and cyphered text to the hydraulis drawing, when decoded, reads:

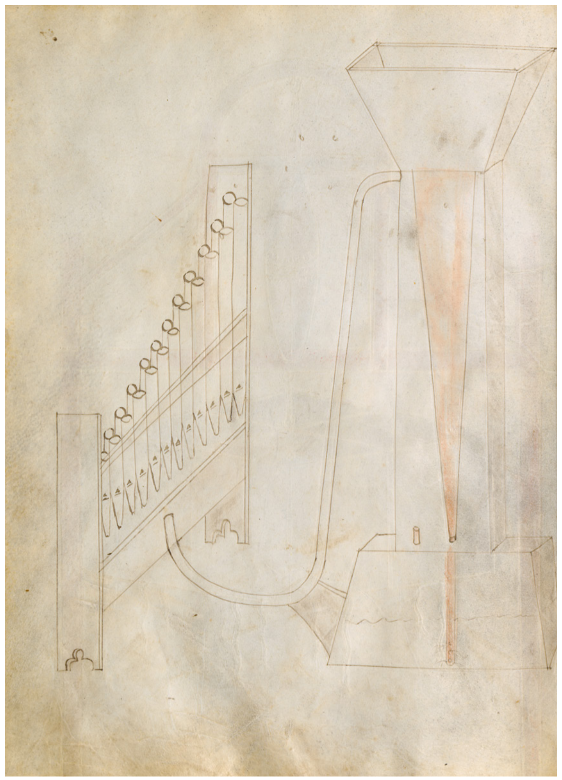

Figure 6.17 Hydraulis illustrated by Giovanni Fontana in his *Book of Military Machines*, early fifteenth century. A water/air mixture falls from the hopper through the narrowing vertical tube into the tank at the base. Compressed air is taken off from this tank, to the organ's wind chest. By kind permission of Bayerische Staatsbibliothek, Munich.

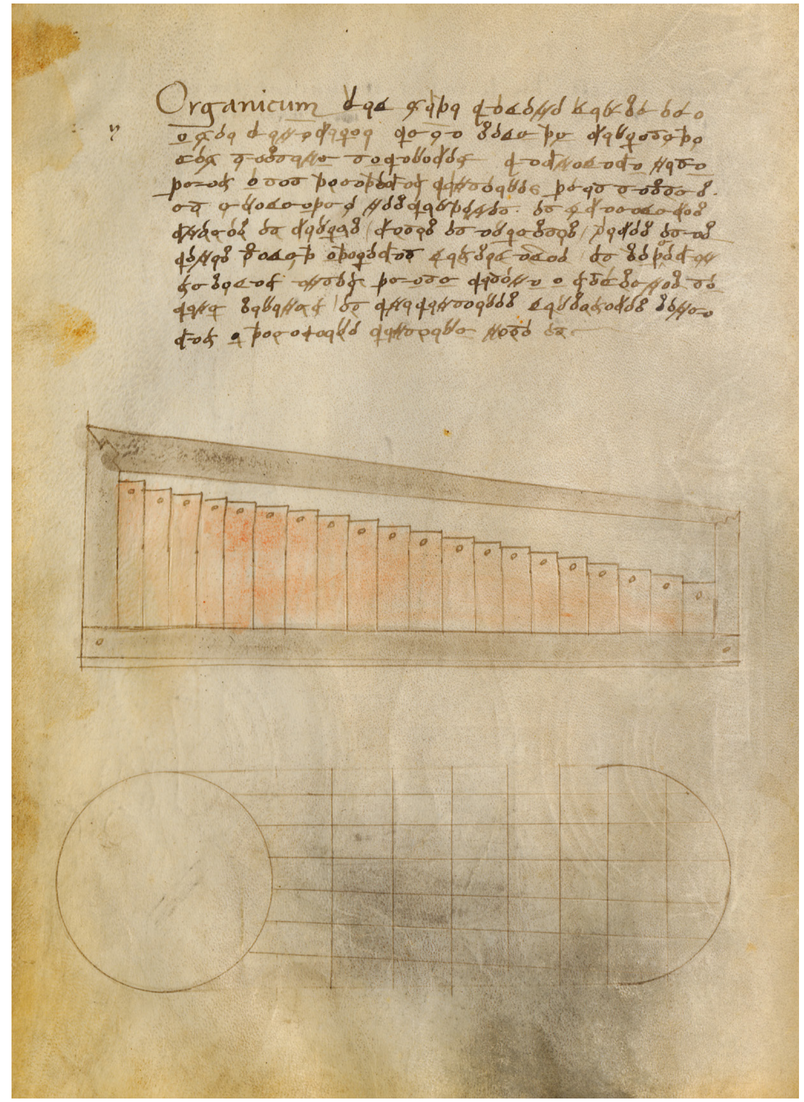

Figure 6.18 Automatic pipe organ illustrated by Fontana in his *Book of Military Machines*. The pinned cylinder is rotated by hand with a crank. By kind permission of Bayerische Staatsbibliothek, Munich.

> [These new] bellows for the organ, of stupendous utility, that I have recently invented and not yet made known, provide an abundant and constant flow of air.
>
> A box is made of wood or metal, hermetically sealed, divided into two parts. In the lower part a great quantity of air is

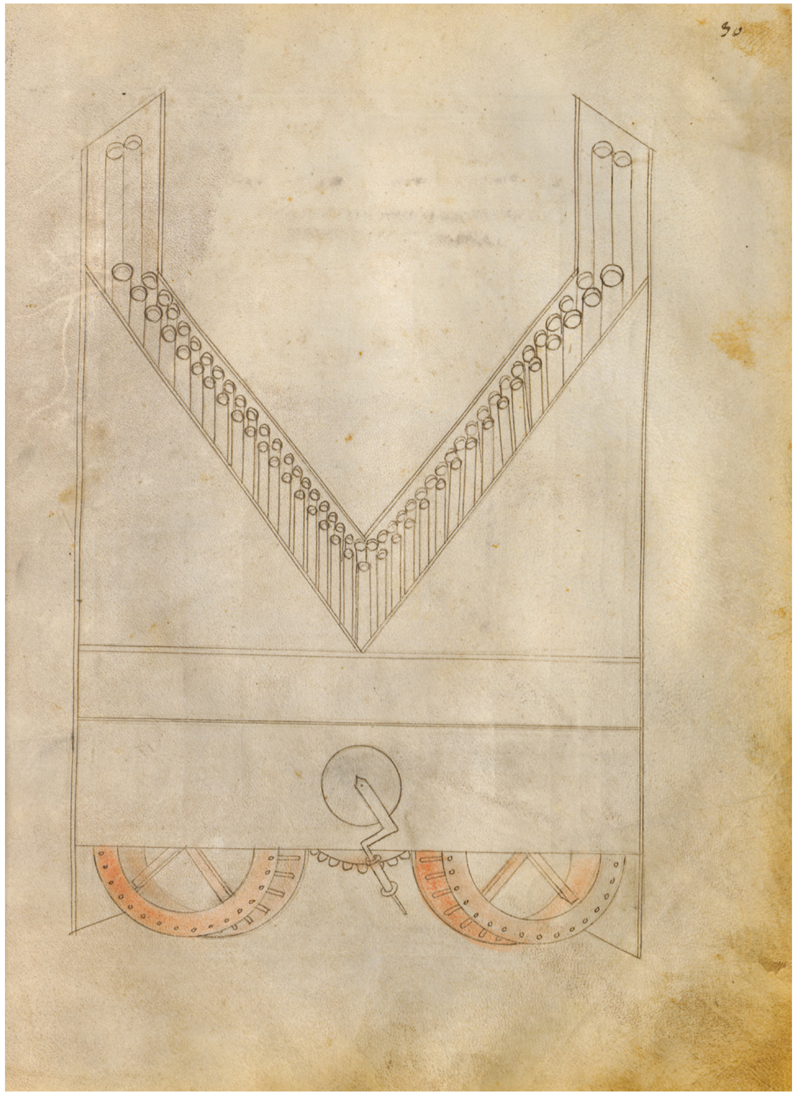

Figure 6.18 Continued

> introduced from the bottom; from here an outlet pipe leads to the organ [wind] chest. Water is poured abundantly into the upper part, which because of its weight descends through a small hole, so that the air below is forced into the organ.[77]

It is clear that this is a type of hydraulis with a tall air compressor or trompe, like those at Tivoli and the Quirinale but invented by

Fontana – if he is to be believed – in the previous century. A mixture of water and air falls from the elevated funnel through the narrowing vertical tube into a tank at the base. The air is held in a reservoir above the water, as in the ancient hydraulis. Compressed air moves up the outer part of the vertical housing and out through a pipe that leads down again to the organ's wind chest. This roundabout route is perhaps to get rid of some of the moisture.

Fontana's drawings of his automatic organ (Figure 6.18) are yet more enigmatic and sketchy. However, they plainly show the organ pipes, and the caption explains what is not otherwise represented graphically.

> In my clock works I have decided to make the ORGAN in this fashion, because I have built a rotating drum as long as the keyboard and I have divided it in as many parts as the keys, so that it matches each of them, and [I have made] teeth that are short and long, wide and narrow, smooth and rough, as required by musical consonance, and I have followed, as much as I could, the art of music in the measures and lengths of the notes, and I have maintained similar proportions in the division of the sections of the drum, etc.[78]

One difference from the late Renaissance organs is that the drum is rotated with a hand crank, not a waterwheel. But otherwise the design is similar.

Did Fontana actually build these instruments? Did he combine the hydraulis and the pinned cylinder to make an automatic water organ? We cannot know. But there are reasons for believing that at least some of the designs we see in his book are not just wild theoretical speculations. Fontana says that he has built his organs in his 'clock works'. The historian of science Frank Prager believes that the clocks in question were likely to have been water clocks, and that Fontana's 'clock works' was probably a workshop for making hydraulic instruments of several kinds.[79]

The modern editors of Fontana's *Military Machines* say that the precedents for these organ drawings are Islamic – as they believe, from twelfth-century sources. But did Fontana know specifically about the work of the Banū Mūsà? He was certainly a scholar of Greek and Alexandrian literature and had read Hero, Philo and Ctesibios as well as the Islamic writers al-Kindī and al-Bīrūnī. There is one more music machine illustrated in the *Military Machines*, labelled 'Reed pipe

Figure 6.19 'Flute sounded by water' from Fontana's *Book of Military Machines*. This closely resembles the hydraulic part of the Banū Mūsà's flute automaton with its two aeolic chambers (compare Figure 6.15). By kind permission of Bayerische Staatsbibliothek, Munich.

(Latin: *fistularum*) sounded by water' (Figure 6.19), that leaves little doubt.[80]

If we compare this picture with Farmer's diagram of the Banū Mūsà's instrument (Figure 6.15) we see striking similarities. Both have the water supply in the tank on top and the two aeolic chambers below. In Farmer's diagram the air supply to the flute is taken off in two tubes, both labelled *X*. Fontana shows two flutes directly attached. In his words: 'The water falls from above into the base, in which is contained air, which arrives at the little tubes and makes them blow; so that he who is skilled in music can create harmony by attaching pipes.' This clearly shows the hydraulic part of the Banū Mūsà flute machine, or something very like it.

A second distant echo of Islamic musical technology is to be found in the writings of a rather better-known Renaissance engineer of the

fifteenth century. In the second of Leonardo da Vinci's two notebooks rediscovered in the National Library of Madrid in the 1960s, there is a short passage running as follows:

> From the fall of spring water we can make harmony, which will sound a *piva* [a type of bagpipe] with many consonances and voices … We will fix our terracotta vessels, and then let a flow of water coming out of the vessels turn a toothed wheel on its axle. These pins open the pipes carrying the water falling from the vessels, as much as is needed, as a hand does on the keys of an organ. And moreover have it fashioned so that it can [also] be played by hand.[81]

Leonardo has a thumbnail sketch of the cylinder with its pins, tripping the levers that control the air supply to the organ pipes or bagpipes (Figure 6.20).[82]

Otherwise there seem to be a few odd and suggestive resonances of the Banū Mūsà's ideas in what Athanasius Kircher and other later Renaissance scholars write about musical automata, which are at least worth mentioning. Like Kircher, the Banū Mūsà recommend that their instruments be accompanied by automaton figures dancing along to the music. They also say that, following the general method used in their flute player, 'it is sometimes proper that we should make an image which plays on the lute … or on an instrument of strings like a psaltery [a kind of harp]'.[83]

In the corner of one of his pictures of organs Kircher includes a strange image of what looks like a rectangular grating being lowered through a triangular grating on a rope controlled by a system of gears and pulleys.[84] This is an automatic harp designed by the English

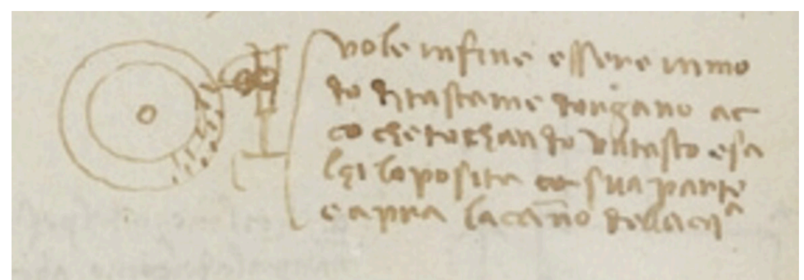

Figure 6.20 Thumbnail sketch by Leonardo da Vinci of a pinned musical cylinder, from Madrid Codex II. Image property of the Biblioteca Nacional de España.

physician, astrologer and mathematician Robert Fludd, mainly known for defending the esoteric philosophy of the Rosicrucians.

Fludd published designs for a number of automated musical instruments in his encyclopaedic work *The Greater and the Lesser Cosmos* of 1617–21.[85] These include water organs modelled on Italian examples. Fludd was possibly acquainted with Cornelis Drebbel and so perhaps knew of the self-playing harpsichords. In Fludd's harp machine (Figure 6.21), the triangular frame carries the harp's strings, the vertical members of the rectangular frame carry quills that scrape the strings as they descend and woollen pads that damp them again.[86] Fludd has other similar automatic devices with frames that play a lute and a peal of small bells.

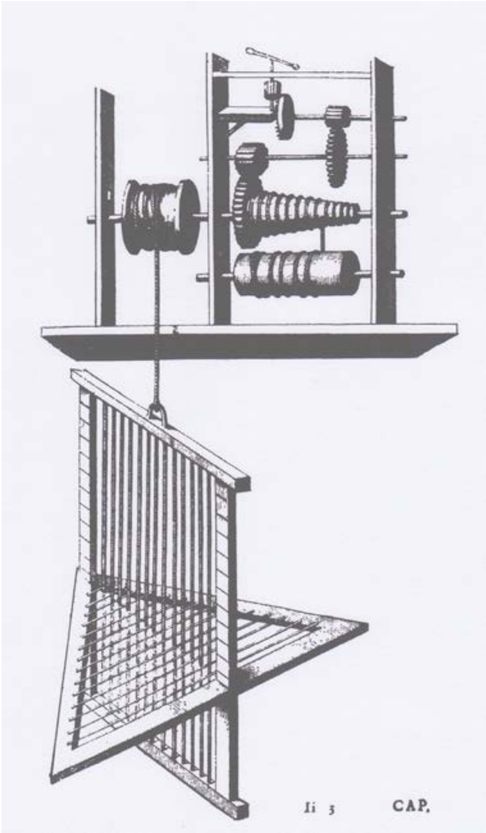

Figure 6.21 Automatic harp designed by Robert Fludd, from *The Greater and the Lesser Cosmos*, 1617–21. The rectangular frame carries plectra that pluck the harp strings, and woollen pads that damp them again.

The Renaissance scholar Joscelyn Godwin has dismissed these instruments as crazed and impractical. As he says sardonically, 'Readers may wish to decide for themselves whether this frame gives a cogent musical result.'[87] One serious drawback with Fludd's harp compared with the pinned cylinder is of course that once the frame has reached the bottom and finished its tune it must be raised back up again, playing the music backwards. As Fludd admits, when this is done 'one will hear something strange and entirely new'.[88] Clearly these ideas of Fludd's never caught on. But that is not the point here, which is to suggest a possible if remote inspiration in the automatic lute and psaltery mentioned by the Banū Mūsà.

Another feature of the Banū Mūsà's flautist that has a parallel in the Renaissance is the way in which several pieces of music could be played in sequence by moving entire cylinders along a common axle. Kircher repeats this idea but in a slightly different form.[89] Many pieces of music, let us say eight, are recorded on the same cylinder by placing eight closely spaced rings of pins on the cylinder, one ring for each tune, and all eight relating to the same organ pipe. Eight more rings relate to the next pipe, and so on. The cylinder then needs to be shifted laterally by only a small distance for all the levers to engage the next set of rings and play the next piece of music. Some cylinders for carillons worked on this principle. Are these similarities enough to justify an argument for a lingering technical influence after six centuries?

The music of the water organ

A final question: what kind of music did the Renaissance water organs play? The evidence is sparse. Cardinal d'Este was a devotee of ancient Greek music – a few pieces of which survived – and funded the publication of a book on the subject by his court musician Nicola Vicentino.[90] Renaissance musical scholars were interested in the hydraulis precisely because it was adapted to this ancient music.

Was the organ at Tivoli programmed to play such pieces? Nicolas Audebert says that the instrument could play just one long composition, divided into five parts. However, he goes on to say that Claude Venard 'also knows the method of making them play all tunes that please him, arranging all the suspended metal bars [linking the drum to the valves] to make them touch the *mesure* that is needed'.[91]

De Caus in *Moving Forces* reproduces a score for a madrigal, 'Chi fara fed' al ciel' ('Who will put faith in the Heavens?') by the composer Alessandro Striggio, arranged for organ by Peter Philips, a contemporary keyboard virtuoso.[92] This is the piece that is programmed on the pinned cylinder in Figure 6.7. De Caus explains how holes are drilled in every grid position on the drum to allow the pins to be rearranged for other musical compositions. As mentioned, the length of pieces suitable for the organ was limited by the circumference of the drum – just as popular songs were constrained in the twentieth century to three or four minutes by the 10-inch gramophone disc.

Athanasius Kircher gives scores for a number of organ works in *Universal Music-Making*, together in some cases with transcriptions onto grids for transfer to cylinders.[93] These include a piece of 'Pythagorean music to the rhythm of hammers', with lyrics, no doubt to be performed by his Pythagorean organ and its animated forge of Vulcan. He says that he prefers his own organ music to be accompanied by singers making 'appropriate leaps and gestures' like his dancing automata. But according to Patrizio Barbieri in his very thorough history of the Quirinale organ, it is not possible to be certain from Kircher about what music that instrument actually played.[94] As for quality of sound, the modern reconstruction of the organ at the Villa d'Este has something of the mechanical flavour of a Victorian fairground steam organ, but with less force.

Tonotechnics

In the late eighteenth century a French monk, Joseph Engramelle, published what seems to have been the first book – and perhaps the only one ever written – on the art of creating pinned musical cylinders, *Tonotechnics*.[95] Certainly Father Engramelle says that his subject is one that has previously been 'hidden behind a shadow of mystery and secrecy'.[96] The book's frontispiece (Figure 6.22) serves to encapsulate in one image the entire history recounted in this chapter. By this date the technical processes have become routine. The craftsman on the right has a roll of paper on a cylinder and is using a keyboard to impress marks in the positions where pins will be inserted. The craftsman at the left (or is it a woman?) uses another revolving device to mark the notes for a *serinette* – a special type of musical box used to teach tunes to canaries and parrots.

Automatic instruments surround the two workers, all of them driven by clockwork. At the back of the room above the door is a

Figure 6.22 Frontispiece from Father Joseph Engramelle's *Tonotechnics*, 1775. Around the room are several automated musical instruments powered by clockwork: a pipe organ over the door, a clock with a carillon in the window, a self-playing harpsichord and a mechanical flute player.

mechanical pipe organ. In the window reveal is a clock with a small carillon to ring the hours. At front right is a self-playing harpsichord, perhaps something like the prototype instrument that Drebbel demonstrated in the 1620s but without the solar power; and behind this is an automated figure of a flautist. For Parisian readers of the eighteenth century this would have evoked Jacques Vaucanson's famous flute-playing automaton of 1737, the greatest achievement of his brilliant career. For us it will carry distant echoes of the Banū Mūsà.

Notes

1 Cardinal d'Este, for whom the gardens were made, had spent time at the French court in the 1530s, so it is possible that he had learned about Leclerc through that connection.
2 G. M. Zappi, *Annali e Memorie di Tivoli*, 1580, ed. V. Pacifici (Tivoli: Studi e Fonti per la storia della Regione Tiburtina, 1920); quoted in Antonio Latanza, 'The Hydraulic Organ', *Music and Automata from Horology to Mechanical Instruments*, 4/14 (July 1990): 305.
3 Hero of Alexandria, *Libro degli artifizii spiritali di fiato d'Herone Alessandrino*, 1582, trans. into Italian by Oreste Vannocci Biringucci, ms L.V.44, Biblioteca degli Intronati, Siena: folio 75r. Trans. into English by Matteo Valleriani, and published in Simone M. Kaiser and Matteo Valleriani, 'The Organ of the Villa d'Este in Tivoli and the Standards of Pneumatic Engineering in the Renaissance', in H. Fischer, V. R. Remmert and J. Wolschke-Bulmann (eds), *Gardens, Knowledge and the Sciences in the Early Modern Period* (Basel: Birkhäuser, 2016), pp. 77–102.
4 Michel de Montaigne, *Journal du Voyage de Michel de Montaigne en Italie, par la Suisse et l'Allemagne, en 1580 et 1581*. English translation by W. G. Waters, 3 vols (London: John Murray, 1903), vol. 2, p. 169.
5 David Dernie, *Villa d'Este at Tivoli* (London: AD Academy Editions, 1996), p. 69.
6 Besides the organs at the Villa d'Este (1572), the Villa di Pratolino, Florence (1569–80) and the Palazzo del Quirinale in Rome (1598), there were others at the Isola Belvedere at Ferrara (1599), the Villa Aldobrandini at Frascati (c.1620), the Palazzo Reale in Naples (1746) and the Villa Pamphilj in Rome (1758–9).
7 Vitruvius, *De Architectura* [*The Ten Books on Architecture*], trans. Ingrid D. Rowland (Cambridge: Cambridge University Press, 1999), p. 116.
8 Vitruvius, *Ten Books*, p. 125.
9 C. F. Abdy Williams, *The Story of the Organ* (London: Walter Scott, and New York: Scribner's, 1903), p. 14.
10 Abdy Williams, *The Story of the Organ*, p. 13.
11 *The Pneumatics of Hero of Alexandria* (London: MacDonald, and New York, Elsevier, 1971): facsimile of edition by Bennet Woodcroft (London: Taylor, Walton and Maberly, 1851), Theorem 76, pp. 105–6.
12 *Pneumatics of Hero*, Woodcroft edition, Theorem 77, p. 108.
13 Abdy Williams, *Story of the Organ*, p. 5.
14 Henry George Farmer, *The Organ of the Ancients from Eastern Sources* (London: William Reeves, 1931), pp. 127–36, where Farmer provides a translation of the Mauristos manuscript. Apparently Roger Bacon made a Latin translation in the thirteenth century. See also Paul Tannery and Baron Carra de Vaux, 'L'Invention de l'hydraulis', *Revue des Études Grecques*, 1 (1908), fascicule 93–4: 326–40. Philo dedicates several of his works including the *Pneumatics* to Mauristos, otherwise Ariston.
15 Farmer, *Organ of the Ancients*, p. 133.
16 F. W. Galpin describes his hydraulis in the foreword to Farmer's *Organ of the Ancients*, pp. vii–viii. See also Abdy Williams, *Story of the Organ*, Appendix B, pp. 210–12, 'The Rev. F. W. Galpin's Hydraulus', which contains photographs. Several other reconstructions have been made more recently and can be seen in action in videos online. A hydraulis was played at the Athens Olympic Games of 2004.
17 Galpin in Abdy Williams, *Story of the Organ*, p. 212.
18 http://odysseus.culture.gr/h/1/eh155.jsp?obj_id=3264.
19 Farmer, *Organ of the Ancients*, p. 32.
20 Vitruvius, *Ten Books*, Rowland translation, pp. 126–7.
21 R. W. Lightbown, 'Nicolas Audebert and the Villa d'Este', *Journal of the Warburg and Courtauld Institutes*, 27 (1964): 164–90.
22 Patrizio Barbieri, 'The New Water Organ at the Villa d'Este, Tivoli', *The Organ Yearbook*, 33 (2004): 33–41, see 34, Figure 1; reproduced from Marco Tiella, *L'Officina di Orfeo: Tecnologia degli Strumenti Musicali* (Venice: Il Cardo, 1995).
23 The translation of Hero's *Pneumatics* by Oreste Vannocci Biringucci (1572). See Biringucci's addendum on the organ at Tivoli in Kaiser and Valleriani, 'The Organ of the Villa d'Este', Appendix 2, pp. 97–100.
24 Salomon de Caus, *Les Raisons des Forces Mouvantes, Avec diverse Machines tant utiles que plaisantes; Ausquelles sont adjoints plusieurs desseins de Grotes & Fontaines* (Paris: Hierosme Droüart, 1624).
25 Luke Morgan, *Nature as Model: Salomon de Caus and Early Seventeenth-Century Landscape Design* (Philadelphia: University of Pennsylvania Press, 2007), pp. 42–5.
26 See Lightbown, 'Nicolas Audebert', pp. 185–6.
27 These features are shown in a drawing in Carl Lamb, *Die Villa d'Este in Tivoli: Ein Beitrag zur Geschichte der Gartenkunst* (Munich: Prestel Verlag, 1966), p. 54.
28 Biringucci, *Libro degli artifizii*, folios 71v, 72r. I do not find the interpretation of the functioning of the instrument made by Kaiser and Valleriani ('Organ of the Villa d'Este'), on the basis of Biringucci's manuscript, very convincing. They talk about a 'choking vessel' with a purpose that is unclear to me (is this the aeolic chamber?), and do not discuss the way in which the water/air mixture is compressed in the vertical supply pipe.
29 Vannoccio Biringuccio, *Pirotechnia* (Venice: Curtio Nauo & Fratelli, 1540). I have used the translation by Cyril Stanley Smith and Martha Teach Gnudi (New York: American Institute of Mining and Metallurgical Engineers, 1942; reprinted New York: Dover, 1990).
30 Trompes are not however mentioned in *Pirotechnia*, so far as I can see.
31 Giovanni Branca, *Le Machine* (Rome: Jacomo Mascardi, 1629), pp. 18–19, Figures 19 and 29.
32 Lightbown, 'Nicolas Audebert', p. 185.
33 Biringucci, *Libro degli artifizii*, folio 73v.
34 Audebert (p. 185 in Lightbown, 'Nicolas Audebert') says that the protruding pins and fins were made of metal: Biringucci says they were of wood (*Libro degli artifizii*, folio 73r).
35 Giovanni Battista della Porta, *Pneumaticorum Libri Tres* (Naples: Io. Iacobum Carlinum, 1601), Book 3, pp. 60–1.
36 De Caus, *Forces Mouvantes*, Book I, Problem XXVIII.
37 De Caus, *Forces Mouvantes*, Book I, Problem XXX.
38 De Caus, *Forces Mouvantes*, text accompanying Book I, Problem XXX.
39 De Caus, *Forces Mouvantes*, Book I, Problem XXXIIII.
40 De Caus, *Forces Mouvantes*, Book I, Problem XXXI.
41 For detailed histories see Patrizio Barbieri, 'L'Organo Idraulico del Quirinale', *L'Organo*, 19 (1981): 7–61; and Simona Antellini Donelli (ed.), *La Fontana dell'Organo nei Giardini del Quirinale: Nascita, Storia e Trasformazioni* (Rome: Fratelli Palombi, 1995).
42 Heinrich Schickhardt, *Voyage en Italie/Reis in Italien (Novembre 1599 – Mai 1600)*, ed. André Bouvard, parallel text in French and German (Conseil Régional de Franche-Comté et du Ministère des Affaires Européennes, n.d.), pp. 116–17 in French and pp. 289–90 in German.
43 Barbieri, 'L'Organo Idraulico': 15.
44 Athanasius Kircher, *Musurgia Universalis sive Ars Magna Consoni et Dissoni* (Rome: 1650), vol. 2, pp. 308–51. Also Joscelyn Godwin, *Athanasius Kircher's Theatre of the World* (London and New York: Thames and Hudson, 2009), chapter 9, 'Music'.
45 http://www.phonozoic.net/paleospectrophony3.html.

46 Athanasius Kircher, *Musurgia Universalis sive Ars Magna Consoni et Dissoni* (Rome: 1650), vol. 2, p. 309, and Figure 1 in Iconismus XVIII, facing p. 311.
47 Kircher, *Musurgia Universalis*, Iconismus XXI, facing p. 343.
48 De Caus, *Forces Mouvantes*, Book II, Problem XVIII.
49 Kircher, *Musurgia Universalis*, vol. 2, Iconismus XV, facing p. 264.
50 Kircher, *Musurgia Universalis*, vol. 2, Iconismus XXII, facing p. 346.
51 Kaspar Schott, *Magiae Universalis Naturae et Artis* (Bamberg: Joannis Arnoldi Cholini, 1674), Part II, Book VI, p. 334.
52 G. A. Sabelli, *La Guida Sicura del Viaggio d'Italia* (Geneva: Herman Widerhold, 1680), p. 277: my translation.
53 See Barbieri, 'The New Water Organ': 33–41; and Antonio Latanza, *Il Ripristino dell'Organo Idraulico del Qurinale* (Rome: Istituto Poligrafico e Zecca dello Stato, 1995). There are numerous online videos of the Villa d'Este organ in operation. Eight sixteenth- and seventeenth-century pieces have been recorded on two pinned cylinders, and are played hourly on the hour.
54 See Morgan, *Nature as Model*, for de Caus's biography and works. De Caus's activities in England and Heidelberg are also described in Roy C. Strong, *The Renaissance Garden in England* (London: Thames and Hudson, 1979), chapter 4.
55 Morgan, *Nature as Model*, pp. 54–5.
56 Rosalie L. Colie, 'Cornelis Drebbel and Salomon de Caus: Two Jacobean Models for Salomon's House', *Huntington Library Quarterly*, 18/3 (May 1955): 245–60; see 248. Also G. Tierie, *Cornelis Drebbel (1572–1633)* (Amsterdam: H. J. Paris, 1932), pp. 25–6.
57 Tierie, *Cornelis Drebbel*, p. 45.
58 Manuscript diary (16 March to 24 July 1610) of Hans Jacob Wurmsser von Vendenheym in the British Library, Add MS 20001: see *Illustrated London News* (28 February 1857), p. 192. Also William Brenchley Rye, *England as Seen by Foreigners in the days of Elizabeth and James the First* (London: John Russell Smith, 1865), p. 61.
59 Epistola Cornelii Drebbelij ad Regem Angliae, *Journael van Js. Beeckman*, Fol. 294^{v} – 295^{v}, 15^{e} Meerte 1631; and British Library, Harleian Ms 7011, Folio 56: both transcribed in F. M. Jaeger, *Cornelis Drebbel en Zijne Tijdgenooten* (Groningen: Noordhoff, 1922). The translation from the Latin here is by Gregorio Astengo.
60 Tierie, *Cornelis Drebbel*, p. 45.
61 Constantijn Huygens, *Mijn Jeugd*, ed. C. L. Heesackers (Amsterdam: Em Querido's Vitgeverij, 1987), pp. 130–1; translation by Gregorio Astengo. Drebbel's instrument is also mentioned by John Wilkins, *Mathematicall Magick: Or, the Wonders That May Be Performed by Mechanical Geometry* (London: Gellibrand, 1648, 2nd edn 1680), pp. 148–9 (2nd edn).
62 Philip Steadman, 'The Thermoscope and Perpetual Motion: Philo, Hero, Leonardo and Drebbel', paper to Leonardo da Vinci Society conference on 'Perpetual Motion', The Royal Institution, London (February 2020).
63 De Caus, *Forces Mouvantes*, Book I, Problem XXXVI. The organisation of the book goes haywire here. The running heads say 'Livre second' before Book II begins; and the illustration for this Problem faces the text for Problem III in Book II.
64 Athanasius Kircher, *Œdipus Ægyptiacus*, 3 vols (Rome: 1652–4), vol. 2, ii, p. 326. See Godwin, *Theatre of the World*, p. 180 and Figure 10.2. Godwin describes Kircher's explanation as 'somewhat desperate'.
65 Vitruvius, *I Dieci Libri dell' Architettvra di M. Vitruvvio*, trans. Daniele Barbaro (Venice: Francesco Marcolini, 1556), p. 266 and plate 69.
66 Kircher, *Musurgia Universalis*, Book IX, pp. 330–3 and Figure on p. 333 showing Kircher's reconstruction.
67 Henry Heathcote Statham, 'Carillon', in George Grove (ed.), *A Dictionary of Music and Musicians* (London: Macmillan, 1900), pp. 310–12.
68 Statham, 'Carillon', p. 311.
69 In the Klok & Peel Museum, Asten, Holland. On the other hand, large and heavy cylinders had the advantage that their speed of rotation was reasonably constant; and cylinders with large diameters allowed for longer pieces of music.
70 The manuscript dates from the twelfth century. A copy was held at the School of the Three Moons in Beirut in the nineteenth century and was photographed by Louis Gheikho for an article published in 1906. The manuscript has since been lost and only the photographs remain, at the Bibliothèque Orientale of the Université Saint-Joseph, Beirut. No other copy is known. A complete English translation is given by Farmer, *Organ of the Ancients*, pp. 88–114, with Farmer's diagrams. A partial translation into German was made by Eilhard Wiedemann in 'Ueber Musikautomaten bei den Arabern', *Centenario della Nascita di Michele Amari* (Palermo: Virzi, 1910), vol. 2, pp. 164–85. The nineteenth-century French scholar Baron Carra de Vaux refers to two ancient letters to Mouristos (Ariston) on the construction of a 'flute organ' and a 'trumpet organ', in the library of Hagia Sophia in Istanbul; but I have not tried to follow these up.
71 René R. Khawam, 'Les statues animées dans les Mille et Une Nuits', *Annales: Économies, Sociétés, Civilisations*, 30/5 (1975): 1084–1104.
72 Mona Sanjakdar Chaarani, 'L'orgue hydraulique des Banu Mûsa', online at http://www.muslimheritage.com/article/hydraulic-organ-of-banu-musa. As well as detailed drawings of the entire machine, this has a link to a computer animation.
73 Farmer, *Organ of the Ancients*, p. 99, Figure 8.
74 Farmer, *Organ of the Ancients*, p. 109.
75 Farmer, *Organ of the Ancients*, pp. 109–10.
76 In 2015–16 an exhibition 'Allah's Automata: Artifacts of the Arab-Islamic Renaissance (800–1200)' was held at the Center for Art and Media Karlsruhe (ZKM) in Karlsruhe, Germany. The catalogue, ed. Siegfried Zielinski and Peter Weibel (Ostfildern: Hatje Cantz, 2015), reprints the Banū Mūsà manuscript in Farmer's version and a new German translation, along with Chaarani's paper, and details of a reconstruction of the Banū Mūsà instrument shown at the exhibition.
77 Giovanni Fontana, *Bellicorum instrumentorum liber cum figuris* [*Military Machines*], ms c.1420, Bavarian State Library, BSB Cod.icon.242, 56v/57r. See Eugenio Battisti and Giuseppa Saccaro Battisti, *Le Macchine Cifrate di Giovanni Fontana* (Milan: Arcadia, 1984), p. 92. Translation by Gregorio Astengo.
78 Fontana, *Military Machines*, 29v/30r. Translation by Gregorio Astengo.
79 Frank D. Prager, 'Fontana on Fountains: Venetian Hydraulics of 1418', *Physis, Rivista Internazionale di Storia della Scienza*, 13/4 (1971): 345.
80 Fontana, *Military Machines*, 48v. Eugenio Battisti and Giuseppa Saccaro Battisti, *Le Macchine Cifrate di Giovanni Fontana* (Milan: Arcadia, 1984), p. 87, say that this drawing is 'too schematic to allow a functional analysis'. They do not recognise it as the Banū Mūsà machine.
81 Leonardo da Vinci, Madrid Codex II, folio 55r. Leonardo makes a note to himself to 'Ask Messer Marcello about the sound made with the water from Vitruvius.' This was a Florentine scholar Marcello Virgili di Adriano Berti.
82 I have reversed this image left to right so that Leonardo's mirror writing is more legible.
83 Translation by Farmer, *Organ of the Ancients*, pp. 107–8.
84 Kircher, *Musurgia Universalis*, vol. 2, p. 334.
85 Robert Fludd, *Utriusque Cosmi Maioris scilicet et minoris Metaphysica, Physica Atque Technica Historia* (Oppenheim: Johann Theodor de Bry, 1617–21). Music is covered in vol. 2 (1618), pp. 159–258.
86 Fludd, *Utriusque Cosmi*: the complete automatic harp is illustrated in vol. 2 on p. 253, and the descending frame on p. 249. Water organs are shown on pp. 483–4.
87 Joscelyn Godwin, 'Instruments in Robert Fludd's Utriusque Cosmi … Historia', *The Galpin Society Journal*, 26 (May 1973): 2–14; see p. 4.
88 Fludd, *Utriusque Cosmi*, p. 258, cited in Godwin, 'Instruments': 7.
89 Kircher, *Musurgia Universalis*, p. 320.
90 Dernie, *Villa d'Este*, p. 64. Nicola Vicentino's book was *L'Antica Musica Ridotta alla Moderna Prattica* (Rome: 1555). It is doubtful however whether such pieces could have been played on the water organ.
91 Lightbown, 'Nicolas Audebert', p. 186 and note. My translation.
92 De Caus, *Forces Mouvantes*, Book I, Problem XXX. Striggio composed music for the Florentine *intermezzi*.
93 Kircher, *Musurgia Universalis*, pp. 324–46. John Evelyn translates these passages and reproduces them more or less in full in his manuscript on gardening, *Elysium Britannicum, or the Royal Gardens*, unpublished until the twenty-first century, ed. John E. Ingram (Philadelphia: University of Pennsylvania Press, 2001), see pp. 232–42. It is amusing to

see how Evelyn at first credits Kircher repeatedly, and later goes through the manuscript crossing the name out, embarrassed by the extent of his borrowing.

94 Barbieri, 'L'Organo Idraulico', p. 28.

95 Joseph Engramelle, *La Tonotechnie ou L'Art de Noter les Cylindres* (Paris: Delaguette, 1775). Engramelle also provided examples of scores for automated organs, for a book by Dom François Bedos de Celles, *L'Art du Facteur d'Orgues* (Paris: Delatour, 1766–78).

96 Engramelle, *La Tonotechnie*, p. i.

Part III
A garden and an opera

7

The 'garden of marvels' at Pratolino

At the start of the book we followed the work of Bernardo Buontalenti as stage designer at the Uffizi Theatre in the 1570s and 1580s. In those decades he was simultaneously designing gardens and grottoes for the Medici, including the Grotta Grande at the Boboli Gardens in Florence. The two activities were not completely disparate. The grottoes were separate little theatrical scenes in themselves, often featuring characters from classical mythology, as were the *intermezzi*.

The play with which the Uffizi Theatre opened in 1586, in the presence of the Grand Duke Francesco, was the comedy *L'Amico Fido*. The third *intermezzo*, designed by Buontalenti, was called 'The Inauguration of Eternal Spring'. The scene opened on an arid hilly landscape where the trees had no leaves and the fields were bare.[1] Then Zephyr, god of gentle breezes, Flora, goddess of flowers, and Primavera, goddess of spring, appeared, and all at once the streams flowed, the fields turned green and the trees started to sprout leaves in full sight. Many in the audience would have recognised this as an allegory of Francesco's great garden at Pratolino outside the city, also designed by Buontalenti, which was just then nearing completion.[2]

Pratolino is in the foothills of the Apennines, some 10 kilometres north of Florence. In 1569 Francesco bought the site for a palatial villa to which the court could move in the summer months – a kind of Tuscan Versailles, where he could escape his obligations in the city. With Buontalenti he planned a garden that would be full of water effects to rival the Villa d'Este and the Villa Lante; but unlike the sites of those two gardens, the land at Pratolino was dry. Montaigne, who visited in 1580, said it seemed that Francesco 'had advisedly selected an inconvenient, sterile and monotonous site … there is no water – in order that he might have the honour of fetching the same from five miles' distance'.[3] Francesco had to have an aqueduct and reservoirs built at huge expense. An English visitor said that he paid more for his water than his wine.[4]

The site is gently sloped towards the south, with a long view back towards Fiesole and Florence. Pratolino means 'little meadow', and there were indeed meadows with wildflowers; but most of the land was wooded. Because of the elevation, the gardens offered a retreat from the summer heat, a cool refuge of shade and recreation. In place of the dusty cypresses, pines and olives of the city there were oaks and fir trees. Cesare Agolanti wrote a long poem in which he described Pratolino as enjoying 'always flowery and verdant April'.[5]

Planning and construction of the villa and gardens continued under Buontalenti's direction for the next 15 years. In 1578 Francesco's first wife, Joanna of Austria, died and he married his adored Venetian mistress Bianca Cappello, a ruthless and ambitious beauty who had fled to Florence with her unsuitable young husband. There she had caught the eye of Francesco and he had seduced her; meanwhile the husband was murdered with Francesco's tacit connivance. These events meant that Francesco and Bianca were unpopular with the Florentines, a dislike exacerbated by Francesco's harsh and melancholy personality. The most secluded rooms at Pratolino became a private haven for the couple: as a contemporary wrote, the Grand Duke was 'inaccessible and almost always withdrawn into these grottoes and fountains with his grand-duchess, more than ever the object of his favours'.[6] They were only able to enjoy the completed villa for a few years, however: they died on successive days in 1587.

The gardens were filled with fountains, statues, games and bathing places. There were more than a dozen grottoes, most of which featured theatres of automata. Some of the figures seemed to play musical instruments. Mechanical birds sang their characteristic tunes. There were two water organs. Above all there was water, everywhere, even running in huge quantities through the ground floor of the villa itself, where half of the grottoes were. Montaigne said: 'The beauty and splendour of this place cannot be set forth properly by details.'[7] Modern critics have called Pratolino a theme park, a kind of Renaissance Disneyland.

Today, however, almost all these 'marvels' have disappeared, the villa is gone and the park is much changed; so we have to try to reconstruct them in the imagination from contemporary sources. In 1587, the year that Duke Francesco died, Francesco de' Vieri published a description *Of the Marvellous Works of Pratolino*.[8] De' Vieri talked for an hour with Buontalenti and was helped in the writing by Buontalenti's son Francesco. In the eighteenth century Bernardo Sansone Sgrilli produced a guidebook, *Description of the Royal Villa, Gardens and Buildings of Pratolino*, illustrated with engravings by Stefano della Bella.[9] Later accounts tend to rely heavily on these two sources, and so will I. Numerous visitors came and noted their impressions in their travel diaries, of whom Montaigne was one of the first and the Marquis de Sade – possibly – one of the last. Artists made drawings, engravings and paintings. And the German engineer Heinrich Schickhardt, whom we have already met, was able to gain access to some of the machinery and make notes and technical drawings.[10]

The layout of the gardens

In about 1600 a Flemish artist, Joos Utens, painted a series of semicircular pictures ('*lunettes*') showing bird's-eye views of Medici villas and their gardens. We can use Utens's painting of Pratolino (Figure 7.1) to orient ourselves and understand the layout of the park. The villa itself was on four storeys, the ground floor much larger than those above, creating a wide terrace at first-floor level. Externally the architecture was plain, with rendered walls and window and door surrounds of grey sandstone. The design was notable mainly for the ingenuity of its plan, which consisted of three linked blocks in a T-shape, so that most rooms in this very large building could have views over the gardens.

The whole estate was surrounded by a wall and was divided into two halves, north and south of the house, of which in Utens's picture we see just the southern half. Here much of the park was wooded, with brick paths criss-crossing through the trees leading to pools, fountains and other small buildings. The land was uneven and undulating, and there was no terracing. On the central axis was a wide avenue set to grass, shown in the eighteenth-century engraving by Stefano della Bella (Figure 7.2).[11] (Della Bella's engravings have a hard, scratchy quality, and his trees are all firs. One can imagine that the mixed conifers and broadleaved trees gave a softer and lighter feel than this, as they do today.) The avenue was lined on both sides with angled jets that made arching parabolas of spray under which one could walk, and which – with the sun in the right direction – created artificial rainbows. John Evelyn, who visited in 1645, described this 'large Walk':

> at the sides whereof gushes out of imperceptible pipes, couched under neath, slender pissings of water, that interchangeably fall

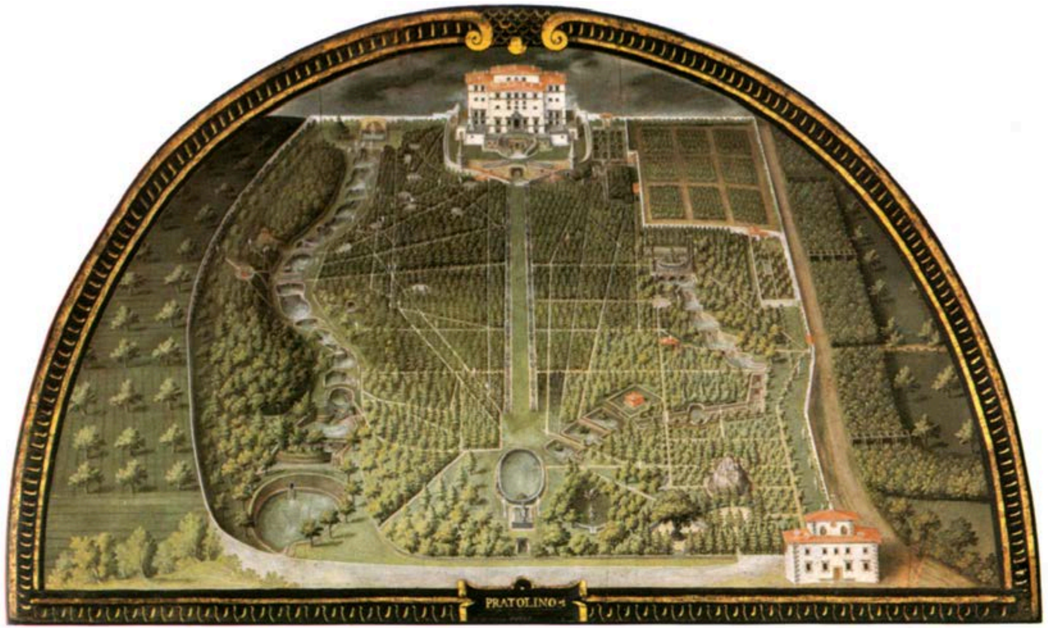

Figure 7.1 Painting of the villa at Pratolino and the southern half of the park, by Joos Utens, c.1600. Wikimedia Commons, Pratolino utens.

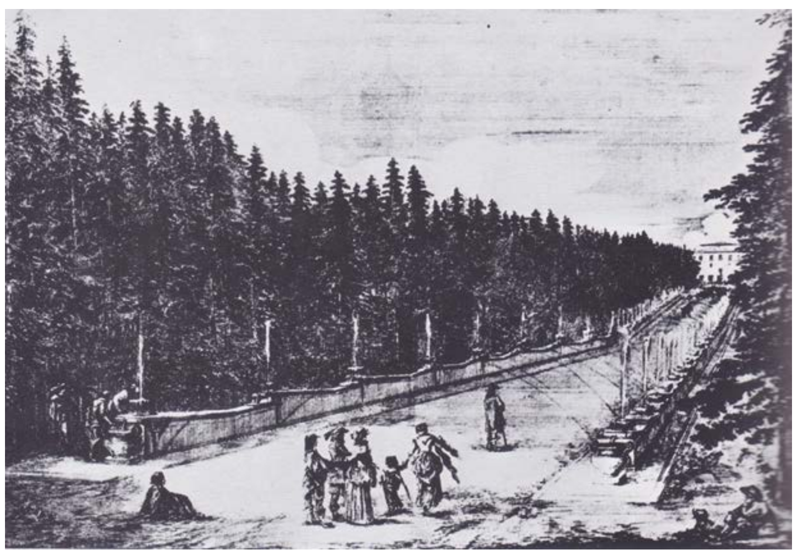

Figure 7.2 The central grassy avenue to the south of the villa with its arching vault of spray: engraving by Stefano della Bella from Sgrilli's guidebook of 1742.

> into each others Chanells, making a lofty & perfect arch, so as a man on horseback may ride under it and not be wet with one drop … this Canopi or arch of Water, was me thought one of the surprizingest magnificences I had ever seene, & exceedingly fresh during the heate of summer ….[12]

Francesco and Buontalenti had travelled together to Spain in the 1560s: they may have found inspiration for these effects in the very similar angled jets that shoot water across pools in the Generalife gardens in Granada.[13] Looking south down this avenue from the villa one would have seen a diminishing theatrical perspective, framing the distant prospect of Florence.

At the east and west sides of the park there were sequences of ponds stepping down the slope (Figure 7.3). Most of these were for raising fish and crayfish for the grand duke's table. But there were also swimming places. De' Vieri describes a pool whose sides were decorated with coloured mosaic.[14] On the banks were small fountains that sprayed the bathers with 'rain' on hot days. There were steps down into the water. Another swimming pool, the Fishpond of the Mask, took its name from a statue of a male figure with a stern expression. This face looked out over a rectangular pond with a sloping bottom where one could bathe among the fish.[15] There was a dressing room supplied with hot water.

Both halves of the park, north and south, are shown in the anonymous woodcut of Figure 7.4, which dates from around 1588.[16] The central avenue and the chains of fishponds appear again in the foreground. The first-floor terrace is reached from the avenue by the curved staircases. Adjoining the palace on the north side – beyond the building in this view – was a grassy meadow, a *pratolino*, which was lined with statues of ancient heroes, and was terminated at the far end by a semicircular pond. At the very top of the garden was a labyrinth of laurels with an octagonal pergola at its centre.

Francesco's guests could hunt in the woods, although he himself preferred fishing. There were plantations of topiarised trees in rows covered with nets for catching small birds for the table. Besides game, animals of other kinds roamed freely including peacocks, gazelles, a porcupine and even, according to one account, ostriches – which seems improbable.[17] There were swans and ducks on the ponds, and more exotic birds in an enclosed aviary.

The existing trees were supplemented with new plantings of beech, spruce, larch, fruit trees and the first horse chestnuts to be introduced to Italy. There were evergreen shrubs and climbers including box, myrtle,

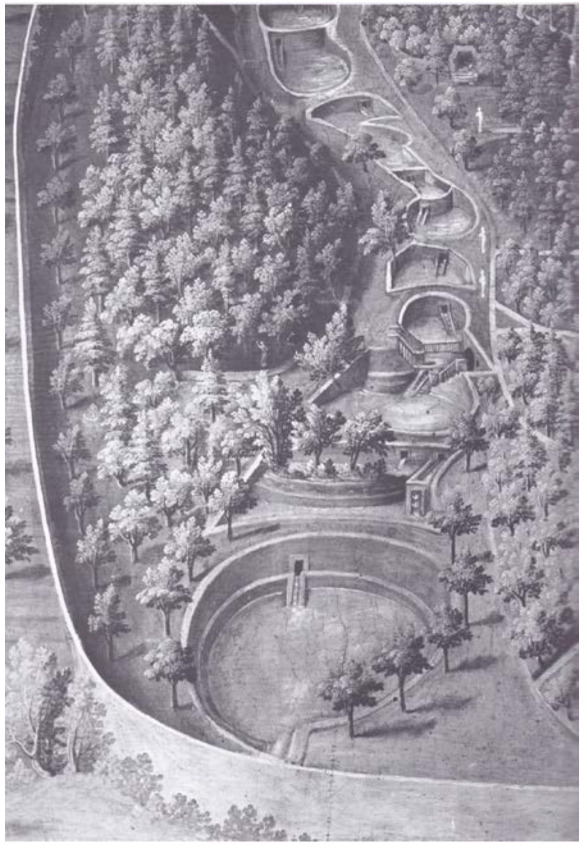

Figure 7.3 Fishponds and swimming places in the south-east corner of the park: detail from Utens's painting of Figure 7.1.

laurel and ivy. A walled 'secret garden' attached to the villa at the east had formal flowerbeds of rare species. If the wildflowers in the *pratolini* were anything like those of the Tuscan hills today, they could have included clover, vetch and wild varieties of cyclamen, gladiolus and orchid.

One of the great old oaks standing in the park was turned into a treehouse by the addition of two wooden spiral staircases around the trunk. These led to a platform in the branches with seats and a table. There are two pictures of this Fountain of the Oak (Figure 7.5), one by della Bella, the other by Giovanni Guerra, who made sketches of many of the fountains and grottoes at Pratolino sometime around 1600. Guerra's drawing is less realistic but more informative. Both artists show the fountains and benches that surrounded the tree in an octagon at ground level. There was another fountain at the centre of the table up above, on

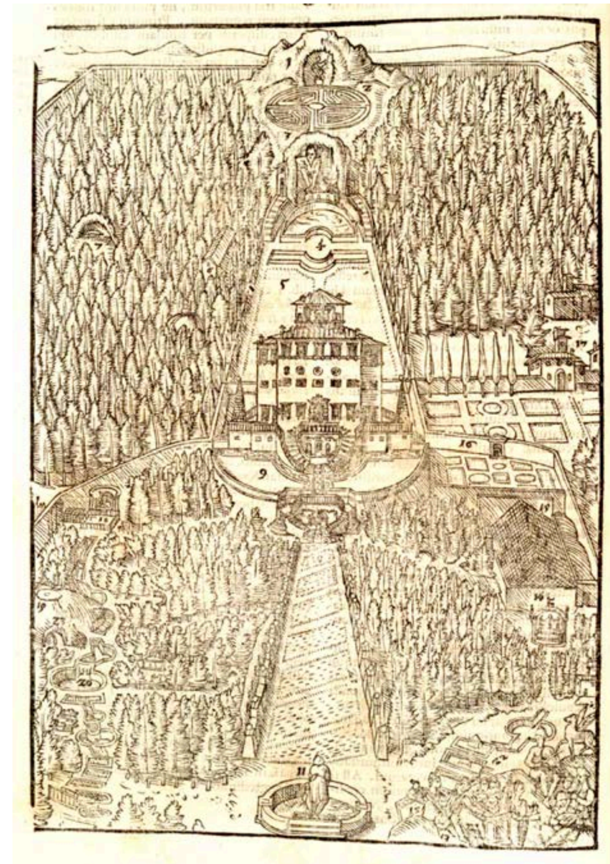

Figure 7.4 The whole of the park including both southern and northern halves, shown in an anonymous woodcut from *Ad Annales Sardiniae*, c.1588. 1) Fountain of Jove; 2) Labyrinth; 3) Appennino; 4) Pond below Appennino; 5) Meadow. The entrance to the grotto complex on the ground floor of the palace is between the curving stairs.

which it seems one could play water games. The sculptor Niccolò Tribolo had designed a very similar treehouse some years earlier at Castello, another Medici garden. This too had a fountain in a table. Montaigne saw it, and wrote that 'By a certain device the water made music.'[18]

The fountains and statues

The many fountains were very varied in the symbolism of their statuary, some of the subjects drawn from classical mythology, others depicting

Figure 7.5 The Fountain of the Oak in two views: left, by Stefano della Bella from Sgrilli's guidebook of 1742; right, by Giovanni Guerra. Creative Commons: echo.mpiwg-berlin.mpg.de/MPIWG:7WEBAFQ9, Plate 6. Guerra's originals are in the Albertina Museum, Vienna.

ordinary workingmen and women. In the first category there were figures of Jove wielding a golden bolt of lightning, accompanied by a black eagle; Pegasus and the nine Muses; Perseus standing over a snake; and Aesculapius, the Greco-Roman god of medicine. In the second group there was a peasant cutting reeds, another emptying a barrel and a larger-than-life-size washerwoman, wringing out wet clothes. Evelyn thought that this last figure was the invention of 'M. Angelo Buonarotti' (i.e. Michelangelo, who had died two decades earlier; it was actually by Valerio Cioli).

Some of the sculptures were ancient, others made especially for the gardens. The leading sculptors employed at Pratolino were Bartolomeo Ammannati and the Flemish artist Jean Bologne, known as Giambologna. In the eighteenth century a number of sculptures were removed from Pratolino to the Boboli Gardens in Florence, where they can still be seen.

On the other hand, there was little that was innovative or remarkable from a technical point of view about the fountains. This was partly no doubt because the shallow slope of the site meant that there were no great heads of water below the reservoirs. There were no opportunities for grand cascades or water staircases – unless one counts the rows of fishponds as water chains of a kind. For the most part the water issued in small single jets or as *giocchi d'acqua*, of which there were huge numbers spurting from the ground or from walls

and benches. Wherever there were sculpted animals in fountains or grottoes there was a strong chance that water would emerge from their mouths.

What *was* unusual was the degree of control that Francesco could exercise over the whole water system, with the help of a small army of *fontanieri* or 'fountaineers'. Figure 7.6 reproduces a map made by Luigi Zangheri, showing where all the pipes ran through the grounds and under the villa.[19] There were three large holding ponds above the park to maintain supplies in summer. The principal flow was down the central axis of the estate, with branches to either side. The villa is at the middle here, and the rows of fishponds at lower right and left. The black circles mark small local reservoirs and the triangles are stopcocks. A survey made in the eighteenth century recorded 172 taps for controlling the supplies to individual fountains or automata.[20] Some of the pipes ran under the villa itself. The indoor grottoes were grouped along the south side of the plan, behind the curving staircases visible in Figure 7.4. Here the pipe network was particularly dense. Water was even supplied to the stairs themselves, for reasons we will see.

'Gentlemen, you will get yourselves wet'

The water was not just for the fountains but provided the motive power for all the animated figures and musical automata. The *fontanieri* maintained the whole plumbing system. They also had the job of going ahead of visitors and discreetly turning the taps and machines on and off. In some parts of the house and gardens there were underground passages where they could pass in secret to operate the various devices. Disney World in Florida has similar hidden access tunnels for the staff that run beneath the attractions. When Francesco had parties of visitors he would send them out on prearranged itineraries, so that the fountaineers knew where they would be going and could ambush them. As Sgrilli says, 'Here and there the fountain-keepers are busy, as always, with the task of furnishing the curious guests with sudden and unexpected baths.'[21] One visitor remembered Francesco sending his group off with the warning 'Gentlemen, you will get yourselves wet.'[22]

Generally the squirtings were controlled by the fountaineers, but some of the *giocchi d'acqua* were triggered automatically. Schickhardt illustrates a mechanism installed at the entrance to the Grotto of Cupid, a building concealed under a small hillock in the park.[23] When the unsuspecting visitor trod on one of the steps up to the grotto, it tipped

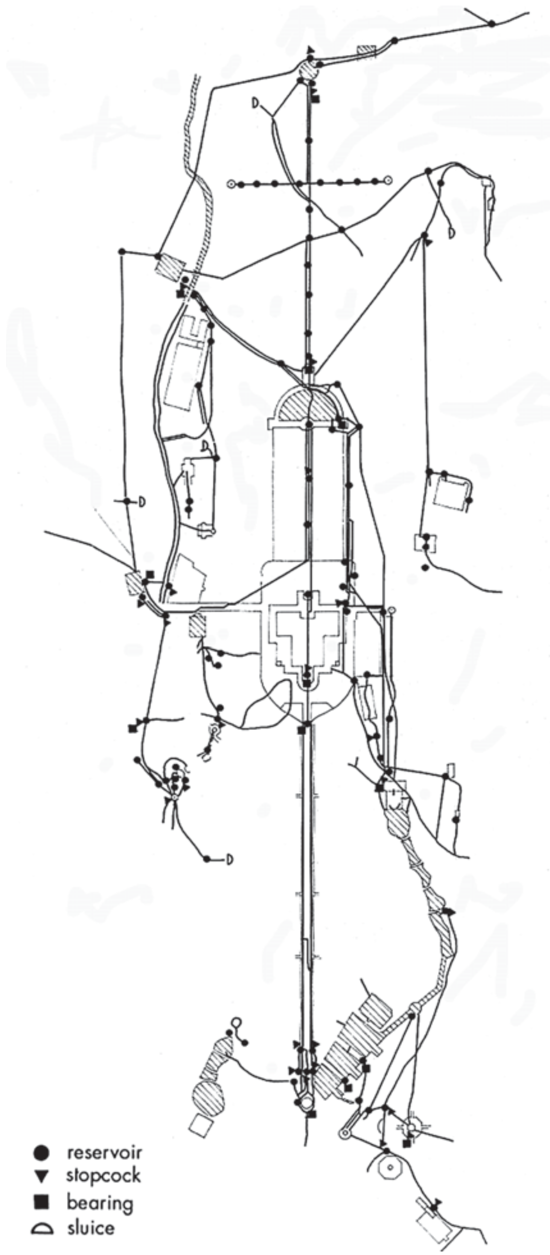

Figure 7.6 Map by Luigi Zangheri of the network of water pipes under the park. North is at the top, and the villa is at the centre. The black circles mark local reservoirs and the triangles mark stopcocks. Ponds are shown hatched. The grottoes inside the house are grouped along the south side, where much pipework is concentrated. By kind permission of Luigi Zangheri.

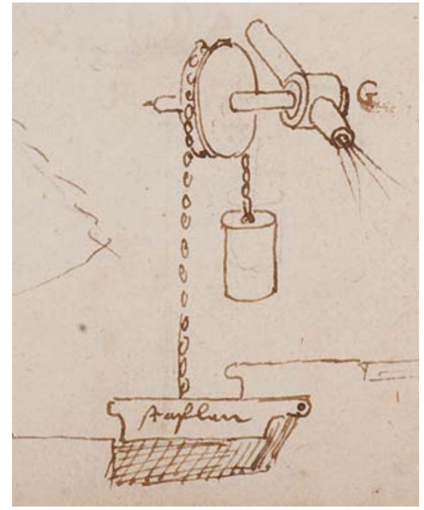

Figure 7.7 Sketch by Heinrich Schickhardt of a device at the entrance to the Grotto of Cupid. The visitor is squirted with water when he puts his weight on a step. Stuttgart, Württembergische Landesbibliothek, Cod. hist. qt. 148,b 0054v.

on a hinge under his weight, pulling a chain over a pulley (Figure 7.7). This opened a tap that released the water. According to De' Vieri, this grotto was 'all trickery, because whoever enters cannot avoid being soaked' by jets on the floor and the benches.[24] An English visitor Fynes Moryson got himself very wet:

> on all sides are marble chaires, whereupon passengers willingly sit after their walking: but as soone as they lightly presse some of the seats, a paile of water fals upon his head that sits upon it; besides the pavement is of marble, and therein many stones are so placed, as lightly touched with a man's foot, they cast up water into his very face and eies.[25]

Yet more spray was created by a dolphin in a basin and by Cupid himself, who turned and shot out water from a torch in his hand.[26] He also cried every hour.

The Grotta della Stufa (Grotto of the Stove) was a room for bathing, inside the villa. At the centre was a basin of red marble supporting a 'mountain' of *spugna* festooned with shells and coral. Two little bronze satyrs served as taps, one spraying cold water, the other hot. In a niche opposite, according to Sgrilli, was a 'graceful copper putto who invites the visitor to approach, but if he accidentally touches a device with his foot, he is suddenly soaked, and this also happens if, drawn by curiosity, he tries to lift the little boy'.[27] Sgrilli does not identify the orifice from which the jet issues, and there are no pictures; but I wonder whether this is perhaps a version of the 'trickster' fountain in *Hypnerotomachia Poliphili* (Figure 5.22), to which there are several resemblances. Recall that in Colonna's design a half-naked boy is lifted up and pees in Poliphilo's face when he treads on a step.

Appennino

One of the few statues remaining on the site of Pratolino today is a gigantic figure of an old man, crouching on the bank of the semicircular pond to the north of the villa (Figure 7.8). This is Appennino, symbol of the Apennine mountains that form the backbone of Italy and from which the park gets its water supply. He has his left hand on the head of a sea monster pouring water from its mouth into the pool below. Appennino was the work of Giambologna. Even on all fours he has the height of a three-storey building.

In fact, he *is* a three-storey building. The structure is built of masonry rendered with cement and reinforced with iron rods. Figure 7.9 shows a cross-section drawn by Zangheri. At the entrance level is a grotto dedicated to the water goddess Thetis. There are vaulted chambers below. Up under the back is a series of small rooms, including one in the head with sufficient space for seven men standing, the statue's eyes providing windows looking towards the villa. It was Francesco's pleasure to sit here in the head fishing, casting his line out through one of the eyes into the pond below.[28] At night he would have torches lit so that the eyes glowed. There is a report of pigeons coming and going through Appennino's ears.[29]

Giambologna created the old man's hair and beard by attaching pieces of *spugna*, the spongy stone used in grottoes. Small pipes supplied water to the head, which dribbled down to give the impression he was continually sweating and weeping. There was more spongy stone on the statue's back, so that in winter one could imagine he was covered with icicles. Originally there was an artificial 'mountain' providing a backdrop to the figure, which had stairs leading to a terrace on top. This later collapsed, however, and a sculpted dragon designed by Giovan Battista Foggini was added to the back of Appennino. There are descriptions of this beast spouting water from the mouth. But the cross-section of Figure 7.9 appears to show a fireplace with the chimney connecting to the dragon's mouth and nostrils, which would be much more appropriate and dramatic.

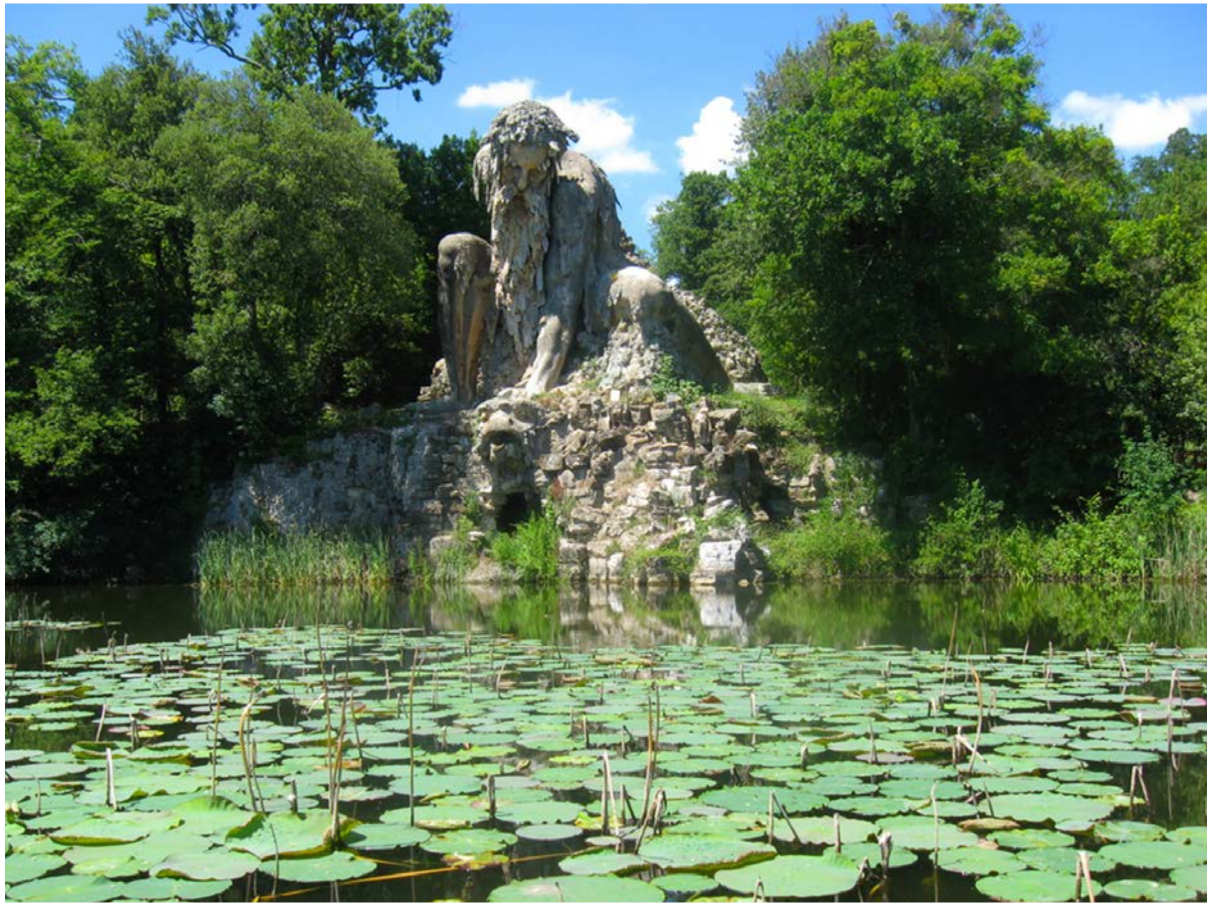

Figure 7.8 Appennino, the giant statue by Giambologna personifying the Apennine Mountains. Water issues from the mouth of the monster under his left hand. Photo by kind permission of Città Metropolitana di Firenze – Turismo and www.firenzeturismo.it.

The Fountain of Thetis inside Appennino is the only grotto remaining at Pratolino in any reasonable state of repair, but even so this must be a shadow of its original appearance. We can get some idea of how it would have looked originally by comparison with the interior of Buontalenti's Grotta Grande at the Boboli Gardens, illustrated in Figure 5.20. This is lined with the ubiquitous *spugna*, the material being used not just to cover the walls and ceiling but to fashion model trees, animals and human figures. Painted landscapes are inset. Accounts of

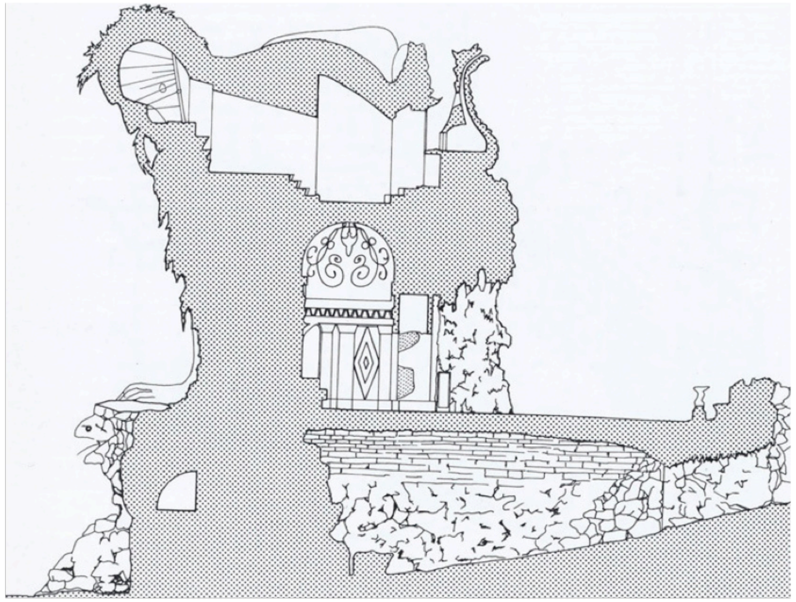

Figure 7.9 Cross-section of the structure of Appennino drawn by Luigi Zangheri, showing the Grotto of Thetis at the entrance level, vaults below, and the rooms under the back and in the head of the statue. At the rear is the dragon by Giovan Battista Foggini that was added later. By kind permission of Luigi Zangheri.

the grottoes at Pratolino mention patterns made with seashells and coloured pebbles, as we see in the Grotto of Thetis. Other decorations elsewhere were made from snail shells, mother of pearl, branches of coral, and even pearls and precious stones. In the Medici gardens at Castello, Tribolo built a grotto full of sculpted animals whose ceiling is ornamented with seashells and *spugna* (Figure 7.10). This design, if not from Buontalenti's own distinctive hand, can give us a feeling for the kinds of effects achievable with these materials.

The *spugna* and the shells came from nearby rivers and caves, and from the Tuscan seashore. But Francesco had some extremely large pieces transported over long distances. A 'great spugna' weighing between 25,000 and 30,000 pounds (about 10,000 kilos) was brought from Corsica in 1584, to be set in the pergola at the centre of the labyrinth.[30] Inside Appennino was a large branch of coral from the Red Sea that 'sprayed a gurgling of water'.[31] In the Grotto della Spugna inside the villa there was a gigantic stalagmite that came from the nearby city of Lucca, and was ornamented with shells and coral. The walls of this chamber were of white *spugna* and the ceiling was a golden pergola.

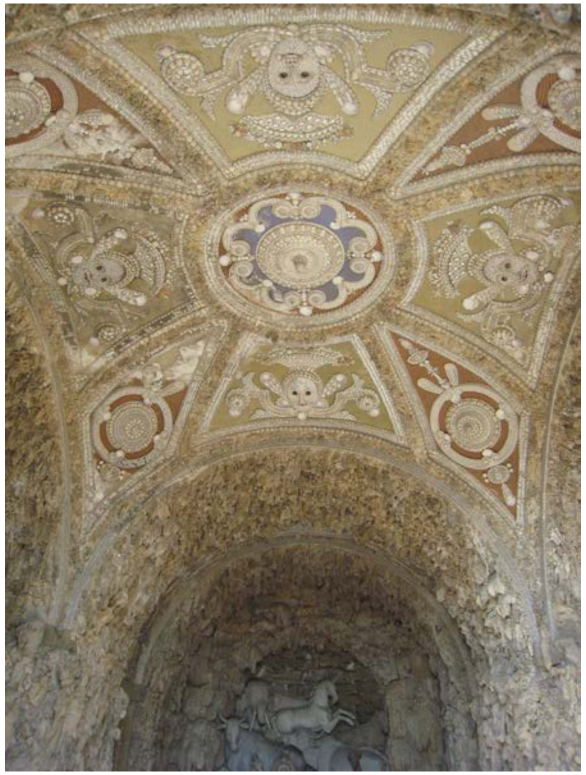

Figure 7.10 Vault of the Grotto of the Animals at the gardens of the Medici Villa of Castello near Florence, designed by Niccolò Tribolo. Wikimedia Commons: Villa medicea di Castello Soffitto Grotta degli Animali.

Guerra's drawings are one of the few graphical sources of information about the Pratolino grottoes, and they are certainly charming and useful up to a point.[32] But comparison of Guerra's sketch of the Grotto of Thetis (Figure 7.11) with the surviving remains shows how schematic, even caricatural, they are, and how much of the decoration he misses out. As Alessandro Vezzosi says, Guerra gives only 'a pallid idea of these ornaments'.[33] Guerra nevertheless provides a nice picture of Thetis herself on her fountain and the little model bats and snails made from seashells and mother of pearl around the rim of the basin.

Elsewhere in the rooms inside Appennino there were paintings of the scenery of the Tuscan coast including the port of Livorno and the island of Elba. There were also frescoes showing mining and the extraction of precious metals, based on woodcuts in Georgius Agricola's

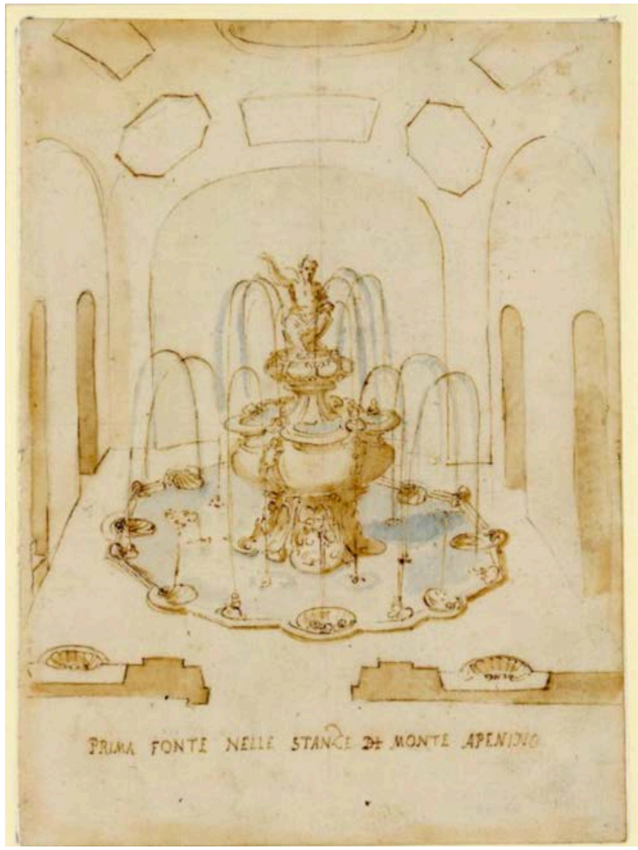

Figure 7.11 Drawing by Giovanni Guerra of the Grotto of Thetis with its statue of the goddess, inside Appennino. Creative Commons: echo.mpiwg-berlin.mpg.de/MPIWG:7WEBAFQ9, plate 8.

famous book *On Metals* of 1556.[34] The first intended reference must be to the Apennines, but these pictures also celebrated Francesco's scholarly interests in mineralogy, chemistry and alchemy. He had a laboratory and workshop in a villa in Florence converted by Buontalenti, the Casino Mediceo. Here the craftsmen worked not on utilitarian technologies but on new kinds of unusual decorative products, including tableware, porcelain and jewellery made of crystal and precious stones. Others experimented with the distillation of spirits, chemicals for fireworks and the production of medical remedies.[35] There is reason to suspect that some of the automatic machinery for Pratolino may have been designed and assembled at the Casino.

Artificial music in the park and the villa

One of the two water organs at Pratolino was in a room on the first floor of the palace, with the hydraulic machinery on the floor below. Later accounts of the restoration of this instrument mention bellows, however, meaning that the air was not compressed by the weight of water.[36] It could be played either by an organist at a keyboard or automatically.

The other was in a Mount Parnassus, an artificial hill in the gardens. An organ-builder from Florence, Giovanni Batista di Givanpaolo Contini, submitted a bill for one of the instruments in 1586; it seems likely that he built both. There is a drawing by Guerra of the Mount Parnassus (Figure 7.12), in which the organ pipes are just visible in an opening towards the summit. Pegasus stands as always at the very top

Figure 7.12 The Mount Parnassus in the park in a drawing by Giovanni Guerra. Apollo and the Muses sit around the opening near the summit where the pipes of the water organ can be seen. Creative Commons: echo.mpiwg-berlin.mpg.de/MPIWG:7WEBAFQ9, plate 21.

and marble statues of Apollo and the Muses are clustered round the organ. A fountain flowed from beneath the feet of Pegasus, representing the Hippocrene spring. There were seats under the trees opposite for an audience to enjoy the performance. At the side of the hill was a large masked face with bat wings that rolled its eyes, moved its mouth and spat water at visitors when they got too close.

Heinrich Schickhardt made a diagram of the organ's mechanism (Figure 7.13), the principles and details of which will be familiar from Chapter 6.[37] The trompe, the vertical pipe supplying the water/air mixture is at the left, and the vaulted aeolic chamber below. Schickhardt has shown only a few of the pins on the musical cylinder at the right:

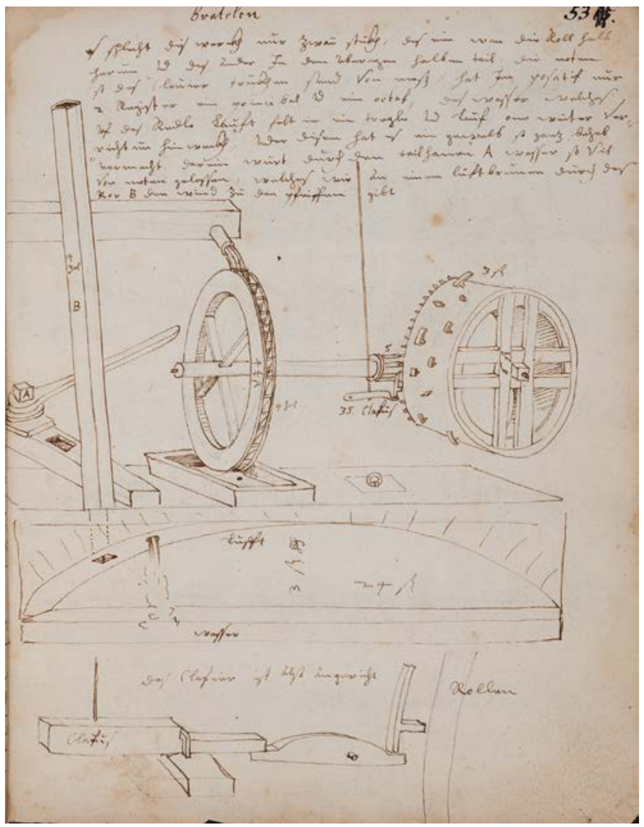

Figure 7.13 Drawing by Heinrich Schickhardt of the mechanism of the organ inside the Mount Parnassus. The trompe supplying the air/water mixture is at the left, the pinned cylinder at the right and the vaulted aeolic chamber is below. The detail at the bottom shows how the fins on the cylinder engage with levers that pull on rods to open the valves to the organ pipes above. Stuttgart, Württembergische Landesbibliothek, Cod. hist. qt. 148,b 0053r.

in fact there were two registers and 35 pipes in all. However, Renzo Giorgetti, who has written a detailed account of these organs, says that they were 'phonically poor' compared for example with the instrument at the Quirinale, which had a much greater range.[38]

Giorgetti mentions another miniature organ made by Contini with 11 pipes and powered by water, which provided the music that seemed to be played by one of the automated characters in the grottoes beneath the villa.[39] He is not explicit about whether this was a type of bagpipes (*zampogna*) played by a peasant or a set of pipes played by the god Pan. But it was probably for the bagpipes, since several sources mention Pan's instrument as having just seven pipes. Elsewhere a statue of Fame played her trumpet and a Triton made music by blowing on a conch shell. We can assume that these were sounded with compressed air forced through the instruments by water pressure, as described by Hero in the *Pneumatics*.

Artificial birds sang 'according to the method of Hero' in several places, including two metal trees, an arbutus and a holly, in the Grotto of the Deluge. Figure 7.14 is a sketch by Buontalenti of Hero's Theorem 14 in which a bird is made to warble and sing different notes. Buontalenti explains that the compressed air not only makes the bird whistle but causes it to open its beak and wag its tail.

Schickhardt illustrates a machine that made the song of a cuckoo (Figure 7.15).[40] This has two whistles (upper left) to make the two notes, the shorter 'cuc' and the longer 'koo'. Water is supplied through a pipe from the reservoir *A* at the top, which branches into two pipes. One of these branching pipes goes to the closed tank *C*; the other drives the waterwheel that turns the pinned cylinder. Compressed air from the tank passes up to the box on which the whistles sit. There is a row of prongs on the musical cylinder to make the 'cucs', and a row of fins to make the 'koos'. These trip levers move rods, which open valves to the whistles. The tap at *B* can be adjusted to control the water flow and make the song play faster or slower. These kinds of machines are in effect simplified water organs. They are the ancestors of those eighteenth- and nineteenth-century musical boxes that imitated birdsong, whose designers perfected the art of miniaturising the pinned cylinder and turning it by clockwork.[41]

Zangheri says that 'around the gardens were scattered dozens of boxes … which imitated the calls of a wide variety of different species of bird'.[42] Perhaps he means inside the grottoes; but if he means literally in the open air, under the trees, this raises the odd question of why one would want to synthesise birdsong in a garden full of real birds

Figure 7.14 Drawing by Bernardo Buontalenti of Hero's Theorem 14. The bird not only whistles but opens its beak and wags its tail. By permission of the Bibliothèque Nationale, Paris.

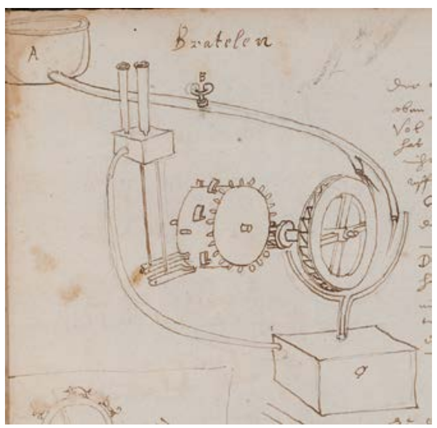

Figure 7.15 Drawing by Heinrich Schickhardt of a machine to produce the song of a cuckoo. The two pipes produce the two notes, the short 'cuc' and the long 'koo'. Stuttgart, Württembergische Landesbibliothek, Cod. hist. qt. 148,b 0052r.

singing. Maybe the sheer perversity of the idea appealed to Francesco and Buontalenti.

The grotto complex under the villa

It may be helpful at this stage to have a picture of the arrangement of the grottoes inside and immediately adjoining the villa. Figure 7.16 shows the layout in detail. I have given a letter key to the spaces. There

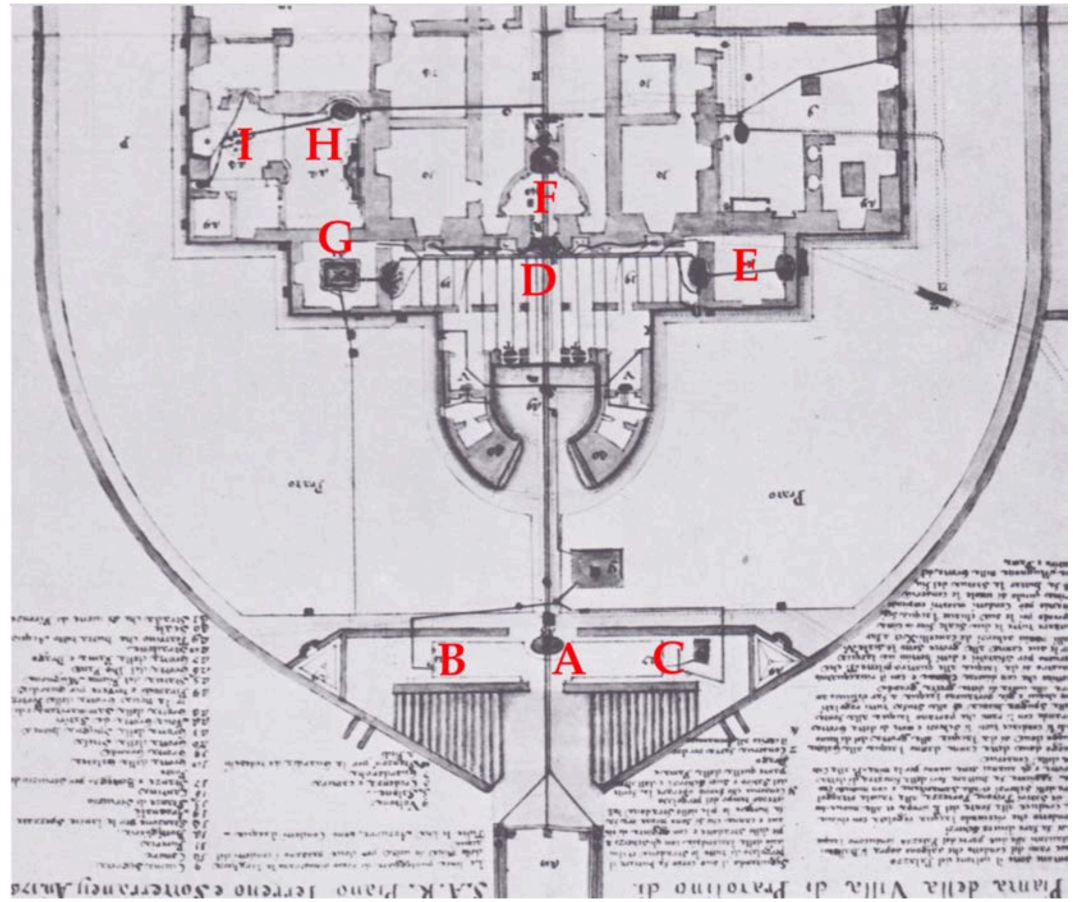

Figure 7.16 Layout of the grottoes in and adjoining the ground floor of the villa. A: Grotto of Mugnone with niches containing B: Pan and Syrinx and C: Fame and dragon drinking; D: Grotto of the Deluge; E: Grotto of the Stove; F: Grotto of Galatea; G: Grotto of Spugna; H: Grotto of Europa and Tritons; I: Grotto of Samaritana (the secret dining room).

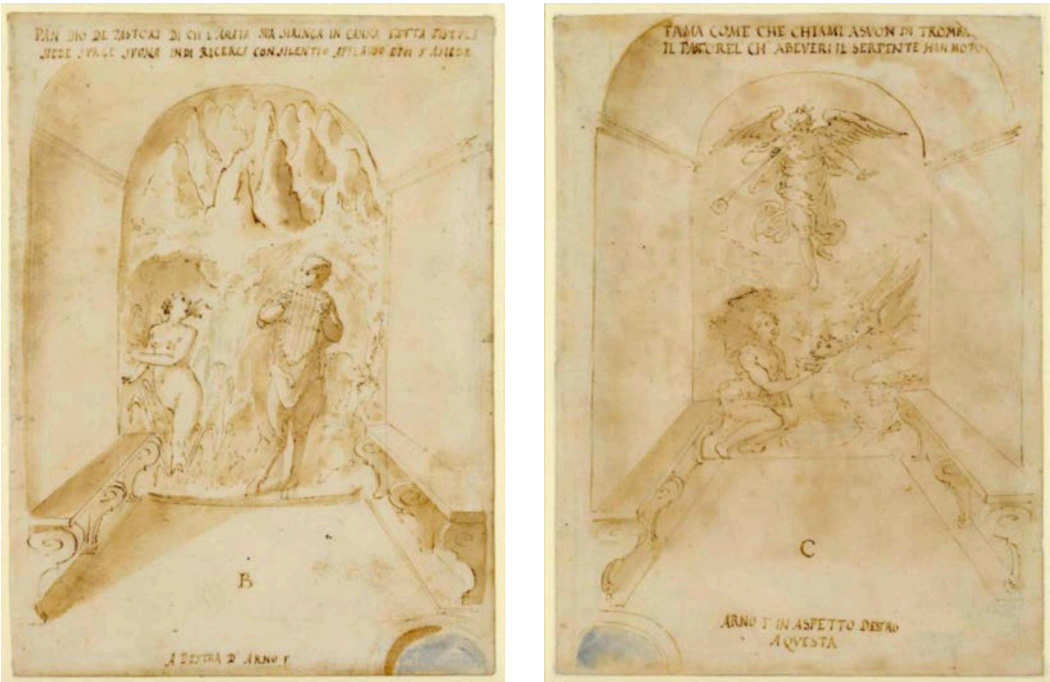

Figure 7.17 Drawings by Giovanni Guerra of automata in the niches in the Grotto of Mugnone: left, Pan playing the pipes, with the nymph Syrinx; and right, Fame playing her trumpet, with a dragon drinking. Creative Commons: echo.mpiwg-berlin.mpg.de/MPIWG:7WEBAFQ9, Plates 16 and 17.

was the Grotto of Mugnone (A), named after a small river that rises near the park and flows into the Arno. This was a separate structure cut into the hill in front of the villa, on a level below the ground floor. We can see the entrance in the view of Figure 7.3, under the straight flights of steps leading up from the grassy avenue, with its statue of a river god personifying the Mugnone, made by Giambologna. At the two ends of the room were niches devoted to Pan playing his pipes, with the nymph Syrinx (B), and the figure of Fame blowing her trumpet (C). These are both shown in drawings by Guerra (Figure 7.17).

The main grotto complex on the ground floor of the house was reached through another doorway encrusted with stalactites and *spugna* between the two curving stairways. This gave access to a lobby and to the largest of the rooms, the Grotta Grande, otherwise known as the Grotto of the Deluge (D). To the right was the room for bathing, the Grotto of the Stove (E); straight ahead a semicircular grotto dedicated to the sea-nymph Galatea (F); and to the left the grotto containing

the giant stalactite from Lucca mentioned earlier (G). Passing through this Grotta della Spugna, one reached the Grotto of Europa and the Tritons (H); and beyond that, in the most secluded position of all, was the 'secret dining room' known as the Grotto of Samaritana (I) or else the Grotta del Cibo ('food grotto'). Most of the automata were in these rooms in the house. Pratolino is called a 'garden of marvels'; but it might equally be described as a 'palace of marvels'.

The contrast could hardly be stronger between the cool restrained architecture of the villa above and the exuberant extravagance of the grottoes below. Although the English architect Inigo Jones came to Florence and saw Parigi's *intermezzi*, there is no record of him visiting Pratolino. But his general advice for the architecture of private houses catches precisely the schizophrenic character of Buontalenti's masterpiece. Jones compares the design of a mansion with the demeanour of the gentleman owner himself:

> For as outwardly every wise man carrieth a gravity in public places, where there is nothing else looked for, yet inwardly hath his immaginacy set free, and sometimes licentiously flying out, as nature her self doth often times stravagantly, to delight, amaze us, sometimes move us to laughter, sometimes to contemplation and horror …[43]

The Stuart masques were put on in Jones's correctly classical Banqueting House on Whitehall in London. Originally, like Pratolino, this had a grotto in the vaults beneath, decorated with seashells on the Italian model, where James I drank to excess with his courtiers.

Hero and Philo at Pratolino

Pratolino is the place where the influence of Hero's *Pneumatics* on Renaissance gardens, through the person of Buontalenti, reaches its highest point. The inventions of Hero and Philo are to be seen everywhere in the park's automata, sometimes as direct implementations of their theorems, at other times in variants and developments dreamed up by Buontalenti and his team. Several specialists are mentioned as working on the fountains and automata, including Tommaso Francini and his younger brother Alessandro.[44] I will try to explain the workings of each type of automaton in the grottoes, insofar as the sources allow, moving from the simple to the most complex. I will

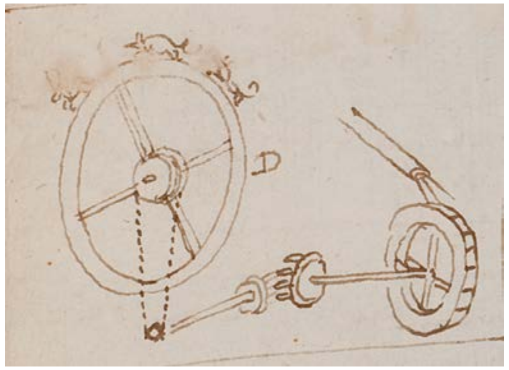

Figure 7.18 Sketch by Heinrich Schickhardt of the mechanism for turning a wheel on which figures of hunters pursue deer. Stuttgart, Württembergische Landesbibliothek, Cod. Hist. qt. 148,b 0052r.

draw on recent research by the historian of science Matteo Valleriani, who has been tracing the influence of Hero on Renaissance science and engineering and on Buontalenti in particular.[45]

Among the simplest are little devices where animals or human figures move round continuously on turntables, like the dancers devised by Hero who were propelled by jets of hot air (Figure 3.13). There was a turntable with hunters on horseback pursuing deer for example in the Grotto of Samaritana, shown in a tiny marginal sketch by Schickhardt (Figure 7.18).[46] Another precedent besides Hero would have been the type of turntable on which characters were made to appear from church clocks. At Pratolino the mechanisms were turned by waterwheels, as Schickhardt illustrates.

Closely related are working models of a number of everyday agricultural and craft machines with rotary motions. Guerra shows four of these in a composite illustration (Figure 7.19). They include a knife grinder with his wheel, a fulling mill in which cloth is beaten, a stone for grinding grain or pressing olives and a blacksmith's shop. In two cases the waterwheels providing the power are included in the little tableaux.

Guerra's drawings, as we have seen, tend to be rather schematic, and it is not clear whether other parts of these machines moved besides the turntables and the hammers. Did the bellows open and close? Was the figure working the grindstone articulated, so that his body and arms moved with the crank handle? Sgrilli describes two tableaux in the Grotto of Samaritana in the form of 'little houses equipped as workshops', one a Forge of Vulcan, the other a flour mill.[47] These sound like the machines drawn by Guerra. On the other hand, Sgrilli says that

Figure 7.19 Four automata of craftsmen working with machines, drawn by Giovanni Guerra. Creative Commons: echo.mpiwg-berlin.mpg.de/MPIWG:7WEBAFQ9, plate 20.

in each case there were several moving figures: blacksmiths working with hammers and other tools, millers moving about and carrying sacks on their shoulders. None of these scenes have close counterparts in Hero. The blacksmith's shop seems to be the model for Aleòtti's and Kircher's later automata of Vulcan's Forge, conceived in the spirit of Hero if not following him directly.

On occasion there are very direct transfers of Hero's ideas. For example, Sgrilli mentions briefly 'an owl that moves towards the birds' in the Grotto of Samaritana.[48] In another of Hero's theorems, as we saw in Chapter 3, an animal or bird is made to 'drink' from a bowl by means of a siphon. This echoes a slightly more complex machine designed by Philo in which a dragon laps up water from a stream. As Philo says, 'the dragon drinks and slurps with great huffing and puffing, as if very excited'.[49] A standing peasant provides a means to control the water supply: when an operator turns the figure, the flow is directed either to the stream or into a tank below.

Beneath the statue of Fame in the Grotto of Mugnone at Pratolino a shepherd offers a bowl of water to a dragon (see Figure 7.17). This clearly derives from Hero's design, or Philo's, or both. However, the mechanism must have been modified so that it worked automatically and continuously. De' Vieri describes the dragon as bending its head to drink the water. In other grottoes there were two ducks and a swan that drank.

Both De' Vieri and Sgrilli mention an automaton in the Grotta Grande in which a boy held up a *mappamondo*, a terrestrial globe, which turned on its axis and threw out streams of water.[50] According to Schickhardt, who gives a sketch of the mechanism (Figure 7.20), this was placed in a circular opening in the front wall of the grotto, so that it could be seen from both sides.[51] The sketch shows how water flows up the central supply pipe, which is turned through an angle at the top to direct the jet at a horizontal waterwheel inside the globe. This and four

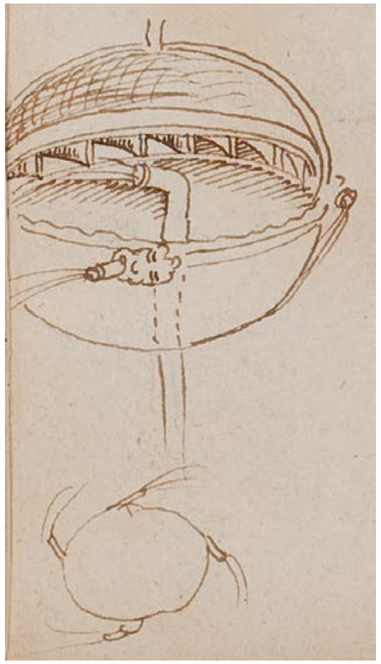

Figure 7.20 Sketch by Heinrich Schickhardt of the mechanism of a spinning globe held up by a boy in the Grotta Grande. Water from the central angled pipe drives the waterwheel inside the globe. The water exits from the angled jets on the exterior. Stuttgart, Württembergische Landesbibliothek, Cod. Hist. qt. 148,b 0050r.

angled jets on the outside are the means by which the sphere is turned. This is surely inspired by Hero's *aeolipile* or 'steam engine', in which a ball is rotated by bent tubes through which steam escapes (Figure 3.10).

Samaritana and Galatea

One figure who 'walked' at Pratolino was Samaritana, a woman from the New Testament who goes to collect water from a well and meets Jesus. She is the major character in a wall of automata in Francesco's dining room, as depicted by Guerra in Figure 7.21. (Above her are the hunting scene on a turntable and the shepherd playing the bagpipes.) The door at the right opens, Samaritana appears and crosses the 'stage', fills her bucket at the fountain at the left and returns. Schickhardt has a sketch to show a mechanism for moving her across the scene (Figure 7.22).[52] She is supported on a post passing through a slot, which is moved with an endless belt beneath the floor, running on two pulleys. I do not see, however, how this could work exactly as drawn, unless the pulleys were horizontal and not vertical. She would also have needed some further device to allow her to fill her bucket.

Salomon de Caus visited Pratolino, and although he did not copy the grottoes precisely, he subsequently published designs in *The Causes of Moving Forces* that were heavily influenced by what he saw. Figure 7.23 shows an automaton from his book, 'A machine by which is represented a Galatea who will be pulled through the sea by two dolphins.'[53] Galatea was a milk-white sea nymph whose love for Acis is chronicled by Ovid in the *Metamorphoses*. In de Caus's design she appears from her cave at the right and travels in her seashell boat across the scene. This corresponds to written descriptions of the Grotto of Galatea at Samaritana, where Sgrilli says the nymph appears through a little door and then 'turns and goes back'.

I suggest that the mechanisms for moving Galatea and Samaritana at Pratolino were similar: both figures were made to move across a scene and back again – although Galatea's boat 'floated' on water and did not run across a floor. If we can accept this idea, then perhaps both grottoes had something like the apparatus shown by de Caus at the right of his drawing. A winch behind the mouth of Galatea's cave at the right pulls ropes that have two functions. One rope pulls the post supporting her boat across the scene and back. The other rotates the boat when it reaches the end of its trajectory, so that it faces the correct way for its return journey.

Figure 7.21 Automata in the Grotto of Samaritana drawn by Giovanni Guerra, including a peasant playing the bagpipes, a hunting scene and the figure of Samaritana who crosses the scene to fill her bucket at a well. In the foreground is Francesco's dining table made of jasper with its basins for keeping glasses cool. At the right is a servant offering water with which guests can wash their hands. Creative Commons: echo.mpiwg-berlin.mpg.de/MPIWG:7WEBAFQ9, plate 12.

Going back to Samaritana: how was she turned once she had filled her bucket? Perhaps she was a flat cut-out painted on both sides, or else a three-dimensional figure that was rotated. Might the inspiration for this figure have been not in Hero's *Pneumatics*, but in his

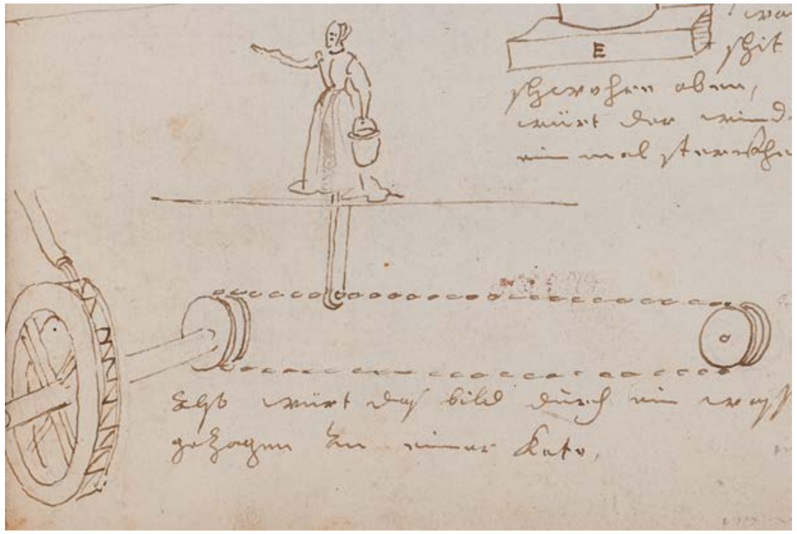

Figure 7.22 Sketch by Heinrich Schickhardt of the mechanism with which the figure of Samaritana was moved. Stuttgart, Württembergische Landesbibliothek, Cod. hist. qt. 148,b 0052r.

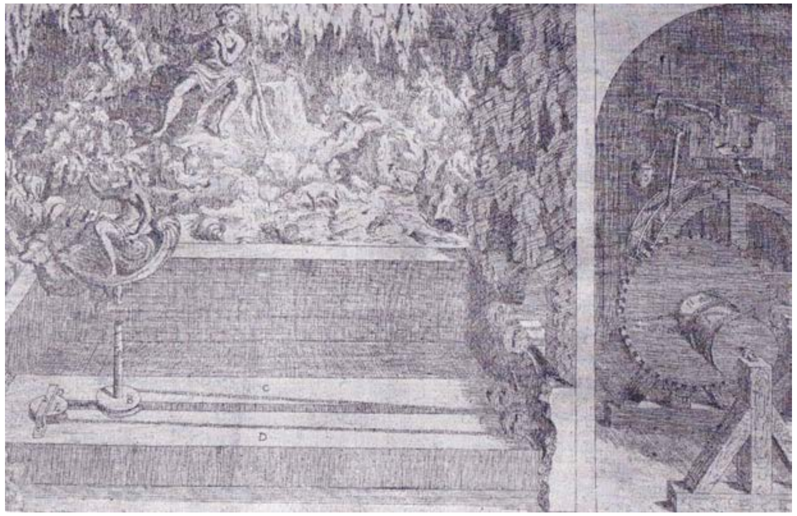

Figure 7.23 'A machine by which is represented a Galatea who will be pulled through the sea by two dolphins': Problem XXIIII from Salomon de Caus, *The Causes of Moving Forces*, Book I. One rope moves Galatea in her shell boat across the scene. A second rope turns her around for the return journey.

book *On Automata-Making*, specifically the devices that move Athena across the stage in *The Legend of Nauplios*? She too is pulled back and forth with one cord and rotated with another, like the machine for Galatea.

Automata or statues?

With some of the figures in the park and the grottoes, it is not easy to know from written accounts or drawings whether they were immobile and made of marble or were automated. The peasant cutting reeds in one of the ponds was a statue and did not actually swing his scythe. Other figures, however, are definitely described as moving their limbs and changing their facial expressions. When Pan performed on the pipes in the Grotto of Mugnone (Figure 7.17), he stood up, moved his head and eyes, played his song, sat down again and turned towards the nymph Syringa beside him, who was transformed into a reed. A sitting cuckoo raised itself, climbed a vine and sang.

In the Grotto of Samaritana, Francesco's dinner guests were attended by a boy servant who poured water from a jug on his shoulder into a bowl for them to wash, and then offered a hand-towel. This figure appears in Guerra's drawing of Figure 7.21. Sgrilli refers to the boy as being made of stone. It is certainly possible that he was a static fountain, with the water pouring continuously from jug into bowl and running away through a hidden drain. Real cloth towels might have been hung over his arm. It is tempting to imagine on the other hand that this is a version of an automated serving woman designed by Philo, who also carried a jug and, instead of a washing bowl, a drinking cup.[54] This woman could move her arms to pour the contents of the ewer, which was a trick vessel providing water and wine in differing proportions, into the cup. The liquids were supplied through tubes.

In the National Library in Florence there is a fifteenth-century codex containing a delightful drawing in what Marco Dezzi Bardeschi says is the 'unmistakeable style' of Francesco di Giorgio (Figure 7.24). This shows a woman holding a jug in the air with one hand, a cup in the other and a long cloth draped across both hands. She too is an automaton, surely inspired by Philo: a mechanism with cords wound round a cylinder for controlling the movement of her arms is visible inside her chest. It appears that the cylinder is turned by a drum or tank in her lower body whose top rises and falls. A detail at lower right shows the machinery removed from the woman's body.

Figure 7.24 Automaton servant, shown in a drawing by Francesco di Giorgio, who pours water from a jug into a cup. The mechanism inside her chest moves her arms. At lower right is the hydraulic machinery shown removed from her body. By kind permission of the Biblioteca Nazionale Centrale, Firenze.

My guess is that liquid in the tank flows via a siphon up to the jug. Meanwhile the cup is drained back into the tank via a short tube from its base. The method of turning the arms resembles the axle and cords with which the batwings of Giovanni Fontana's 'flaming witch' were operated (Figure 4.17). Could these details provide clues as to how other automata at Pratolino were made to move their arms and legs? Maybe Sgrilli thought the pageboy at Pratolino was marble because he never saw him in action.

Francesco's secret dining room

The Grotto of Samaritana, hidden at the greatest depth in the grotto complex, served as a very private dining room for Francesco, Bianca and their closest friends. It had an octagonal table made of jasper in which there were eight bowl-shaped recesses, one for each diner. Water flowed through these bowls to cool the guests' glasses of wine. A ninth bowl at the centre contained a fountain, as seen in Guerra's drawing (Figure 7.21). Perhaps bottles of wine were set to cool here: Francesco had a passion for cold drinks.[55] Montaigne was surprised – as any Frenchman would be – by the Florentine habit of putting ice in wine. There were two special houses in the gardens at Pratolino in which stocks of ice, cut in the winter, were insulated under straw for use in the summer. This table with flowing water was in a tradition going back through Cardinal Gambara's outdoor table at the Villa Lante to Pliny's Tuscan villa.

Adjoining the secret dining room was a secret kitchen, but instead of these intercommunicating via a door, there was a *ruota da monache*, a wheel of a kind used in nunneries for exchanging packages in such a way that the nuns never had to meet strangers face to face. By this device the guests could be supplied with dishes without any servant present – other than the automaton boy – to overhear their conversation or observe the goings-on.

The fountain in the table was equipped for playing games, changing the shape of the spray by means that we have already seen. Sgrilli says that with 'ingenious devices of many shapes' one could make 'pretty jokes and representations from water'.[56] Another account refers obliquely to two such games, one involving a lily, the armorial flower of Florence – perhaps where a jet was formed in the shape of a fleur de lys – the other the balls that feature in the Medici coat of arms.[57] My guess is that the latter was a game that featured in several grottoes and gardens elsewhere, in which lightweight balls were balanced on top of vertical jets of air or water. The balls do not fall but are kept aloft by what is known as the Bernoulli effect. At the Villa Aldobrandini at Frascati near Rome there was an amusement of this kind in the Stanza dei Venti (Room of the Winds). In a detail from an engraving by Giovanni Battista Falda, we see three gentlemen studying a ball that hovers above the floor of this room (Figure 7.25).[58]

Francis Mortoft visited the villa and saw this very ball for himself. It was supported on a jet of air created by water pressure. As Mortoft describes:

Figure 7.25 A ball supported on a jet of air in the Room of the Winds at the Villa Aldobrandini at Frascati: detail from an engraving by G. B. Falda.

> In the middle of this Hal is A great Round hole, where the man pulled up a thing with a string, the water that is underneath casts up such a strong wind that, laying a Bal upon the mouth of that hole, it makes it spin above the ground as long as it keepes within the compasse of the place.[59]

This idea comes originally (needless to say) from Hero and the *Pneumatics*: in Theorem 45 Hero describes how to support a hollow ball on a jet of steam.[60]

The Grotto of Samaritana was a veritable toyshop crammed with automata, and when they were all working simultaneously the impact must have been overwhelming. By far the most mysterious and magical-sounding were machines that could be set in the middle of the table and were driven by the force of the fountain beneath. Giovanni Rosini describes these:

> Now there is placed at the centre a miniature ship, and the water makes the sails, the rigging, and the flags. Now a little garden, where the water forms streams, the leaves on trees, and hoarfrost on the grass. Now a palace, where the water imitates the glass of the windows and the smoke drifting from the chimneys. Now the water makes an eagle spread its wings ready for flight; it raises its neck and moves its eyes, fixing them on the rays of the sun. Now a bunch of flowers – tulips, jonquils, carnations, jasmine, roses and lilies – all in their natural colours formed from water, flowing inside the thinnest tubes of coloured metal.[61]

Not the least part of the mystery is the source of this account. Rosini was a nineteenth-century writer and the passage is from his novel

The Nun of Monza: A Tale of the Seventeenth Century. The narrator's party meet a peasant woman on the road from Florence to Bologna. She says: 'Who has not seen Pratolino, has not seen a wonder of the world.' So they arrange a visit. What follows is a lengthy and detailed account of the park and its marvels, consistent with the descriptions by De' Vieri and Sgrilli – who are quoted almost verbatim. There are even footnotes and references (in a novel). The machines in the quotation from Rosini are the exception, though: I have not seen them mentioned anywhere else. But given that he was a historian and student of the arts, and given the accuracy of his account generally, it seems reasonable to trust him here. And there is further supporting evidence.

Several authors besides Rosini describe another complex scene in the Grotto of Samaritana, depicting a miniature fortress that was defended from attack by soldiers with muskets on the battlements. The fighting was accompanied by sounds of cannon fire and drumbeats. Sgrilli says this was the work of Ferdinando Tacca, a sculptor and stage designer, son of Pietro Tacca who worked with Giambologna.[62] Since Ferdinando was born in 1619, this would put the date at around 1640 at the earliest. Does this mean that the other automated tableaux described by Rosini were all seventeenth-century additions at Pratolino, after Buontalenti's time? Were they also created by Ferdinando Tacca?[63]

Not all, it seems. Montaigne visited Francesco's workshops in the Casino in Florence in 1581:

> What struck me most there was a rock of pyramidal shape made of all sorts of mineral stones, the mass being composed of one fragment of each. From this rock a spring of water gushed forth and set in motion a great number of devices, water-mills, windmills, bells, soldiers, animals, hunting scenes, and many others of the same sort, all placed in a chamber inside.[64]

This must surely have been destined for Pratolino. So there were automata similar to those described by Rosini from the very start.

A Renaissance theme park

If Pratolino was a theme park, what was the theme? Garden historians have had trouble with this question, even more than with the supposed iconography of other sixteenth-century Italian gardens. De' Vieri in his original 1587 description offered a series of moralising interpretations of separate features of the park. The estate is a 'portrait of the well-governed republic'.[65] The vault of spray over the central avenue represents the trials of life, where only the virtuous can avoid a wetting. The many spurts of cold water in the Grotto of Cupid are reminders of the tears shed by lovers. These ideas do not add up, however, to any systematic structure or coherent narrative that might have originated with Buontalenti or Francesco, and later critics have not been convinced.

Among modern writers, Eugenio Battisti in a chapter on Pratolino in his book *Antirenaissance* suggests that the park was 'a permanent exhibition of technology', a real-life version of the contemporary type of illustrated engineering treatise known as a 'theatre of machines'.[66] This is also unconvincing, for two reasons. The machinery of all the automata was of course carefully concealed to preserve their marvellousness; and those few tableaux that did demonstrate machines in operation, as illustrated by Guerra (Figure 7.19), featured not sophisticated examples of advanced technique but simple age-old devices such as olive presses and grindstones.

The garden specialist Claudia Lazzaro has proposed that – as at the Villa Lante – the fountains on the central axis of the park constitute an allegory of the passage of water through nature, specifically through the landscape of Tuscany.[67] Jupiter at the very top of the garden creates thunder and rain; Appennino stands for the mountains with their springs; Mugnone below the villa personifies the river leading down from the hills to join the Arno, passing through Florence to the sea; and the washerwoman at the southern end of the park is representative of the uses of water in everyday life. The plausibility of this interpretation as evidence of a deliberate structure of meaning is seriously undermined, however, by the fact that Giambologna's original plan was for a giant statue of the river Nile where Appennino now stands.[68] Also Lazzaro's scheme covers just a small minority of the fountains, those on the main axis, and ignores many others elsewhere, as well as all the grottoes.

At the end of a lengthy discussion of possible iconographies, Hervé Brunon comes to agree with other writers that the park actually lacks any overall structure of meaning. Instead he sees the distinctive character of Pratolino as being explained 'in large part by the personalities of its client and his architect' – a kind of double portrait of Francesco and Buontalenti.[69] This would account for much of the garden's eclectic and fragmented quality.

For Francesco's part there are expressions of his varied scientific pursuits: botany in the planting of rare species; mineralogy in the decorations inside Appennino, the corals and the stalactites; mechanical and hydraulic engineering in the (hidden) apparatus of the automata. The fishponds, the ball games and the treehouse allowed Francesco to relive the pastimes of his boyhood. The seclusion of the grottoes and groves let him and Bianca hide from public view. Could one even see symptoms of the cruelty of Francesco's character in the proliferation of *giocchi d'acqua*, which were approached by some visitors with trepidation and alarm?

For Buontalenti's part, his artistic imagination was more scenographic and pictorial than systematic and structured. He was a man for dramatic moments and surprises. Several authors have made the connection to the *intermezzi*, which had only the most exiguous of plots and depended for their impact on machines and spectacular *coups de théâtre*. The grottoes inside the villa were experienced in sequence, but outside in the park, visitors came across them at random while wandering among the trees. The Mount Helicon in Buontalenti's *intermezzo* for the *Kidnap of Cephalus* in 1600 (Figure 2.14) might have been transposed directly from the Mount Parnassus at Pratolino. And better than the *intermezzi*, the Pratolino audience were not observers from the safety of the auditorium but were caught up directly in the action. In the words of Mila Mastrorocco:

> The same atmosphere of overpowering emotion, the surprise, the delicious thrill of terror that unexpectedly seized the audience; admiration for the ingenuity and technical expertise; the perfect balance between the most varied elements; all these characterise the productions that we can consider as Buontalenti's greatest works. Time has added to both [gardens and *intermezzi*] a precariousness and unrepeatability, which in the case of Pratolino was not the intention of the author; in this way for us the analogy is made even closer.[70]

Francesco and Buontalenti were not just client and designer; they were lifelong friends and collaborators. When Buontalenti was attached to the household of Francesco's father Duke Cosimo, he became the young boy's tutor and mentor. One wonders whether the model which gave Buontalenti his nickname, with its figures and revolving lights, its *girandole*, was made to amuse his young protégé. In later life the two of them would drive out together incognito, on hot nights, through

the streets of Florence.[71] By day they would experiment together in the Casino. Buontalenti's biographers describe him as a witty sociable man, full of jokes and good humour. Francesco must have valued the many ways in which Buontalenti could cheer him up, drawing him out of his habitual gloom and lethargy. Pratolino, one might say, was their monumental *folie à deux*.

The later fortunes of the villa and park

When Francesco died in 1587 the cause of his death was given as malaria, but there were persistent rumours that he had been poisoned, especially since Bianca died the following day. These events continue to intrigue medical historians. A study by the University of Florence in 2006 found arsenic in the exhumed remains of both their bodies.[72] I wonder whether the culprit might not have been Francesco himself. His alchemical activities included the production of an Elixir of Life, which he seems to have believed had aphrodisiac powers and which he drank in large quantities.[73] He also self-medicated with other concoctions, which were made from frightening ingredients that included 'spirits of oil of vitriol' – vitriol usually meaning sulphuric acid.

Traditionally, however, the poisoning has been blamed on Francesco's brother Ferdinando, who inherited the title of grand duke and, with his successors, maintained the house and gardens in good condition throughout the seventeenth and early eighteenth centuries. The English landscape gardener William Kent visited in 1714 and noted the 'very fine Grotos adorn'd with shelles and petrified stone'.[74] Sgrilli's account of 1742 shows that the estate was not greatly changed by that date, and the fountains and automata were still in good order. There are reports of maintenance and repair work being carried out.

Towards the end of the eighteenth century, however, the years were beginning to tell. The massive flow of water through the ground floor of the villa had undermined the foundations and large cracks were appearing in the structure. In 1737 the last of the Medici had died and ownership had passed to the House of Lorraine, who saw the 'marvels' as frivolous luxuries, too expensive to maintain. For the first time visitors' reports begin to refer to the entertainments as childish and repetitious. Tastes in garden design were changing. Plans were made to replace the villa with a new palace, but these came to nothing. By the time the Marquis de Sade was in Florence in 1774, the house was uninhabited and the gardens overgrown. It is not entirely clear whether he made a visit;[75] but if he did, it was perhaps this atmosphere of melancholy ruination that prompted him to make Pratolino the venue for an episode in his novel *The Story of Juliette*, completed in 1797. Sade describes the heroine's arrival: 'And so we were called for the following morning and conducted to Pratolino, in the Apennines and on the road by which we had gained Florence. That villa, shaded, solitary, and voluptuous, lacked none of the features characteristic of a retreat for debauchery.'[76]

In the *Story* he does indeed transform the villa into the location for an orgy – presided over by the Russian giant Minski – whose details are not at all suitable for a book about fun.[77] One will suffice. Sade imagines the house equipped with pieces of furniture made from naked immobilised human beings: as Sergio Salvi says, a cruel inversion of the real Pratolino, where inanimate sculpted humans sprang to life.[78]

Many of the statues and all the lead and bronze from the hydraulic system were removed, and in 1814 the house was demolished. Most of the fountains and garden grottoes were lost. But the grounds were not completely abandoned: instead they were remodelled into what the Italians call a *bosco all'inglese*, an English wooded park. The *pratolini* were reimagined and reshaped in the romantic landscape style of William Kent and Capability Brown.

In 1872 Pratolino was bought by a rich Russian émigré, Count Demidoff, who made a villa out of one of Buontalenti's surviving outbuildings and mounted archaeological campaigns to rescue the ruins of some of the other surviving structures.[79] In 1982 the estate passed to the Provincial Administration of Florence, which saved it from development for housing. They have carried out more restoration work and have opened the Parco Demidoff to the public. Figure 7.26 shows the Villa Demidoff as it appears today.

The legacy of Pratolino

Even before it was completed, Pratolino's fame and influence began to spread across Europe, in parallel with the influence of the Villa d'Este and the Villa Lante.[80] By marrying Joanna of Austria, Francesco had linked the Medici to the Habsburgs, and he was keen to help his new relatives with their own gardens. He lent them the services of Medici gardeners and sent drawings and rare plants. In 1581 he dispatched a big consignment of seashells to Wilhelm V of Wittelsbach to decorate his Grottenhof (grotto house) in Munich (Figure 7.27). This structure,

Figure 7.26 The Villa Demidoff and the park today. Photo by kind permission of Città Metropolitana di Firenze – Turismo and www.firenzeturismo.it.

if architecturally lumpish, can again help us to visualise the grottoes at Pratolino, in particular the basin of red marble that supported a 'mountain' of *spugna* in the Grotto of the Stove. The golden statue of Mercury is a copy of an original by Giambologna.[81]

Francesco's brother Ferdinando looked politically to France and was a supporter of King Henri IV. In 1600 their alliance was cemented with Henri's marriage to Ferdinando's niece, Marie de Medici. (It was on this occasion that the third of Leonardo's walking lions made its appearance.) Henri lured Tommaso and Alessandro Francini, who designed grottoes and automata at Pratolino, to work on the royal gardens at Saint-Germain-en-Laye near Paris. The two brothers were

Figure 7.27 The Grottenhof (grotto house) in the former palace of the Bavarian monarchs in Munich. The shells were supplied by Francesco de' Medici. The Grotto of the Stove at Pratolino had a red marble basin and mountain of *spugna*, similar to the basin on the left here. The golden statue of Mercury above is after an original by Giambologna. Wikimedia Commons: 2014-08-06 München, Residenz 039 Grottenhof.

to become 'general superintendents of the waters and fountains of France'.

At Saint-Germain there was a row of grottoes under a terrace, supplied with water from a reservoir above.[82] The largest of these featured the myth of Perseus and Andromeda. Perseus, son of Zeus, was flying over Ethiopia when he saw the beautiful Andromeda chained to a rock, waiting to be eaten by the sea monster Cetus. Falling immediately in love, he descended, killed the beast and rescued Andromeda. In the Francinis' version, a fully armoured Perseus comes down from the ceiling like a flying god in one of the *intermezzi*, and fights a dragon that rises up from a pool.

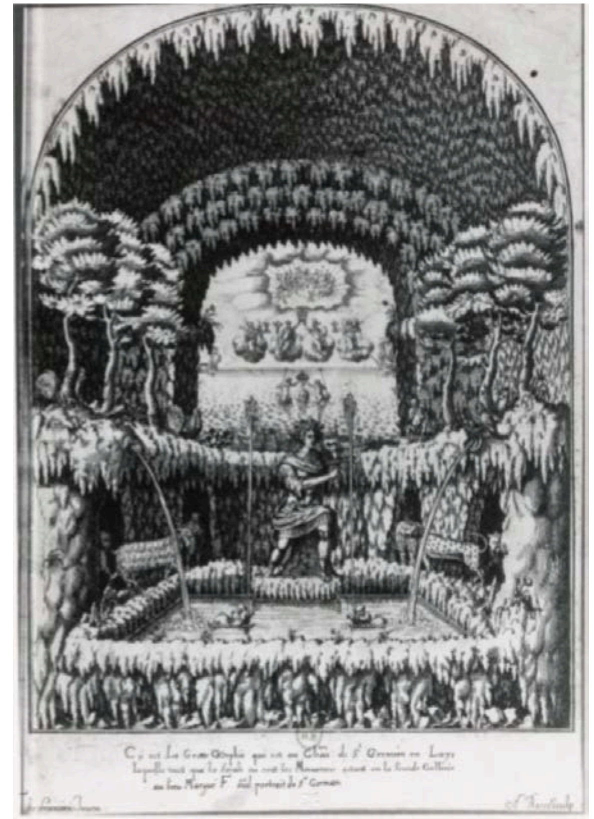

Figure 7.28 The Grotto of Orpheus in the royal gardens at Saint-Germain-en-Laye near Paris, built by Tommaso and Alessandro Francini. Orpheus plays to the animals on his viol. Engraving by Abraham Bosse.

There was also a water organ and grottoes of Hercules and Orpheus. Figure 7.28 reproduces an engraving by Abraham Bosse of this last grotto, in which Orpheus charms the animals and birds with the music of his viol. The scene visible through the opening at the back, with its sea nymphs, ships and heavenly chorus in the clouds, could again be taken directly from one of the *intermezzi*. Later, members of the Francini family went on to work at Versailles.

Still in France, it is clear that Cardinal Richelieu's octagonal marble table in his grotto at Rueil, with its central fountain and erotic water games, was copied from Buontalenti's dining room for Francesco. The cardinal's architect Jacques Lermercier had previously worked for a time in Italy. And the designer of the automata and hydraulic apparatus was none other than Tommaso Francini.[83]

In parenthesis: Alessandro Francini also brought Italian stage machinery to Paris as early as 1615 for the *ballet de cour*, the French equivalent of the *intermezzi*. Some of his most admired scenes featured fountains on stage. French theatre historians have wondered where Francini might have learned stagecraft and have searched without success for productions in Italy with which he might have been associated.[84] He would have learned, of course, from Buontalenti.

We saw how Salomon de Caus illustrated something very like Buontalenti's Grotto of Galatea in *The Causes of Moving Forces*. He borrowed many other features and elements from Pratolino and reproduced them in gardens in Belgium, England and Bohemia.[85] It was in around 1610 or 1611 that he moved to London and – as mentioned in Chapter 6 – entered the service of Henry Prince of Wales, in company with Cornelis Drebbel. Henry involved de Caus in garden works at Richmond Palace along with the Medicean architect Constantino de' Servi, who seems to have been in charge. The prince wanted them to erect a monstrous statue of an old man, three times the size of Appennino. This was to have many apartments inside, a dovecote on top and in the cellar a means to supply wind to two grottoes.

De Caus also worked in England for Anne of Denmark, wife of King James I, who commissioned the court masques from Inigo Jones and Ben Jonson in which she herself danced. De Caus constructed a Mount Parnassus for Anne in the gardens of Somerset House on the Thames: according to a German visitor this was much superior to its model at Pratolino.[86] The mountain was built of 'sea-stones' and covered with mussel and snail shells. A golden Pegasus stood on top; the Muses sat in a cave inside. Later Salomon's younger brother Isaac de Caus, also a garden designer, joined him in England to work at several country houses. It was Isaac who designed the grotto under Jones's Banqueting House.

In 1613 the Prince of Wales's sister Elisabeth married the Elector Palatine Frederick V, and the couple took Salomon with them to create a great garden for their castle at Heidelberg. This was to have been his masterpiece, the Hortus Palatinus, whose detailed plans we know from a magnificent volume with many illustrations.[87] There were to have been grottoes in two buildings. What de Caus calls the Great Vault was to have contained a heated bathing pool and a water organ playing ancient Greek music.

The second grotto complex, which de Caus says would have taken at least an hour to visit properly, was to have featured a nicely elaborated version of the ball dancing on a jet (Figure 7.29).[88] Here

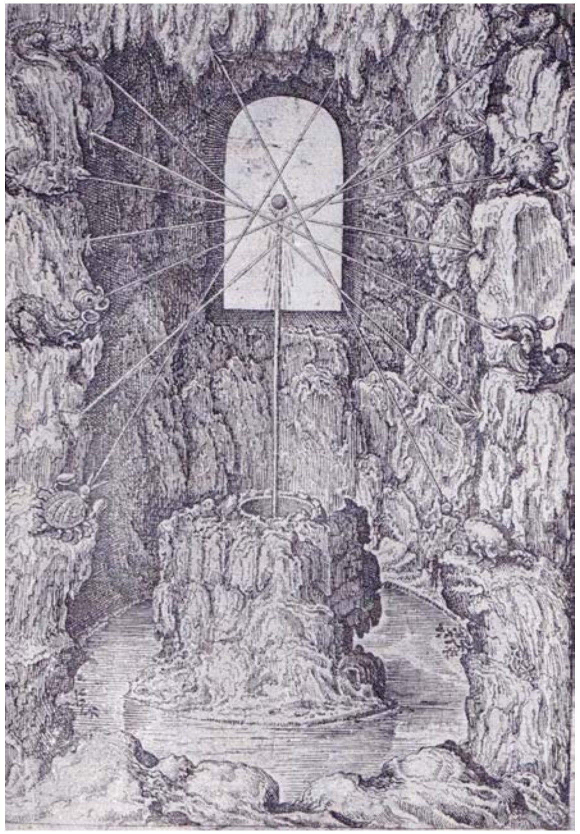

Figure 7.29 Ball supported on a water jet, designed by Salomon de Caus: Problem II in *Causes of Moving Forces*, Book II. The little animals made of shells shoot water at the ball, trying to dislodge it. When they succeed, the ball falls into the conical pot below and rises up again. De Caus planned this for the Hortus Palatinus at Heidelberg.

de Caus has introduced little model animals made of shells cemented together, which shoot streams of water at the ball and try to dislodge it. When they succeed, the ball falls into a pot below, which is cone-shaped and replaces the ball on its jet so that it rises again.

De Caus's plan was only partly completed, however. In 1619 the Thirty Years War reached Heidelberg and the castle was overwhelmed. Later the gardens were further neglected. Today little remains of de Caus's work beyond a reclining figure of the river Rhine and the entrance to one of the grotto buildings.

The one place where it is still possible to see garden entertainments modelled on Pratolino is at the Palace of Hellbrunn near

Figure 7.30 Outdoor dining table at the Palace of Hellbrunn near Salzburg, with a trough for cooling bottles at the centre. Water jokes soak anyone who sits down. By kind permission of Schlossverwaltung Hellbrunn. Photo Auer.

Salzburg, built for Archbishop Markus Sittikus between 1613 and 1619.[89] Here there are mechanical birds singing, vaults of spray under which one can walk, stags' heads spurting water from their antlers and an outdoor stone table like Cardinal Gambara's at the Villa Lante, with a trough for bottles, and stone seats from which jets squirt upwards (Figure 7.30). (The archbishop reserved for himself the one seat that has no jet.) Indoors there is a grotto with sea creatures and mermen circulating in a pool, like de Caus's design of Figure 5.21. A grotesque face called the Germaul – perhaps resembling the mask on the Mount Parnassus at Pratolino – rolls its eyes, sticks out its tongue and squirts water from its nostrils. The artistic quality of these designs is sadly diminished from the originals, but the hydraulic machinery is the same.

Otherwise the legacy of Pratolino has all but disappeared. Not only was the Hortus Palatinus left unfinished, but all the Francini grottoes in France have also been lost. Roy Strong, in his book *The Renaissance English Garden*, asks rhetorically 'Where, in fact, can we today go and see these gardens [in England]? The answer unfortunately is nowhere.'[90] Gardens, he says, are always fragile, often transitory. Grottoes and automata are especially vulnerable, as we know. 'None of these foes however', says Strong, 'was to be as devastating in its effect as the advent of the one style for which England was famous, *le jardin anglais*.'

Some have seen Pratolino, in its transformation to the Parco Demidoff, as a victim of this eighteenth-century European taste for English romantic landscape gardening. But there is a paradox here. William Kent, one of the originators of the style, was an admirer of Pratolino, and reproduced some of its features in his own work. The truth is that Buontalenti's garden displayed many of the defining characteristics of the English manner from the outset: its informal asymmetric layout, its undulating topography, its mixture of native woodland and open meadows, its garden pavilions glimpsed from a distance between the trees. Can Buontalenti be said to have invented English landscape architecture?[91] Not on his own. But as David Coffin points out, it is an irony that Demidoff's *bosco all'inglese* should have replaced Buontalenti's original, since Pratolino 'played at least a minor role in the formulation of the eighteenth-century English garden'.[92]

Orange and bergamot

The Grotto of the Deluge at Pratolino was so called because all who entered were bound to be soaked even more completely than elsewhere. This is what happened to Montaigne. He writes in his diary:

> By a single movement the whole grotto can be filled with water, and all the seats will squirt water over your breech; then, as you flee from the grotto and run up the staircase into the mansion on the other side, a pleasant trick will make the water stream from two of the steps in a thousand jets which drench you till you reach the top.[93]

Visitors running this gauntlet were, says Sgrilli, a 'delightful madness to watch'.[94]

Guests would surely have escaped with some relief from all this water torture onto the south terrace of the villa; and if it were summer would have been happy to relax and dry off in the sun. Maybe if Buontalenti was showing them round the gardens, he might have served them one of his special ices, flavoured with orange and bergamot.[95] Buontalenti devised this recipe for a diplomatic delegation from Spain received by Grand Duke Cosimo I, Francesco's father. Because of his success on this occasion, he has been credited, alongside all his other achievements, with the invention of the Italian *gelato* – which must be an exaggeration, because iced desserts were known well before this in the Middle East. Nevertheless, the Gelateria Badiani in Florence still serves a *gelato Buontalenti* today.[96] It is not flavoured with orange and bergamot, but is quite delicious in its own way.

Notes

1 Alois M. Nagler, *Theatre Festivals of the Medici 1539–1637* (New Haven, CT, and London: Yale University Press, 1964), p. 64.
2 There is a large literature on Pratolino but it is not so easily accessible, and rather little of it is in English. One of the earliest modern descriptions is by Webster Smith in his PhD thesis for New York University, 'Studies on Buontalenti's Villas' (1958). Eugenio Battisti devoted a chapter of his book *L'Antirinascimento* (Milan: Feltrinelli, 1962), pp. 220–53, to an 'iconology of automata' at Pratolino. Detlef Heikamp published an excellent descriptive overview with many pictures, 'Les merveilles de Pratolino', *L'Oeil*, 171 (1969): 16–27 and 74–5. The scholar who has devoted most attention to Pratolino is Luigi Zangheri: his two-volume *Pratolino: Il Giardino delle Meraviglie* (Florence: Gonnelli, 1979; 2nd edn, 1987) describes all the buildings and grottoes in detail. It is comprehensively illustrated and contains transcriptions of many documents. Since the Provincia di Firenze acquired the park in 1982 a number of conferences have been held there to discuss the history of Pratolino, whose proceedings have been published by Alinea, Florence. Of these I have learned most from Alessandro Vezzosi (ed.), *La Fonte delle Fonti, Iconologia degli Artifizi d'Acqua* (1985). The catalogue of an exhibition held in 1986, *Il Giardino d'Europa: Pratolino come Modello nella Cultura Europea* was published by Mazzotta, Florence. A magnificent volume, *Pratolino: Un Mito alle Porte di Firenze [Pratolino: A Myth at the Gates of Florence]*, with parallel texts in Italian and English, was published under the auspices of the Provincia di Firenze by Marsilio, Venice, in 2008. In 2001 Hervé Brunon defended his doctoral thesis at the Sorbonne, 'Pratolino: art des jardins et imaginaire de la nature dans l'Italie de la seconde moitié du XVI^{e} siècle'. This exhaustive and exhausting 1,200-page document is available online (without its illustrations): it sets the design, experience and possible meaning of the gardens in their wider cultural, social and intellectual contexts.
3 Michel de Montaigne, *Journal du Voyage de Michel de Montaigne en Italie, par la Suisse et l'Allemagne, en 1580 et 1581.* English translation by W. G. Waters, 3 vols (London: John Murray, 1903), vol. 2, pp. 43–4.
4 Fynes Moryson, *The Itinerary of Fynes Moryson*, 4 vols (London: John Beale, 1617), vol. 2, p. 152.
5 Cesare Agolanti, *La Descrizione di Pratolino del Ser.mo Gran Duca di Toscana …*, ms 1580s, National Library of Florence, Biblioteca Magliabechiana Classe VII cod. 8.
6 Letter from Simone Fortuna to the Duke of Urbino, 1584, cited by Brunon, 'Pratolino', p. 772.
7 Montaigne, *Journal*, vol. 2, p. 45.
8 Francesco de' Vieri, *Delle Marauigliose Opere di Pratolino* (Florence: Giorgio Marescotti, 1587).
9 Bernardo Sansone Sgrilli, *Descrizione della Regia Villa, Fontane e Fabbriche di Pratolino* (Florence: Stampa Granducale, 1742).
10 Heinrich Schickhardt, *Zweite Reise* ms, 1599–1600, Württembergische Landesbibliothek, Stuttgart: Cod. hist. 148b, 4 vols. The drawings relating to Pratolino are in the notebook digitised as Zweite Reise_urn_nbn_de_bsz_24-bsz3114809777. A page number is given to each double spread in the book. Zangheri provides a transcription of the text in *Pratolino*, vol. 1, pp. 221–5. Schickhardt accompanied the party of Friedrich I, Duke of Württemburg.
11 A stage set by Alfonso Parigi for *Le Nozze degli Dei di Coppola*, shown in an engraving by Stefano della Bella, is strangely reminiscent of the avenue at Pratolino: reproduced in Giulio Ferrari, *La Scenografia: Cenni Storici Dall' Evo Classico ai Nostri Giorni* (Milan: Ulrico Hoepli, 1902), plate 17, between pp. 56 and 57.
12 *The Diary of John Evelyn*, ed. E. S. De Beer, 6 vols (Oxford: Clarendon Press, 1955), vol. 2, p. 418.
13 Brunon, 'Pratolino', p. 214.
14 De' Vieri, *Marauigliose Opere*, pp. 46–7.
15 Sgrilli, *Regia Villa*, p. 26. The Mask was restored in the nineteenth century and the pond, now dry, survives: see Zangheri, *Pratolino*, vol. 2, p. 127.
16 'Pratolinum Magni Ducis Hetruriae', in Salvatore Vitale, *Ad Annales Sardiniae* (Florence: Sermartelli, 1639).
17 Brunon, 'Pratolino', pp. 376–7.
18 Montaigne, *Journal*, vol. 2, p. 57. Vasari in his *Life* of Tribolo (De Vere translation (London: Philip Lee Warner, 1914), vol. 7, p. 25) says that 'the water of the oak' could be turned on in many ways 'in order to drench anyone at pleasure with various instruments of copper, not to mention that with the same instruments one can cause the water to produce various sounds and whistlings'.
19 Luigi Zangheri, 'The Gardens of Buontalenti', in Monique Mosser and Georges Teyssot (eds), *The History of Garden Design* (London and New York: Thames and Hudson, 1991), pp. 96–9; see p. 96.
20 Zangheri, *Pratolino*, vol. 1, p. 36.
21 Smith, 'Buontalenti's Villas', p. 60, paraphrasing Sgrilli.
22 Alessandro Vezzosi, 'Pratolino d'Avanguardie *Fonti d'Ingegni Stupori e Controveleni*', in *Fonte delle Fonti*, pp. 49–67; see p. 60.
23 Schickhardt, *Zweite Reise*, p. 54.
24 De' Vieri, *Marauigliose Opere*, p. 53.
25 Moryson, *Itinerary*, vol. 2, p. 153.
26 De' Vieri, *Marauigliose Opere*, pp. 52–3.
27 Sgrilli, *Regia Villa*, p. 14.
28 Federico Zuccari, *L'Idea de' Pittori, Scultori et Architetti*, 2 vols (Turin: 1607); discussion of Giambologna, vol. 2, p. 40.
29 Robert Dallington, *A Survey of the Great Dukes state of Tuscany … in 1596* (London: Blount, 1605), p. 13. Dallington's account of Pratolino is otherwise somewhat erratic.
30 Zangheri, *Pratolino*, p. 31. The piece was later split into two, and the halves remain at the site today, covered with vegetation.
31 De' Vieri, *Marauigliose Opere*, p. 28.
32 Guerra's drawings are held in the Albertina Museum in Vienna: Graphische Sammlung 37197–37235. They were discovered and attributed to Guerra by Walter Vitzthum.
33 Alessandro Vezzosi, 'Pratolino d'Europa', degli antichi e dei moderni', in *Il Giardino d'Europa*, pp. 19–60; see p. 57.
34 Georgius Agricola, *De Re Metallica* (Basel: Hieronymus Froben and Nicolaus Episcopius, 1556).
35 Brunon, 'Pratolino', pp. 429–30.
36 Renzo Giorgetti, 'Gli organi idraulici e gli automi musicali della Villa Medicea di Pratolino', *Strumenti e Musica*, 40 (1988): 41–3, 49–50; see 41.
37 Schickhardt, *Zweite Reise*, p. 53.

38 Giorgetti, 'Organi idraulici'.
39 Giorgetti, 'Organi idraulici', p. 50.
40 Schickhardt, *Zweite Reise*, p. 52.
41 See Arthur W. J. G. Ord-Hume, *Clockwork Music* (London: Allen and Unwin, 1973), chapter 3, pp. 63–102, 'The Early Musical Box'.
42 Zangheri, 'The Gardens of Buontalenti', p. 99.
43 Edward Chaney (ed.), *Inigo Jones's 'Roman Sketchbook'* (London: The Roxburghe Club, 2006), vol. 1 (facsimile), 76r, and vol. 2 (transcription), pp. 167–8. I have adjusted Jones's very erratic spelling a little.
44 Other sources refer to Bonaventura da Orvieto (Agostino del Riccio, *Del Giardino di un Re*, ms, Biblioteca Nazionale Centrale, Firenze, Targ. 56, vol. 3, fol. 58r); Carlo Marcellini (Sgrilli, *Regia Villa*, p. 17); and 'Gocerano da Barma [i.e. Parma]' (Schickhardt, *Zweite Reise*, p. 53) as responsible for some of the machinery at Pratolino.
45 Matteo Valleriani, 'Il ruolo della pneumatica antica durante il Rinascimento: l'esempio dell'organo idraulico nel giardino di Pratolino', in A. Calzona and D. Lamberini (eds), *La Civiltà delle Acque dal Medioevo al Rinascimento* (Florence: Olschki, 2010), pp. 613–32; 'Ancient Pneumatics Transformed during the Early Modern Period', *Nuncius*, 29/1 (2014): 127–73; and 'The Transformation and Reconstruction of Hero of Alexandria's *Pneumatics* in the Garden of Pratolino', *A Myth at the Gates*, pp. 151–81.
46 Schickhardt, *Zweite Reise*, p. 52.
47 Sgrilli, *Regia Villa*, p. 18.
48 Sgrilli, *Regia Villa*, p. 19.
49 Philo of Byzantium, *Pneumatica: The First Treatise on Experimental Physics*, ed. Frank David Prager (Wiesbaden: Ludwig Reichert Verlag, 1974), p. 219; Prager says that the shepherd is Paniscus or 'little Pan'.
50 De' Vieri, *Marauigliose Opere*, p. 36; Sgrilli, *Regia Villa*, p. 14.
51 Schickhardt, *Zweite Reise*, p. 50.
52 Schickhardt, *Zweite Reise*, p. 52.
53 Salomon de Caus, *Les Raisons des Forces Mouvantes, Avec diverse Machines tant utiles que plaisantes; Ausquelles sont adjoints plusieurs desseins de Grotes & Fontaines* (Paris: Hierosme Droüart, 1624), Book I, Problem XXIIII.
54 Philon de Byzance, *Le Livre des Appareils Pneumatiques et des Machines Hydrauliques*, French translation by Le Baron Carra de Vaux (Paris: Imprimerie Nationale, 1902), section 30.
55 See Brunon, 'Pratolino', pp. 211–12.
56 Sgrilli, *Regia Villa*, p. 17.
57 Giovanni Rosini, *La Monaca di Monza: Storia del Secolo XVII*, 4th edn (Pisa: Niccolo Capurro, 1829), Book 1, p. 151.
58 Giovanni Battista Falda, *Le Fontane di Roma* (Rome: Gio. Giacomo de Rossi, 1691), Part 2, plate 7.
59 Francis Mortoft, *Francis Mortoft: His Book, Being his Travels through France and Italy, 1658–59*, ed. Malcolm Letts (London: The Hakluyt Society, 1925), p. 166.
60 Hero, *Pneumatics*, p. 68.
61 Rosini, *Monaca di Monza*, pp. 151–2.
62 Sgrilli, *Regia Villa*, p. 17.
63 Anthea Brook makes no mention of automata in 'Ferdinando Tacca and His Circle', PhD thesis, Courtauld Institute, London (1987). Luigi Zhangeri (in 'Ferdinando Tacca, architetto e scenografo', *Antichità Viva*, 13/2 (1974): 50–61) mentions only the fortress scene described by Sgrilli.
64 Montaigne, *Journal*, vol. 3, p. 106.
65 De' Vieri, *Marauigliose Opere*, p. 8.
66 Battisti, *L'Antirinascimento*, p. 238.
67 Claudia Lazzaro, *The Italian Renaissance Garden* (New Haven, CT: Yale University Press, 1990), pp. 162–5.
68 Brunon, 'Pratolino', pp. 518–19.
69 Brunon, 'Pratolino', p. 767.
70 Mila Mastrorocco, *Le Mutazioni di Proteo: I Giardini Medicei del Cinquecento* (Florence: Sansoni, 1981), p. 117; my translation.
71 Smith, 'Buontalenti's Villas', p. 9.
72 Francesco Mari, Aldo Poletini, Donatella Lippi and Elisabetta Bertol, 'The Mysterious Death of Francesco I de' Medici and Bianca Cappello', *British Medical Journal*, 333/7582 (23–30 June 2006): 1299–1301. Another study in 2010 found the parasite that causes malaria in Francesco's body.
73 Zangheri, *Pratolino*, p. 11.
74 Hugh Honour, 'John Talman and William Kent in Italy', *Connoisseur*, 134 (August 1954): 3–7. Kent visited again in 1730.
75 Sade mentions Pratolino in his *Voyage d'Italie*, ed. Gilbert Lely and Georges Daumas (Paris: Tchou Éditeur, 1967), p. 159, but just as 'one of several country houses that are worth visiting'.
76 Marquis de Sade, *Histoire de Juliette*, *ou Les Prospérités du Vice* (1797–1801), trans. Austryn Wainhouse (New York: Grove Press, 1968).
77 De Sade, *Juliette*, pp. 578–94.
78 Sergio Salvi, 'La Dimora di Minski', in *Giardino d'Europa*, pp. 11–12; see p. 11.
79 See Zangheri, *Pratolino*, chapter 8 pp. 72–7, 'I Demidoff: dal ritorno feudale all'esilio'.
80 See Luigi Zangheri, 'I Giardini d'Europa: una mappa dell fortuna medicea nel XVI e XVII secolo', in *Il Giardino d'Europa*, pp. 82–92.
81 Giambologna made four versions of his 'Mercury', and the work was later copied many times by others.
82 Silvio A. Bedini, 'The Role of Automata in the History of Technology', *Technology and Culture*, 5/1 (1964): 27–8.
83 Naomi Miller says that the automata and grottoes at Rueil were designed by Tommaso Francini: 'Domain of Illusion: The Grotto in France', in Elisabeth Blair MacDougall (ed.), *Fons Sapientiae: Renaissance Garden Fountains* and *Fountains, Statues and Flowers* (Washington, DC: Dumbarton Oaks Research Library and Collection, for Harvard University, 1978 and 1994), pp. 117–206; Appendix, p. 206.
84 Madeleine Horn-Monval, 'La grande machinerie théâtrale et ses origines', *Revue de la Société d'Histoire du Théâtre*, 4 (1957): 297–8.
85 Luke Morgan, *Nature as Model: Salomon de Caus and Early Seventeenth-Century Landscape Design* (Philadelphia: University of Pennsylvania Press, 2007); Luigi Zangheri, 'Salamon [*sic*] de Caus e la fortuna di Pratolino nell'Europa del primo seicento', in *Fonte delle Fonti*, pp. 35–43.
86 The Duke of Saxony and his escort Neumayr; see Roy C. Strong, *The Renaissance Garden in England* (London: Thames and Hudson, 1979), pp. 90–1.
87 Salomon de Caus, *Hortus Palatinus a Friderico Rege Boemiae, Electore Palatino Heidelbergae Exstructus* (Frankfurt: J. T. de Bry, 1620).
88 De Caus, *Forces Mouvantes*, Book 2, Problem II.
89 Zangheri, 'I Giardini d'Europa', p. 85. There are numerous videos of the gardens at Hellbrunn online.
90 Strong, *Renaissance Garden*, p. 11.
91 As suggested by Germain Bazin in *Paradeisos ou l'Art du Jardin* (Paris: Chêne, 1988), p. 112.
92 Bazin, *Paradeisos*, p. 279.
93 Montaigne, *Journal*, vol. 2, p. 45.
94 Sgrilli, *Regia Villa*, p. 12.
95 This was a sorbet made with ice, salt (to lower the temperature), lemon, sugar, egg, honey, milk and a drop of wine; plus the orange and bergamot flavouring. Giovanni Battista della Porta describes a method by which 'Wine may freeze in glasses' using saltpetre (*Natural Magick*, English edn, 1658, p. 324).
96 Gelateria Badiani, Viale Dei Mille 20, Florence.

8
Mercury and Mars in Parma, 1628

The Farnese Theatre in Parma was inaugurated on 21 December 1628 with the first and only performance of an 'opera tournament', entitled *Mercurio e Marte* [*Mercury and Mars*].[1] In this idiosyncratic form of entertainment, *intermezzi* were alternated with bouts of formal sword fighting. By seven in the evening every seat in the immense auditorium was filled. The official *Description* said that there were 10,000 in the audience, but this was propaganda: the true number, still very large, was probably nearer 2,500.[2] The occasion was the marriage of Odoardo Farnese, Duke of Parma, to Margherita de' Medici of Florence, both aged 16. Once the young couple had entered with their entourage and taken their places under a baldacchino of silver and white brocade, the performance began with Claudio Monteverdi's orchestral overture. Six hours later the final and most spectacular scene closed to wild applause. Camillo Giordano, who was present, said: 'There has never been a grander tournament, one employing a greater number of ingenious machines.'[3]

For Buontalenti and Parigi's Florentine *intermezzi* there are many illustrations of the scenery as seen by the audience, but up until recently – as mentioned in Chapter 1 – it was thought that no contemporary drawings had survived of the backstage machinery with which the special effects were created. For *Mercury and Mars* this situation is reversed. Only a couple of pictures of scenes remain that might possibly be for this production. On the other hand, there are many illustrations of seventeenth-century stage machinery, including a number that relate specifically to the Teatro Farnese in 1628.[4] These were to provide models for the technical equipment of theatres right up to the nineteenth century. It was the architect of the Farnese Theatre, Giovanni Battista Aleòtti, who conceived and built the scenic apparatus used in Parma, together with his assistant and successor as stage designer, Francesco Guitti.

The building of the Teatro Farnese

The theatre building had in fact been finished ten years earlier and had been dark since 1618. Odoardo's father Ranuccio and his advisers had long wanted to create a political alliance with Florence. When Odoardo was just an infant they approached Grand Duke Cosimo II of Florence about the possibility of the boy eventually marrying one of Cosimo's daughters. Cosimo was doubtful. But when Cosimo planned a pilgrimage to Milan in 1617, Ranuccio decided to welcome him in Parma on his journey north with a series of grand celebrations. These would include a dramatic presentation in a specially constructed new theatre.

For help in overseeing the building works and programme of entertainments, Ranuccio turned to his friend Marquis Enzo Bentivoglio of Ferrara, a city that had a long-established reputation for its theatrical activities. Bentivoglio was a music lover and man of letters, and the leading figure in Ferrara's learned society, the Accademia degli Intrepidi, the Academy of the Undaunted. The history of the Academy's productions and theatre buildings is complex.[5] The group used a large multipurpose hall, the Sala Grande, and also put up temporary outdoor stages. The permanent Teatro degli Intrepidi that Aleòtti built for the Academy in 1606 bears several resemblances to the Teatro Farnese, for which it can be seen as an architectural dress rehearsal. It had a proscenium arch, a tapered perspective stage and a U-shaped auditorium with stepped seating.[6] In 1610 Ranuccio had been sent drawings of sets at the Intrepidi, which he 'very much admired'.[7] Aleòtti had other experience in theatre building, including the temporary structure at Sassuolo described in Chapter 1.[8] He was thus the natural choice to design the Farnese Theatre in Parma.

And there was another reason for appointing Bentivoglio and Aleòtti. Both were experts in mounting a special type of entertainment popular in Ferrara, the formal tournament known as the *campo aperto* ('open field'), for which the new theatre in Parma was also to be used. Aleòtti had worked on one such event in the courtyard of the Bishop's Palace in Parma in 1616.[9] This was a descendant of the medieval tourney, but in which brute force and physical danger had been replaced by formalised ritualistic combat and where elegance and tactics were valued, as in modern fencing. There was a historicising, even quixotic quality to the form.

When such tournaments were held outdoors, they featured choreographed horsemanship – in which Bentivoglio was an expert – but indoors, competitors on foot crossed swords over a raised barrier. The fact that the Farnese Theatre was to accommodate this activity had a major impact on its plan. It was decided to convert an extremely large existing hall, some 30 metres by 90 metres – as long as a football pitch – on the first floor of the sprawling Farnese palace in Parma known as the Pilotta.[10] This is the biggest private theatre ever constructed. We have already seen something of the interior in the photograph of Figure 1.22.

The auditorium has a strongly Vitruvian character, with a central flat *orchestra* floor, raked seating and colonnade at the rear behind the seats. But there are two major departures from ancient precedent. The *frons scenae* contains a single large proscenium opening, as discussed in Chapter 1. And the *orchestra* is not semicircular but is stretched, to provide an elongated flat arena for the tournaments. The roof was originally decorated as a sky with the Olympian gods and 'an infinite number of figures flying in the air'. Behind the colonnade, the walls were painted with perspective views of yet more tiers of seats and spectators.[11] (Maybe the 1628 *Description*'s 10,000 counted these.) Only fragments of these decorations survive.[12]

Figure 8.1 is a cutaway perspective section of the building in which one can see the great depth of the stage, comparable in length to the auditorium. Here there was ample space to store scenery, flying machines and the decorated vehicles in which actors came on stage. On either side of the proscenium there are two grand entrance doors for the audience and competitors, with equestrian statues of former dukes above, one of whom is visible here. There is a long staircase from ground level up to a third entry at the back of the auditorium, which is sufficiently shallow for horses to be ridden up into the theatre.

Preparations in 1618

By January 1618 the building was largely complete, and Aleòtti was working to finalise the scenery and the machines for the show that was to greet Cosimo's entry to Parma. Ranuccio had commissioned an opera tournament with libretto by Count Alfonso Pozzo and music by the composer Antonio Goretti. The title was *La Difesa della Bellezza* [*The Defence of Beauty*]. A series of letters survives from Aleòtti to Ranuccio giving progress reports.[13] There are references to delays and trouble among the workforce, but Aleòtti's main purpose is naturally to reassure. One of the scenes in Pozzo's script demanded the reconstruction on stage of the (real) Garden Palace in Parma with its fountain. Aleòtti describes visiting the palace with scene painters to make sketches.

In another letter Aleòtti describes the testing of several vehicles and flying machines, to which we will return. He mentions a wave machine built by two colleagues 'turned by screws, which when set going makes a most beautiful effect'.[14] Figure 8.2 illustrates a seventeenth-century machine of this type, although this may not be the actual device at the Teatro Farnese. The waves are cut-outs given a circular motion with crank handles. They are supported on a frame that is simultaneously pulled from side to side with ropes. For *Mercury and Mars*, the crests of the waves were made to sparkle with white tinfoil.

In August the boy Odoardo was brought to see the works and was reportedly 'delighted, looking at all those lovely things with close attention'.[15] Cosimo had been expected finally to arrive from Florence in September, but his journey had been repeatedly delayed by illness, and it became clear that he was never coming. *The Defence of Beauty* was cancelled, and after a few more months of work the theatre was mothballed. However, Aleòtti's machines and some of the scenes were put into storage.

Ranuccio continued over the following years to press the case for Odoardo marrying a Medici, and eventually an engagement was agreed with Cosimo's oldest daughter Maria. More time passed, and Maria died at the age of seventeen. But Ranuccio was happy with any Medici daughter, so the young Margherita took Maria's place: hence the wedding in 1628.

The plot of *Mercury and Mars*

In 1627 the writer Claudio Achillini was asked to prepare a new text with which to finally open the theatre.[16] He was tightly constrained in three ways: the format for the production had to be that of another opera tournament; it had to celebrate the wedding of Odoardo and Margherita; and since time was short, the old machines from 1618 were to be reused. His solution was to imagine the Olympian gods in

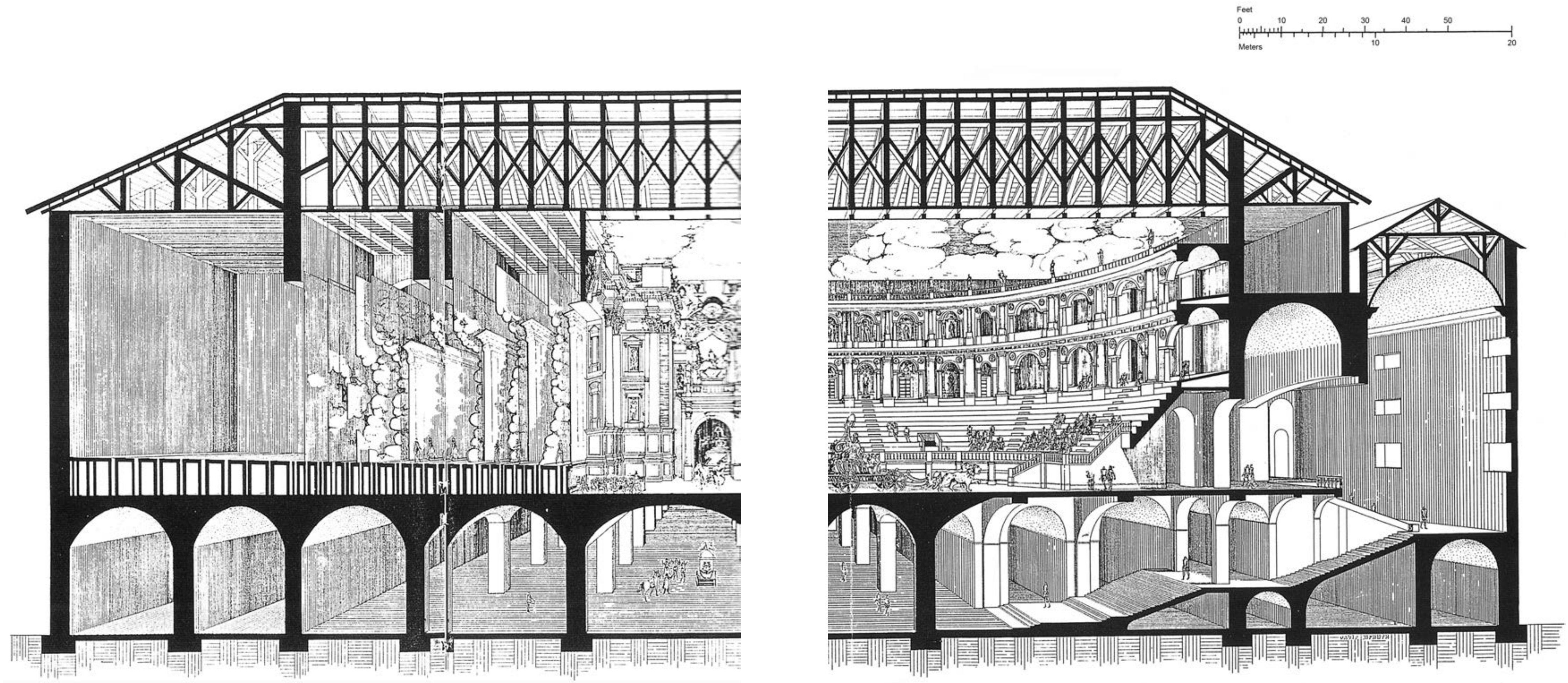

Figure 8.1 Cutaway perspective section of the Teatro Farnese designed by Giovanni Battista Aleòtti in 1618. The drawing is by George C. Izenour. Notice the very large backstage areas and the perspective scenery on flats; the stepped seating; the shallow staircase up from ground level by which horses could enter the arena; and the chariot of Berecynthia drawn by lions. By permission of Yale University Press.

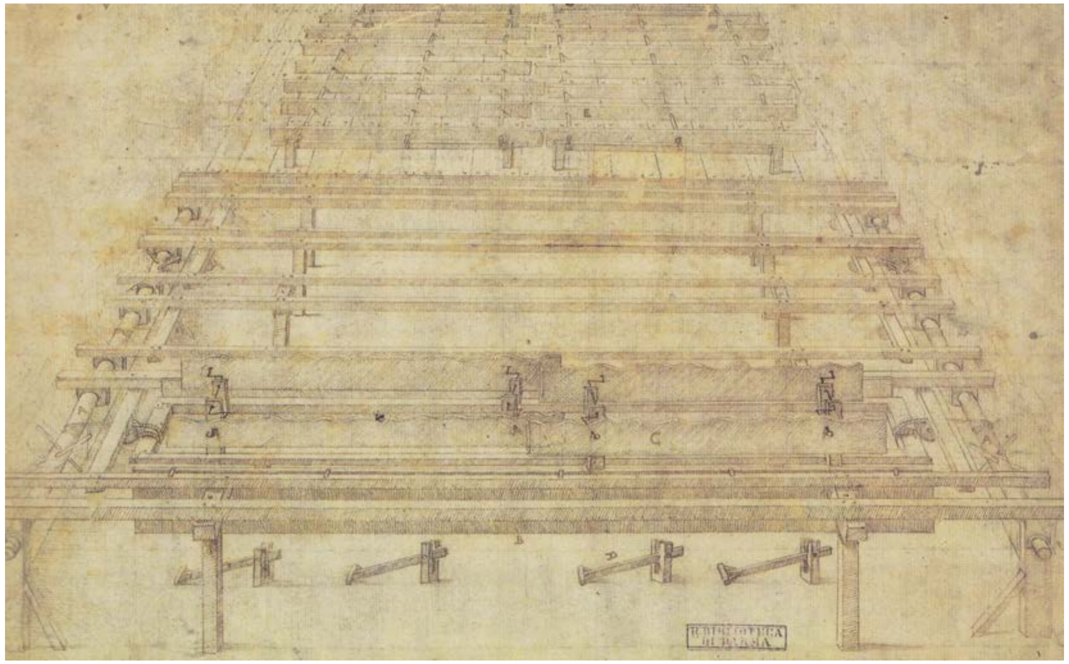

Figure 8.2 A wave machine. The cut-out wave profiles are rocked with crank handles. The complete waves are supported on a frame that is simultaneously moved from side to side. Parma, Biblioteca Palatina Ms Parm f.35, courtesy of the Ministry of Cultural Heritage and Tourism.

disagreement about the young duke's future career and style of life. Should Odoardo continue his studies and become a poet and intellectual, or should he take up arms and turn to soldiering? (Achillini was the young man's tutor, so he had a personal interest.) Mercury, god of eloquence and messenger of the gods, takes the first view, and seeks to delay the marriage. Mars, god of war, takes the second view, and is in favour of the planned tournament in which the duke will prove himself in swordsmanship: he will compete with 40 young men from the best families of Parma, divided into four teams. Odoardo and these 'adventurers' are to perform not just in the tournament but in the drama itself.

In order to frustrate this plan, Mercury arranges for Odoardo and the swordsmen to be locked away in inaccessible places: in the depths of a mountain, in a hellish swamp, in caves beneath Etna and in the bellies of sea monsters. There seems to be some suggestion of Earth, Fire and Water here, perhaps with Mount Olympus representing the realm of the Air. Mars then enlists the help of other Olympians to free the heroes. As each of the ten-man squadrons is released, a formal swordfight ensues.

Mercury and Mars follows the broad dramatic structure of Pozzo's *The Defence of Beauty*. This too included four episodes of fighting. Achillini took over some scenes directly, including an introduction featuring Aurora, goddess of dawn. Old machines were made to carry new occupants. Some old settings, including the City of Cnidus, associated with the goddess Venus were introduced just to reuse scenery from 1618. All this fantastic action, on Mount Olympus, in the Underworld and in the other places where the adventurers were held, proceeded on stage. But when it came to the tournaments, the participants descended to the floor of the auditorium. I imagine that the music was also paused at these points. Etiquette required, of course, that Odoardo was the victor in his contest.

Aleòtti was now in his eighties, so his assistant Francesco Guitti took over as set designer: but Guitti worked as mentioned with much of his master's existing machinery from 1618. Enzo Bentivoglio was again put in overall charge of the production. However, he was in Ferrara most of the time, so Guitti and others sent him updates on the preparations. This correspondence reveals many details that supplement the full *Description* by Marcello Buttigli published afterwards.

Bentivoglio invited his friend Monteverdi, then at the height of his powers, to compose new music for Achillini's text. Antonio Goretti who had written the music for *The Defence of Beauty* acted as Monteverdi's assistant. Monteverdi was alarmed at the great length of Achillini's verses.[17] He was also concerned about the acoustics of such a large hall and whether his music would be heard above the grinding and rumbling of the machines. Eventually ducts or tubes of some kind were devised with which to direct the sounds of the harpsichords towards the audience.[18]

The art of opera had been conceived in Florence in the 1570s and 1580s by an academy of scholars, poets and musicians, led by Count Giovanni Bardi, calling themselves the Camerata. This group believed that ancient Greek plays had been sung not spoken, so they sought to recreate this fusion of drama with music in new works, of which the first was *Dafne*, put on in 1598. (The term 'opera' came later.) Ranuccio Farnese saw this production and was evidently captivated.[19] The Camerata introduced the characteristic operatic method of intoning rhythmical speech that was to become recitative. Choral singing was alternated with solos and duets. Opera can also be seen as an evolution from the *intermezzi*, whose dancing, music and special effects became woven into the continuous plots of the comedies of which they were previously the notional intervals.

Monteverdi began his career in Mantua, and his *Orfeo* was performed there in 1607. In 1613 he moved to Venice, where he became choirmaster at the basilica of San Marco, then the chapel of the Doge. Here he composed several operas for Venice's public theatres, including his sensational *Coronation of Poppea* of 1643. Monteverdi travelled from Venice to Parma to rehearse *Mercury and Mars* (although it seems he was not at the actual performance). His score was lost when Mantua was sacked in 1630, but from contemporary correspondence it becomes clear that Monteverdi set out to give life to Achillini's plodding book by conveying individual character and emotion through his music. There is a character Discord, for example, who brings disruption and argument to the drama, as we will see. According to Claudio Gallico, she was made 'to speak as if she were singing, but without the singing being based on any kind of instrumental harmony'.[20]

Drawings for stage machinery in Parma and Ferrara

Much of the technical apparatus employed in *Mercury and Mars* would seem to resemble that used by Buontalenti and Parigi in the Florentine *intermezzi*. Certainly, many of the effects created were similar, going by illustrations of scenes and eyewitness accounts. There were wheeled chariots, sea monsters, the flames of Hell and tall structures rising from the traproom. But now in the early seventeenth century we have detailed technical backstage drawings, in particular illustrations of elaborate multi-person cloud and flying machines.

There are two collections of historic drawings for stage scenery and machines kept in Parma, one at the Palatine Library, the other in the State Archives. Several of these are highly complex and not easy to understand. In 1959 the theatre specialist Elena Povoledo proposed that some of them showed the actual machines used in *Mercury and Mars*.[21] Other historians questioned this idea. A luxuriously illustrated volume of essays on the Farnese Theatre and its inauguration, published in 1992, reproduced many of the drawings, implying a direct connection; but the text was evasive and did not spell this out explicitly.[22] The difficulty is that none of the pictures is signed or dated, and none carries references to particular theatres or productions. Several of the sheets are annotated, but these notes only explain the various components of the machines – although on occasion they mention that vehicles are for carrying specific characters (including both Mercury and Mars).

However, all this changed in the late 1990s when the art historian Giuseppe Adami discovered two previously unknown sketchbooks from the private family archive of Pietro Paolo Floriani.[23] Floriani was a military engineer active in Ferrara in the early seventeenth century who was involved in several tournaments, and also directed the rebuilding of the city's fortifications. He employed Francesco Guitti, Aleòtti's assistant stage designer, in these construction works. The sketchbooks contain drawings for many kinds of stage machinery, with notes and explanations. The books can be dated to around 1630, and are mostly in Floriani's hand, with the exception of two sheets by Guitti.

Around 15 drawings relate specifically to *Mercury and Mars* in Parma,[24] others to different productions that Guitti designed at the Teatro degli Intrepidi and elsewhere in Ferrara. The drawings are rough and schematic, but they are clearly not preliminary studies, since they are made after the event. One gets the impression that Floriani is setting down for his own purposes, as an aide-memoire, what Guitti has told him. Possibly he made sketches from the very machines themselves.

I will refer in detail to several of Floriani's sketches. At this point it may be helpful to see some of the general principles and standard components that Aleòtti and Guitti use repeatedly. Figure 8.3 reproduces one drawing for an apparatus with which an actor in *Mercury and Mars* representing the Golden Age descends from the sky in a shining chariot covered in polished metal.[25] The car is supported on a vertical beam *D* that slides inside an elongated open-ended box *C*. Floriani uses military terminology to describe these two components. The box is the *cassa*, meaning the barrel of a cannon. The beam inside is the *anima*, meaning the mould on which the barrel is cast. The *anima* slides inside the *cassa* and can be lowered and raised with ropes and a winch (not shown here). The *cassa* is supported in the roof of the theatre on a trolley running on a pair of rafters. In this way the chariot can be made to move both up and down, and across the stage. When the machine is not in use it can be shifted into the wings.

The structure is concealed from the audience by clouds made from painted boards. These are attached to battens *E* that are hinged at their ends and open out as the *anima* descends, so that the arrangement of clouds changes. Aleòtti applies the same principle in machines where the telescopic beam is horizontal and appears from the side or back of the stage, or is vertical and rises from the traproom below stage.

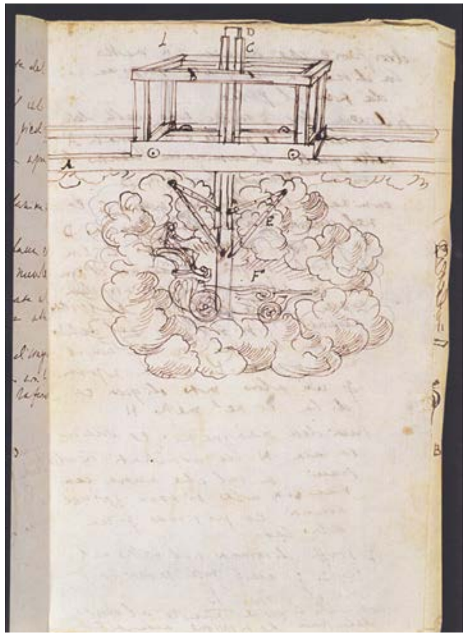

Figure 8.3 Sketch by Pietro Paolo Floriani of a machine by which an actor representing the Golden Age descends in a chariot, in *Mercury and Mars*. The car is supported on a vertical beam *D* (the *anima*) sliding inside an elongated box *C* (the *cassa*). The *cassa* hangs from a trolley running on rails in the theatre roof. As the *anima* is lowered with a winch (not shown), the hinged battens *E* straighten out, causing the attached clouds to change their positions. Associazione Compagnoni Floriani di Villamagna. All rights reserved ©.

The chariot system for moving scenery

Besides the enigma of the Parma machine drawings, there has been a long technical debate about the nature of the scenic wings at the Teatro Farnese. We know that these were flats, moved sideways. Marcello Buttigli in his *Description* of *Mercury and Mars* says there were four banks of flat wings in use on each side of the stage.[26] The argument relates to the exact method by which they were moved. I will propose, as have others including Giuseppe Adami, that Aleòtti made major innovations here. The method in question became known as the 'chariot system', with which flat scenery can be changed very rapidly and semi-automatically. Theatre historians have taken different views about who invented the system and where it was first used.[27]

The impresario Giacomo Torelli, who built and ran opera houses in Venice and Paris in the mid-seventeenth century and designed their

scenery, claimed to be the inventor and was believed by many later writers.[28] His effects were so spectacular that he became known as *il grande stregone*, the great sorcerer, reputed to be in league with the devil.[29] But Torelli was an agile self-promoter whose claim, I suggest, is not entirely to be trusted. I will explain how the machinery worked, and we will then be in a position to assess the evidence for Aleòtti being its originator.

Each wing rides on a thin two-wheeled 'chariot' that runs in a groove or along a rail on a lower floor beneath the stage. The chariot guides the wing through a slot in the stage. Figure 8.4 is a drawing of a chariot from a modern French book, *Traité de Scénographie* (showing that the technology survived essentially unchanged in some theatres right up until the twentieth century).[30] *P* is the stage, *S* marks the beams either side of the slots in the stage, *D* is the floor below and *Ch* is the chariot running on the rail *R*. Notice the hooks on the chariot for

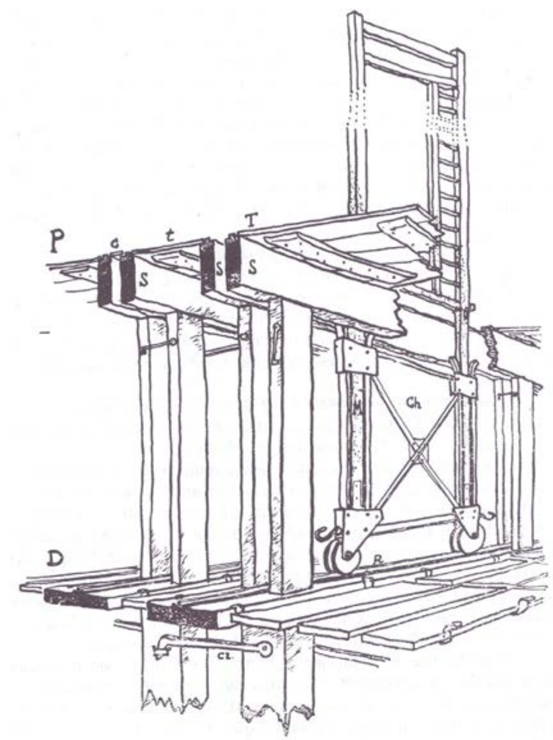

Figure 8.4 A 'chariot' carrying a flat wing. The chariot *Ch* runs on wheels below stage, moving through a slot between the beams *S*, *S*. Notice the hooks on the chariot to which the ropes are attached. From Pierre Sonrel, *Traité de Scénographie*, by kind permission of Librairie Théâtrale, Paris.

attaching the ropes with which it is pulled along. The wooden supports for the flat are slotted into the vertical elements of the chariot frame. The wing itself might not be rectangular but could be a cut-out shape representing for example a tree or a rocky cliff. Instead of a flat, a chariot could support a pole on which a slender piece of scenery, such as a classical column, could be moved.

The ropes on the chariots run over pulleys and are wound round a long drum positioned below the centre of the stage. When this drum is turned, one set of chariots is pulled towards centre stage and a second set is pulled to the edges of the stage. In this way the flats for one scene are all replaced with the flats for the next scene.[31] This movement can be very fast. Fabrizio Carini Motta was a stage designer and theatre architect who worked in Mantua in the second half of the seventeenth century. He wrote a text on theatrical machines, not published until the twentieth century, in which he illustrates several types of chariot system including the layout shown at the top of Figure 8.5.[32] Here the drum would be turned manually by stagehands using levers. The three drawings of chariots in front view below illustrate different ways of connecting the cords. Carini Motta says that chariots are the most convenient method of changing scenery ever devised.[33]

Sir Philip Skippon, the English traveller, saw a chariot system in operation at the Teatro Santi Giovanni e Paolo in Venice in 1665.[34] His sketch (Figure 8.6) is a little amateurish but again conveys the basic principles. There is one new feature here: the drum is turned not by hand but by a falling weight. Skippon apologises for the fact that his drawing is wrong on this specific point: the stone *S* serving as the weight 'should appear downwards in the motion', descending towards the point *M*. 'There is a man always standing ready at *M*', Skippon says, 'who upon the given signal, lets the stone fall, and changes a great number of scenes [wings], on a sudden … Before another scene appears, the stone must be wound up again.'[35] A second visitor who also went backstage in Venice saw a single boy of 15 operating a chariot system with counterweights that shifted 16 wings, eight on each side of the stage.[36]

What is the evidence for chariots at the Teatro Farnese? Unfortunately, the surviving plans for the building by Aleòtti do not show the stage layout in detail. However, in one of the letters that Aleòtti sent to Duke Ranuccio in 1618 he says that 'some of the flats that must go forward and back are in position, and a winch is in place for pulling and pushing them back and forth'.[37] Official court records in the same year mention an order for 'twenty walnut wheels, each six inches in diameter, for rolling cars which bear the scenic wings'.[38]

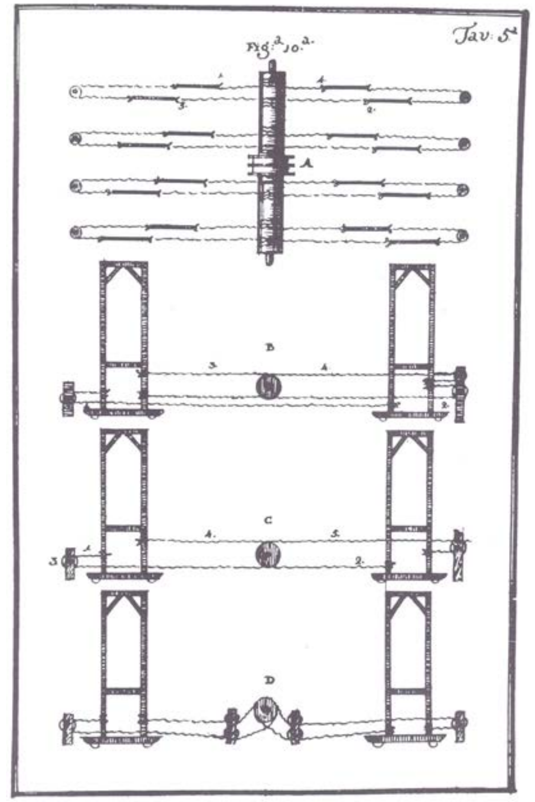

Figure 8.5 Design by Fabrizio Carini Motta for a chariot system. The plan at the top shows the central drum that pulls the flats with ropes. The three elevation drawings below illustrate different ways of connecting the ropes. By permission of the Biblioteca Estense, Modena.

And a letter from the time when the theatre was being renovated for *Mercury and Mars* in 1628 refers to a problem with scenery not running smoothly on stage, for which the answer was to install a second winch 'in the bottom of the scene', 'it being clear that the problem arises in the attachment and detachment of the ropes'.[39]

A page from Floriani's second sketchbook shows chariots used in a production in Ferrara, perhaps in the 1620s.[40] These are carrying cut-out profiles of what looks like vegetation or perhaps low clouds. Another sketch, a few pages later, shows the drum below stage on which the cords are wound.[41] This drawing is slightly confusing but shows chariots, the drum itself and four counterweights.

At the very least, all this disposes of Torelli's claim to have introduced chariots for the first time in Venice in the 1640s.

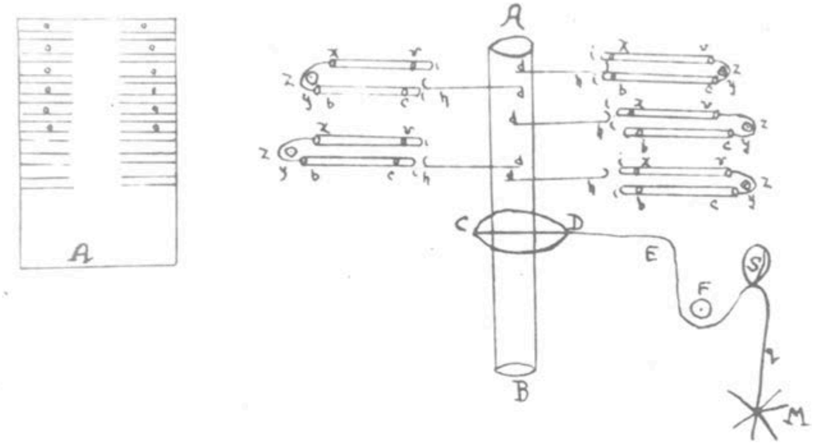

Figure 8.6 Sketch by Sir Philip Skippon of chariots in operation at the Teatro Santi Giovanni e Paolo in Venice. The stone *S* acts as a counterweight, and should be shown, Skippon says, falling towards the point *M* (not 'hanging upwards' as he has drawn it).

Giuseppe Adami believes that Aleòtti conceived them for tournaments at the Teatro degli Intrepidi in the 1610s, that he 'almost certainly' installed them at the Teatro Farnese in 1618 and that they were taken over by Guitti both in Ferrara and then in Parma in 1628. Another letter to Bentivoglio from 1628 about preparations at the Teatro Farnese says: 'On the scenes that rise up, counterweights have been fixed, and I trust that the next time we pull them, they will move correctly; and all the others are adjusted.'[42] This is scenery that moves *vertically*, not horizontally. But if Aleòtti was using weights to move flats up and down, it seems probable that he was doing the same to move flats sideways.

Flat wings and the perspective illusion

A special issue arose with the integrity of the perspective illusion, in the transition from the scenery of Peruzzi and Serlio, to the *periaktos* and then the flat scenic wing. Peruzzi and Serlio's 'houses' were built solidly in three dimensions, and each receding face extended the full length of the building represented. But if an architectural scene was to be painted on standard *periaktoi* or flats of equal width, this could mean that buildings of unequal size had to be divided between two or more scenic

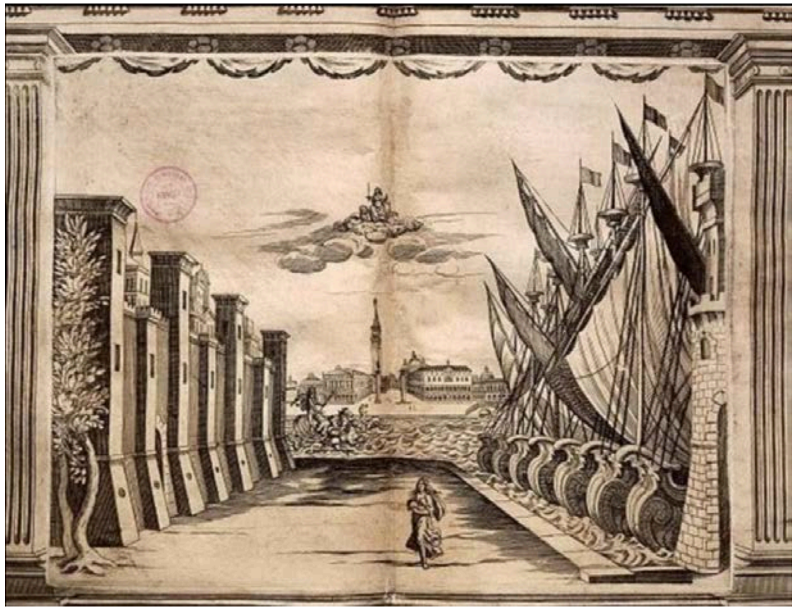

Figure 8.7 A scene by Giacomo Torelli for *Bellerofonte* with flats painted as repeated bastions on the left and repeated ships at the right. Wikimedia Commons: Teatro Novissimo, set design by Giacomo Torelli, 1644.

units. When viewed from the correct eyepoint, the result could still be convincing. But when viewed from the sides of the auditorium, the lines of the buildings would be broken, and the desired visual 'joins' between the flats would cease to work.

Buontalenti and Parigi got round the difficulty by confining themselves, for the most part, to non-architectural settings made up from rocks, trees or clouds. Here the eye is more forgiving and the audience does not look for visual alignments. Palaces and other buildings could be painted on the backdrop or built solid in centre stage. In the scenery associated with the theatres in Ferrara and Parma, and in the Venetian opera houses, designers found a different solution. All the flats were painted with similar repeated architectural elements, such as niches with pilasters, archways or towers. Figure 8.7 is a Venetian set design by Giacomo Torelli for *Bellerofonte*, where the flats are painted as bastions on one side and the prows of ships on the other. A backdrop is used to close the scene. This type of regular box-like format was endlessly repeated in the later seventeenth century. (These are still accelerated perspectives on tapering stages, which look deeper than they really are.)

The curtain falls

Let us now join the audience on the night of 21 December. I will act as narrator, drawing on Achillini's script and Buttigli's *Description*. I will use Floriani's sketches and other drawings to explain how the various machines worked.

Monteverdi has divided his players into five groups: two in balconies above the side entrances to the auditorium, two inside the proscenium, and one on the auditorium floor, below the parapet of the stage. The whole orchestra strikes up. The curtain falls and the audience can just make out a rocky harbour – the sea created by wave devices – flanked by craggy mountains. The stage is in near darkness, the sky full of stars. Gradually a rosy light spreads over the scene. Aurora emerges from the water at the left in a sparkling silver chariot drawn by Pegasus and rises diagonally across the scene, singing 'with an angelic voice'.

> *The set is shown in Floriani's drawing of Figure 8.8.*[43] *Aurora's flying chariot is attached with a hook C to an* anima *A that runs in a* cassa *or box beam B. This beam is set diagonally behind the backdrop. A long cut is made in the cloth through which the hook can protrude to support the car. A winch at top right pulls the* anima *and the car upwards.*
>
> *This sea, and another at the very end of the show, come right to the front of the stage, and are not created in a rear stage as some seas were in the Florentine* intermezzi*. Floriani illustrates machinery – for another theatre, not the Farnese – that moves the entire stage floor backwards on rollers, uncovering wave machines below.*[44] *Buttigli says that the stage floor was removed 'in an instant' for the final sea in Mercury and Mars.*
>
> *Two of Floriani's sketches show a wave machine whose operation is similar to the apparatus turned by crank handles of Figure 8.2. But he has other novel designs (none explicitly for* Mercury *and* Mars*).*[45] *In one device the waves are attached to a thin wooden rod that is flexed up and down. In another each wave is mounted on a pivoted rocker that has gear teeth engaging with the units on either side, so that rocking one wave moves all the others.*

There is then a 'great change in the air' and clouds appear from all directions. These float up and down and from side to side, as though playing games.

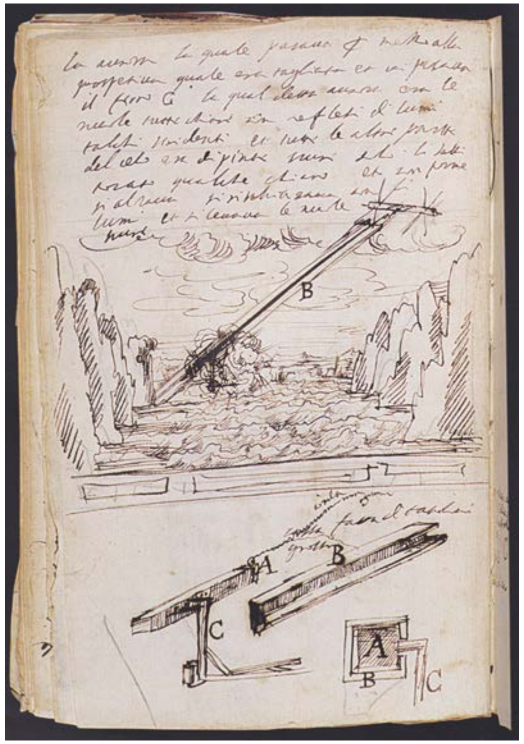

Figure 8.8 Sketch by Floriani for the mechanism by which Aurora rises in her chariot diagonally across the scene. The vehicle is carried by a hook *C* attached to an *anima*, A, running in the *cassa*, B. A winch at top right pulls the *anima* upwards. The sea is created with wave devices. Associazione Compagnoni Floriani di Villamagna.

> *Floriani has no illustration, but it seems possible that behind this effect was the type of machine illustrated in the drawing from the Parma State Archive of Figure 8.9. Painted cut-out clouds are fixed to hinged battens. The ends of the battens hang on ropes, wound on a series of cylindrical drums on a common axle above. This axle is turned with the windlass at the top. Because the cylinders have different diameters, the ropes are raised or lowered at different speeds, causing the battens to tilt as they move up and down, and the arrangement of clouds to shift and change.*

The clouds part to reveal a circular Zodiac chart, some 7 metres across, carrying 12 seated actors representing months of the year. At the centre, according to Buttigli, are the concentric circles of the cosmos. The machine advances slowly towards the audience, accompanied by

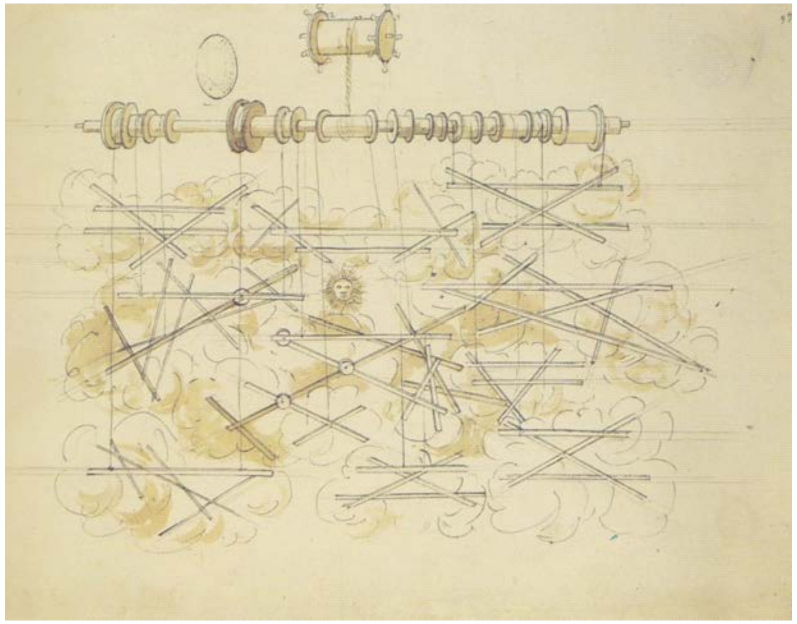

Figure 8.9 'Machine of the whole sky'. Clouds painted on shaped boards are attached to hinged battens that hang from drums on a common axle, rotated by the winch at the top. The drums are of different diameters, so that the ropes move at different speeds and cause the configuration of clouds to shift and change. By kind permission of L'Archivio di Stato di Parma.

Monteverdi's version of the music of the spheres. The disc rotates, and as March, June, September and December reach the top of the wheel, each sings a madrigal.

> *The wheel is suspended from the roof by an* anima *and is turned with a loop of rope by a winch D (Figure 8.10).*[46] *A bracket C at the top stabilises the rim of the disc as it moves. Floriani shows not concentric circles at the centre but radiating lines labelled 'splendore', suggesting a representation of the sun, perhaps using lamps with mirrors behind, like Furttenbach's 'glory'.*[47] *This is surrounded by an ouroboros, a snake eating its own tail, symbolising the eternal cycles of time.*

The Zodiac disappears again behind the clouds. The beautiful young man personifying the Golden Age enters in his flying car (Figure 8.3) drawn by two snowy white doves, and sings. Flames erupt in the backstage announcing the arrival from Hell of the figure of Discord

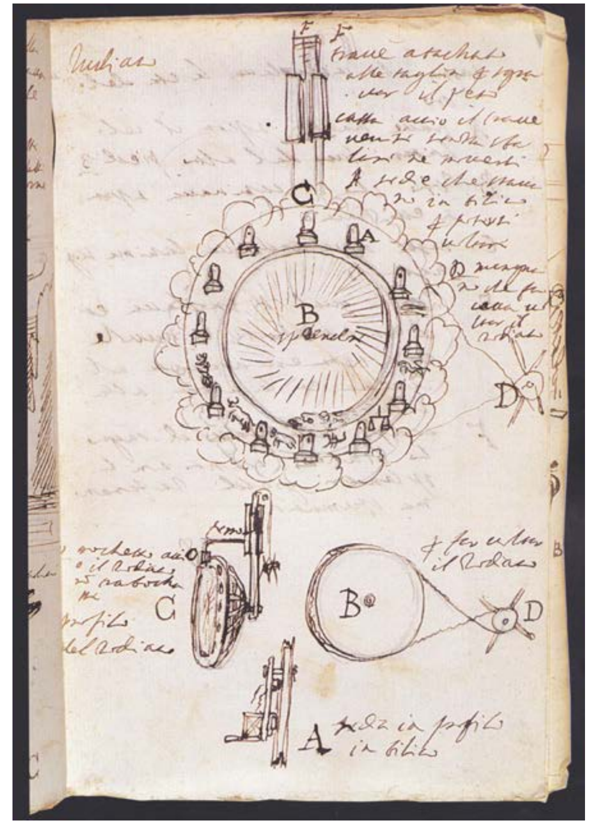

Figure 8.10 Sketch by Floriani of the Zodiac machine in *Mercury and Mars*. The 7-metre diameter wheel is hung from an *anima* and turned with a loop of rope by the winch *D*. The 12 seats carry actors representing the months of the year. The centre of the wheel is labelled *splendore*, suggesting a glowing image of the sun. Associazione Compagnoni Floriani di Villamagna. All rights reserved ©.

with her two sister Furies. Discord is dressed in bloodstained bandages and has serpents in her hair: her companions have serpents for belts and carry fiery trumpets. At this point we reach the first allusion to Achillini's plot proper, since the discord in question is the argument between Mercury and Mars over Odoardo's future. The three Furies fly off stage in a swirl of smoke and flames, Discord travelling in a straight line upwards, the other two moving diagonally up to left and right.

> *Buttigli says this was done with* occulte machine *(hidden devices).*[48] *Floriani reveals that these were similar to the method used for*

transporting Aurora, but with three beams at different angles set behind the backdrop.[49] *The one difference is that the Furies do not have vehicles but appear to be strapped bodily onto platforms with harnesses. The flames could have been produced with Sabbattini's clouds of explosive powder. Adami suggest another possibility: that there was a real (controlled) fire in the wings, and stagehands reflected images of these flames with mirrors onto the Furies. Floriani says elsewhere that the 'smoke' was in fact steam, produced by boiling water below stage.*

As the Furies disappear, Mercury himself flies in through a gap in the clouds, circles the stage and lands at the centre. So effective is the illusion that members of the audience, according to Buttigli, imagine that he is supporting himself just with the wings on his sandals and helmet.

In fact he is strapped to a metal framework hung by a rod from a rotating bar (presumably concealed by clouds) with which he is swung across the scene and lowered to the stage.[50] *We have seen similar apparatus used later to make Mercury fly in the Venetian theatre, in Philip Skippon's sketch of Figure 2.13.*

Mercury explains the essence of the drama. He is angered that Odoardo, who shows artistic and literary promise, has decided to take part in the tournament. He is therefore locking away the young duke and other contestants in places from which they cannot escape. There is a peal of thunder and a flash of lightning (made by 'artificial weather'), and the sky opens to reveal Mars and a large armed party riding on a blood-red cloud. Buttigli describes the cloud as changing its shape: first a rhombus, next an octagon then a rectangle.[51]

Floriani uses two sheets of drawings to explain how this machine works (Figure 8.11).[52] *Once again, the apparatus is suspended on a vertical* anima *A attached to a heavy trolley carrying winches, running in the roof. The* anima *supports a large flexible structure consisting of two linked frames, one behind the other. Each frame is made of six beams hinged together at their ends. The frames carry seats on the inside and are masked with clouds on the outside. In its initial position (at the top of the left-hand drawing) the structure takes a trapezium shape. (Buttigli, who calls this a 'rhombus', seems to have been uncertain of his geometrical terms.) The structure then*

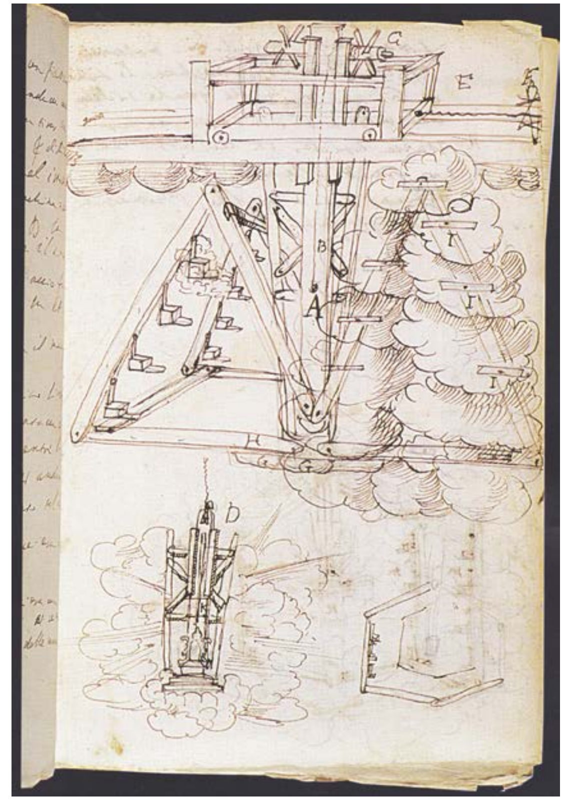

Figure 8.11 Two sheets by Floriani depicting the machine on which Mars and his military entourage ride. This is again supported by a heavy *anima*, suspended from a trolley on the roof. There are two frames, each made of six jointed beams, joined together into a structure that supports seats for 16 actors. The shapes made by the frames as they descend are first a trapezium, then a hexagon (at the right), then a rectangle. Mars's throne is at the centre. The entire machine is camouflaged with clouds. Associazione Compagnoni Floriani di Villamagna. All rights reserved ©.

unfolds to create a hexagon (not an 'octagon' as Buttigli has it), as in the right-hand sketch. Finally the top and bottom bars in the frames become aligned to produce a rectangle.

Mars has a separate throne at the centre, shown in the detail D. There are 16 other seats. Buttigli describes the 'chorus of many deities' who accompany Mars as forming a 'theatre', with eight figures representing Fame, Victory, Fortune and other military virtues and vices, and eight more dressed as Roman soldiers. This scene is one of just two in the whole production for which there are – as Alois Nagler believed – drawings of what was seen by the audience

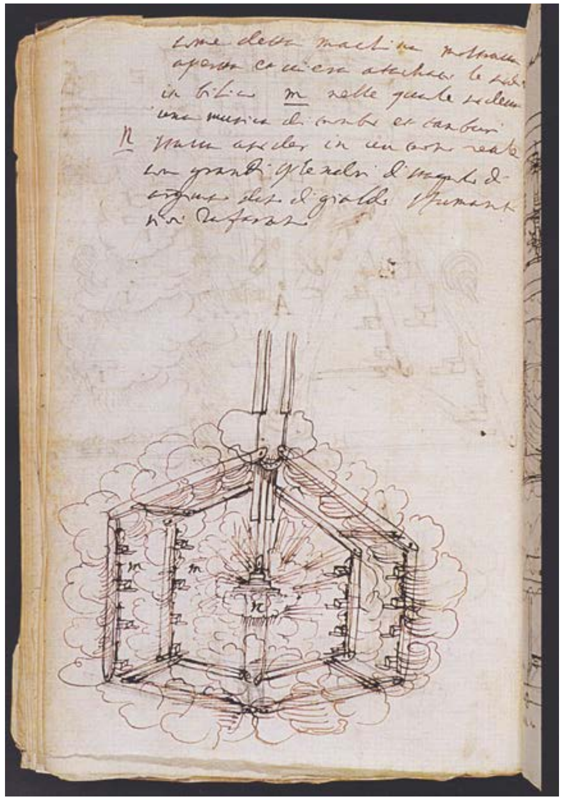

Figure 8.11 Continued

(Figure 8.12).[53] *Here the shape-shifting cloud carrying Mars is in the middle of the sky, his supporters on arcs of clouds below, soldiers and cavaliers at the sides and on the ground. Notice the wings painted as identical fragments of classical architecture, four to each side.*

There are two drawings in the Parma State Archive (Figure 8.13), with the caption in both cases 'Mechanical device for the followers of Mars'. The reference must be to a Mars in some different production. But there are nevertheless affinities with the present scene in Mercury and Mars*. In the sky is an arrangement of hinged battens suspended on cords. These could support and transform the shape of Mars's cloud vehicle. In the first drawing they form a star pattern. In the second drawing they are rearranged, by lowering or raising the cords at different rates, first into a rough half-circle (above) and then into a linear pattern (below). At the sides of the scene are rows of seats on hinged beams, like see-saws. These are linked by cords to*

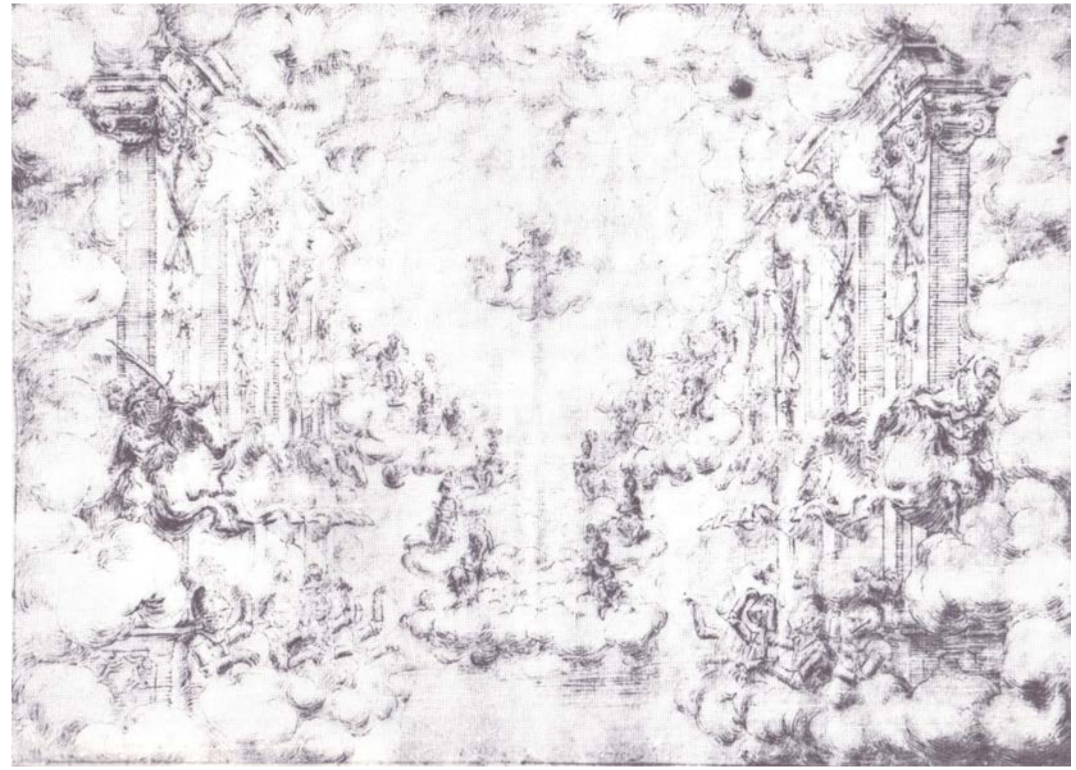

Figure 8.12 Drawing of a scene showing the entry of Mars in his flying throne, with his followers on clouds below. Alois Nagler suggests that this drawing relates to *Mercury and Mars*. Parma, Biblioteca Palatina Ms Parm f.16, courtesy of the Ministry of Cultural Heritage and Tourism.

a drum below the stage, with which the occupants can be swung up into the air. Perhaps devices like these might have been used to lift up the knights on horseback that we see in Figure 8.12.

Mars announces that he will enlist the help of Venus to help free Odoardo. She duly arrives on her own cloud lit from inside with golden lamps, which advances, grows and opens to reveal the goddess with her *amorini* or infant Cupids. The cloud lands on the water and splits into two parts. One half carrying the three Graces drifts up and away on its own. Meanwhile the remaining half turns into a decorated shell boat in which Venus floats in the sea. The audience is mystified.

This is another machine for making a vehicle move through the sky, but this time the cloud/boat sits on a platform suspended by four

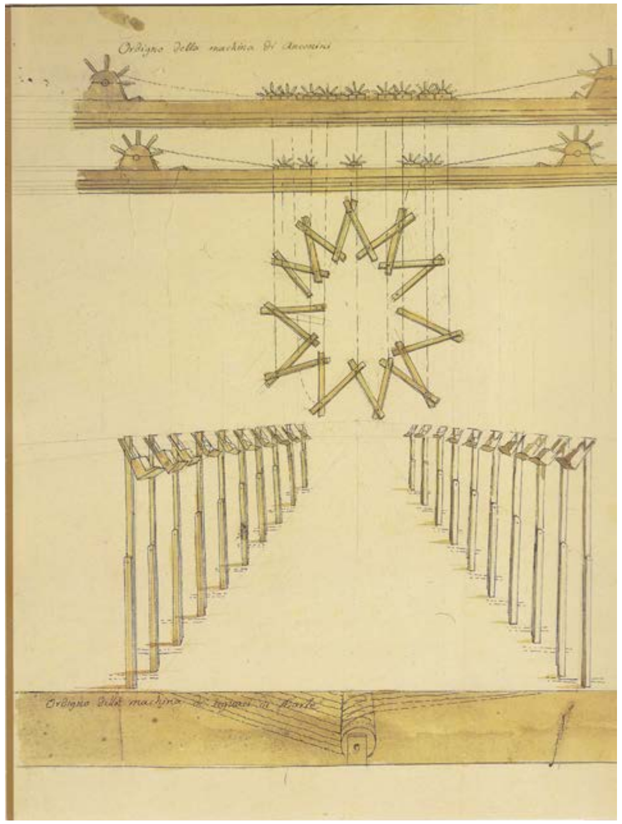

Figure 8.13 Drawings showing a 'Mechanical device for the followers of Mars'. Hinged battens for supporting clouds – perhaps also carrying actors – are hung by ropes from a series of winches. At the left these form a star shape. At the right the battens have been lowered at different speeds to create a rough oval pattern in the sky and then a linear arrangement on the ground. The devices at the sides are seats for more actors, raised on beams like see-saws. These might have been used to carry the knights in Figure 8.12. By kind permission of L'Archivio di Stato di Parma.

cords from a trolley above (Figure 8.14).[54] *Floriani shows the trolley in plan view. Inside the boat we see Venus sitting at the right and her little Cupids at the left. The vessel is lowered into the sea, where a slot in the base engages with a spike on a second trolley below stage. I imagine that the ropes attached to the base are released at this point, so that the boat can be pulled away on its trolley through the waves. Meanwhile the cloud takes off again carrying the Graces (not shown in Floriani's drawing).*

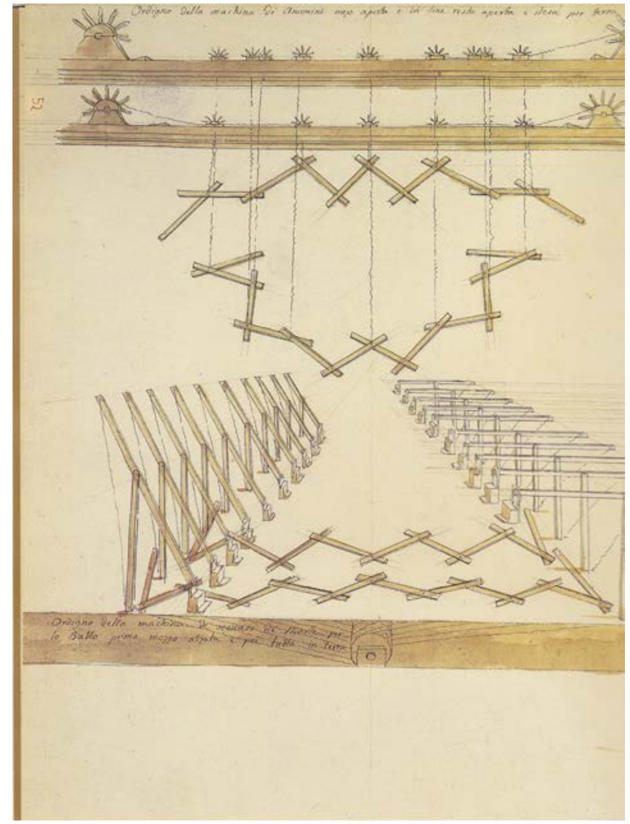

Figure 8.13 Continued

Of particular interest here is the fact that there are pulleys of several different diameters on each of the axles in the upper trolley. Those labelled D and F, and their counterparts on the second axle, carry the four ropes for the boat. The smaller pulleys labelled A, B and C must be for other ropes that lower clouds at different rates, as in the machine of Figure 8.13. In this way the whole downward trajectory of the vehicle would have been eventually covered with an ever-extending mass of cloud.

At Venus's command a castle, glittering as though made of diamonds, starts to rise from the waves, complete with escarpment, battlements and keep, the Farnese flag fluttering from its round tower. Odoardo has been held captive inside. A drawbridge is lowered on golden chains, and the duke emerges and joins Venus in her boat. (He carries written instructions from the dramatist Achillini, reminding him what to do and say.)

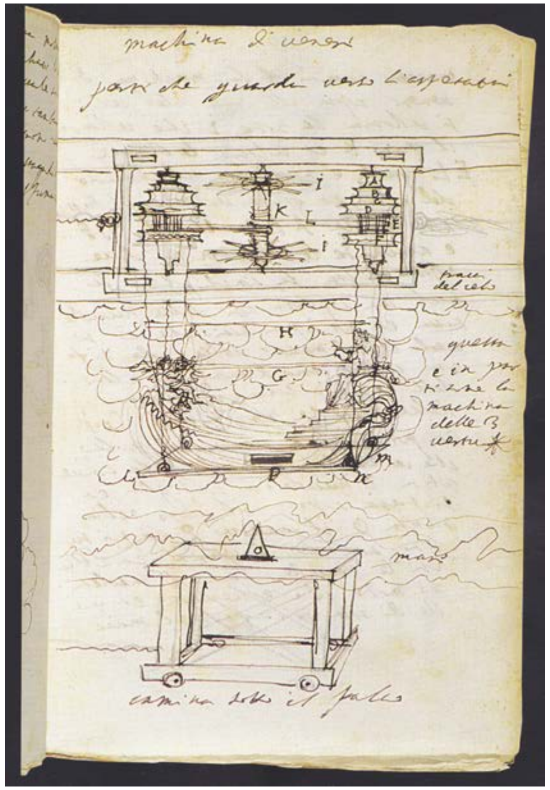

Figure 8.14 Sketch by Floriani for the flying boat in which Venus descends with her *amorini*. The boat sits on a platform lowered on four cords by winches on a trolley (shown in plan view) in the roof. When the boat reaches the 'sea', it is released from the cords and lands a second trolley below stage, on which it can be moved through the waves. Clouds surrounding the boat are lowered at different speeds, to cover the vehicle's entire trajectory. Associazione Compagnoni Floriani di Villamagna. All rights reserved ©.

> *The problem of lifting this fortress was the same as that faced by Buontalenti when creating his Mount Helicon, much taller than the height of the traproom (Figure 2.14). Buttigli describes how the building was constructed on five levels, each smaller in plan than the one below.*[55] *A drawing by Floriani shows that, like Buontalenti's mountain, the structure was telescopic and was raised in stages with winches.*[56] *The diamond effect was produced with* talco specchiato*, a phosphorescent coloured dust that glinted and sparkled.*

For the duke's entertainment – and largely irrelevant to the plot – Venus now conjures up for him a vision of Cnidus, a real city in Asia Minor where she has a temple. The rocks at the sides of the stage retreat, the sea fills the stage and the city rises from below. There are palaces, colonnades, a giant column with a spiral relief depicting the triumphs of Cupid and the temple of Venus. Buttigli says that all this painting, in a curious melange of gothic and classical styles, is the work of 17-year-old Carlo Rainaldi, later to become a leading church architect. But this is one of the scenes remaining from the aborted *Defence of Beauty* of 1618. Perhaps the young Rainaldi elaborated on or repainted the old set.

Pages and drummers enter from between the colonnades. Two Tritons lay a golden bridge from Venus's shell to the 'beach' at the front of the stage. Odoardo crosses the bridge and, with his entourage of pages and drummers, descends the steps to the flat floor of the auditorium, ready for the tournament.

The next phase in Mars's scheme is to free the first squadron of swordsmen from beneath the mountain where they are held. His plan is to get Apollo, god of music, to persuade Orpheus to sing underground and break the spell. The city of Cnidus and the sea disappear, as does Venus in her shell, and all are immediately replaced with another set depicting the Elysian Fields, the resting place of virtuous souls after death. Buttigli takes six pages to describe this setting with its pastures, gardens, galleries, cottages and wild animals.

> *Buttigli says the change of setting happens so fast that the audience is unsure whether the new scenery comes in from above, below or from the sides of the stage. But given that the Elysian Fields are part of the Underworld, it seems probable that they rose from below (especially since there are references to this vertical movement, achieved with counterweights, in the letters to Bentivoglio).*

The tournament begins

Apollo enters in a golden-wheeled chariot pulled by four white mares. Orpheus cannot just sing alone. More musicians are needed, so Apollo conjures up Mount Parnassus with its full complement of occupants. Pegasus is at the summit under a laurel tree. On the slopes are the Muses and a crowd of ancient and modern Florentine poets. A spring flows with pure water, just as in Buontalenti's version of 1600. This mountain machine occupies the full width of the stage. Orpheus sings to his lyre, accompanied by the Muses on their various instruments. Three large self-propelled boulders respond to their call and appear through the right-hand entrance to the arena. To the sound of trumpets and a roll of drums the stones break apart and the knights leap out. The first round of the tournament begins, while Apollo and the Muses watch from the stage.

Most of the machines used in the show so far have been for cloud effects and flying. We have not yet seen the last of them. But the second half of the performance is dominated, so far as mechanical apparatus is concerned, by land and seagoing vehicles. The mobile boulders must have rolled on hidden wheels and would have been pushed from inside by stagehands.

The typical chariot or 'pageant car' had four wheels: small at the front and large at the back. The bodywork was always decorated with sculptured and architectural motifs, richly painted, often gilded. The principal occupant sat on a raised throne at the rear. The cars in Mercury and Mars *were pulled by doves, lions, geese and hippogriffs. The hippogriff is a mythical creature with the front half of an eagle and the back half of a horse. Figure 8.15 shows a 'Chariot of Midday' pulled by hippogriffs in a tournament in Munich in 1658.*[57] *(On the same occasion a 'Chariot of the Evening' was pulled by centaurs.)*

The lions and hippogriffs in Parma and Munich are likely to have been real horses in disguise. Other creatures were perhaps made from wood and canvas, like the sea monster in the Palatine Library drawing of Figure 4.3. Maybe some were built like the man-powered centaur of Figure 4.4. Floriani illustrates designs for self-propelled four-wheeled carriages to be used on stage.[58] *These are powered by stagehands who ride inside and turn crank handles or treadmills geared to the road wheels, like simplified versions of Leonardo's 'automobile'.*

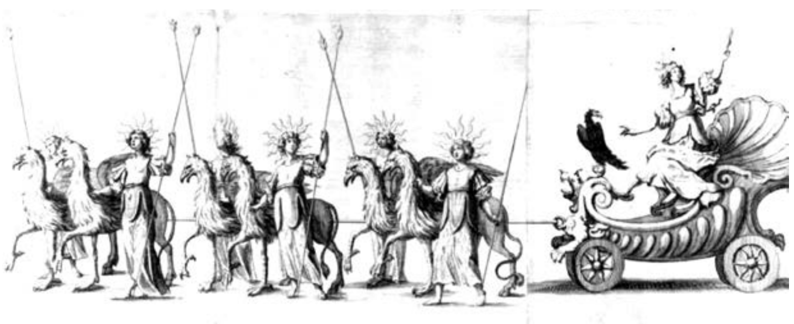

Figure 8.15 A 'Chariot of Midday' pulled by hippogriffs in a tournament in Munich in 1658. *Applausi Festivi*, Wolfenbütteler Digitale Bibliothek.

The first round of the tournament ends, and Juno wife of Jupiter enters in a triumphal car pulled by peacocks, birds sacred to her honour. Buttigli says that these 'seem to walk'. Juno seeks the help of two more goddesses Berecynthia and Proserpina to free the second squadron of knights from the infernal swamp in which they are trapped. Proserpina's vehicle carries a vase from which flames issue, giving off an aromatic odour – perhaps the smell of burning Greek resin. They must negotiate for the heroes' release with Pluto, ruler of the Underworld.

The scene moves to Pluto's fortress, guarded by demons and the three-headed dog Cerberus, with the burning city of Dis beyond. The wings are painted as ruined classical architecture in flames. Harpies suffer in agony. Bats and owls perch on the ruins. Pluto enters in a chariot drawn by fire-breathing horses. He agrees to release the combatants. The side entrance to the arena opens once again, and flames burst into the auditorium. Horrid devils appear pushing a mobile mountain on which the fighters are seated, together with their pages and drummers. The knights jump off, and the second round of combat begins.

The next episode brings blessings on the marriage of Margherita and Odoardo. The setting is a rural landscape with eight hills: part wild, part cultivated with fig trees, peaches, oranges and grapevines. The backdrop shows a palace with a grotto, a bridge, a fishpond and statues of reclining women spouting water from their nipples. This is the real Garden Palace in Parma, which Aleòtti and his scene painters were sketching in 1617, one of the buildings that the young couple will enjoy.[59] Cupid, god of desire, hovers on a cloud above. The cloud rises, advances towards the audience and divides to reveal the six balls of the Medici coat of arms. *Amorini* sitting on the spheres sing a sextet in honour of Margherita. Cupid joins them in an aria.

This machine for Cupid is yet another that descends on an anima.[60] *Cupid himself, armed with his bow and arrow, is strapped to a frame and stands on a sphere decorated with fleurs de lys, the armorial flower of the Medici. Below him is a triangular structure made of hinged frames – something like a triptych for an altar – covered and masked with clouds. This is unfolded with ropes to discover the* amorini *seated inside.*

Now Bellona, goddess of war, arrives in the car pulled by hippogriffs, to announce that the captives beneath Etna have been freed. They enter in a *quadriga*, a triumphal chariot drawn by four horses, and the third round of the tourney follows. Only one squadron of fighters now remains to be released: those trapped inside the bellies of sea monsters. The rural landscape disappears, to be replaced by another sea filling the whole scene. The wings again represent cliffs and the background shows Neptune's palace. Saturn enters on a glittering gold cloud, like a giant planet; eight Tritons rise up from the waves; and Neptune himself arrives in his seashell boat pulled by horses with the heads of sea creatures. He commands that the knights be freed. Then he addresses the waves of the sea on stage: 'Go out now, go all of you, directly from this pool.'[61]

The final sea battle

The audience is astounded and alarmed to see that real, not simulated water is beginning to pour in large quantities from openings beneath the stage. This starts to fill the arena and rises to a level of half a braccio (30 centimetres). These developments are particularly surprising given that the theatre is not at ground level. A visiting Florentine who was present, Abbot Folchi, wrote the next day of his nervousness.[62] 'We heard the great noise of the water gushing from the two sides of the proscenium and all of a sudden saw the whole of the arena filled with water …' 'We were above the ceiling of a vast room, which bore the weight of thousands of people and many machines, not to mention the fact that the room also had to bear the weight of the water.'

Monteverdi's musicians in front of the stage have not been forgotten. They are protected by a low curving waterproof wall and continue playing.[63] This is one of the world's first orchestra pits, and the historical moment at which the ancient term *orchestra* is transferred from the theatre floor to the musicians who play there.[64] A 'confused crowd' of sea monsters – six dolphins and a whale – is carried into the arena by the force of the current. The whale is 9 metres long. It carries the squadron of knights on its back and sprays their accompanying pages with two 'water cannons' as it moves. The creature swims up to the ducal party's dais and pays its respects by opening its mouth, waving its fins and disgorging yet more water. The Tritons keep singing on stage. Now two floating islands appear carrying the water goddess Galatea and her nymphs. She invites the knights to join her. The islands are connected together and provide a floating arena for the final battle.

> *The whale and dolphins are built on flat barges with holes at the centre so that stagehands inside can stand in the water and propel them along.*[65] *It would have needed several men to move the whale and work its mouth and fins. The 'water cannons' were, we can imagine, pumps of some kind. Hero has a design for a fire pump that would have served the purpose. Guitti says the dolphins are beautiful. They too can open and shut their mouths, and move their eyes.*

The evening comes to a glorious end with an assembly in the sky of all the Olympian gods and goddesses, seated on animals, presided over by Jupiter flying on an eagle. Buttigli says that a hundred actors are on stage together, riding on an 'apotheosis machine' which advances towards the proscenium. The audience is staggered by this great marvel. Jupiter condemns the actions of Discord and the Furies and dispatches them back in chains to Tartarus, the deepest level of Hell.

> *Floriani sketches only parts of this giant apparatus: a wooden floor lowered from the roof on four belts unrolled from axles, with thrones for the gods sliding out horizontally from the wings.*[66] *In overall form the machine apparently resembled a huge staircase facing the auditorium, fixed in the roof at its furthest and highest point, and with its lowest step reaching to the front of the stage. It seems that the entire machine moved downstage as the audience watched.*
>
> *A mobile apotheosis machine of this kind was installed in the Theatre of San Salvatore in Venice. Three large beams, perpendicular to the front of the stage, were supported from the roof with versions of Aleòtti's* cassa *and* anima *mechanism. These beams in turn carried frameworks with seats on, which could be lowered on vertical members. At the sides were hinged battens to which clouds were attached. The machine as a whole could move forwards on the three main beams, while simultaneously being unfolded downwards. This type of apparatus was generally employed in the culminating scene of a production, not just because it was the most spectacular but because – one imagines – it was difficult to replace rapidly with any following set.*

Figure 8.16 Drawing of a scene depicting a sky full of deities. Alois Nagler suggested that this shows the final scene in *Mercury and Mars*; that the central figure is Jupiter and the figures falling at the bottom are Discord and the Furies on their way to Hell. Parma, Biblioteca Palatina Ms Parm f.14, courtesy of the Ministry of Cultural Heritage and Tourism.

Alois Nagler proposed that the drawing of Figure 8.16 might show the audience's view of this very scene from Mercury and Mars.[67] *The image is faint, but it is just possible to make out major gods at the centre and minor deities around the edges, all riding on clouds. Nagler suggests that the falling figures at the bottom are the Furies on their way to Hades. There might be something approaching a hundred actors here.*

Odoardo's future is decided: he will cultivate both the arts and swordsmanship. Heavenly musicians play Monteverdi's finale. The combatants in the arena shout 'Peace! Peace!' The Olympians disappear and the water drains from the theatre floor, leaving the islands and sea creatures stranded.

How the arena was flooded

Some early historians of the Teatro Farnese doubted whether the inundation in *Mercury and Mars* could actually have taken place.[68] But not only are there the eyewitness accounts by Buttigli, Abbot Folchi and others; the surviving correspondence, rediscovered in the twentieth century, reveals details of the elaborate and careful preparations that made it possible.

There can be little doubt that Aleòtti first planned this *coup de théâtre* for *The Defence of Beauty* in 1617. The author Alfonso Pozzo describes the final flooding of the arena explicitly in his script. And Aleòtti was the very man to design the system of pumps, pipes and tanks involved, since he had devoted a large part of his professional career to hydraulic engineering. His great work *On the Science and Art of the Proper Regulation of Waters* has long sections on aqueducts and pumps.[69] The extra 'theorems' that he added to his translation of Hero's *Pneumatics* also give designs for pumps of various kinds – citing Ctesibios and Vitruvius – including a 'Method for making a channel of live or dead water rise to the top of any tall tower'.[70] Giuseppe Massera has calculated that the total quantity of water pumped up and released must have amounted to some 350 cubic metres, roughly the contents of a large swimming pool.[71]

There has been discussion about the possible source of the water – whether it was a stream running close to the Pilotta Palace, or the city's aqueduct. In letters to Bentivoglio in 1627, Guitti's colleague Francesco Mazzi mentions several more technical details.[72] He reports on large tanks being installed under the stage. He worries about the tanks' dimensions and the obstruction they may cause to other operations.

Craftsmen from Venice specialising in *terrazzo* – the hard Italian flooring material made from marble chips and cement – are at work waterproofing the floor and sides of the arena. Designs have been completed and tested for the outlets in the front of the stage. There are taps with which to release the water and drains to direct the flow away at the end of the scene. The floor of the arena has been propped from below. Temporary waterproof barriers are ready to put across the entrances to the auditorium. Buontalenti might have organised a *naumachia* in the courtyard of the Pitti Palace; but Parma has gone one up on Florence, with a sea battle on the first floor.

The legacy of the Teatro Farnese and its machines

The year of the opening of the Farnese Theatre, 1628, marked the highest point in its history. Occasional productions of operas, ballets and concerts continued through the seventeenth century, some for great weddings and state occasions, but none matching the splendour of *Mercury and Mars*. The final performance in the theatre was in 1732. At around this time, as Marzio dall'Acqua observes, 'The "opera tournament", for which the theatre had been built, also went into oblivion.'[73]

The building was damaged in the eighteenth century. It was used as a workshop for painting sets for plays in other theatres in Parma, and the painters burned Aleòtti's wooden statues to keep warm. The roof was failing, and in the mid-nineteenth century there were discussions about demolition; but the committee appointed to make the decision 'did not want to take responsibility for killing the sick giant'.[74] Then in 1944 the Teatro Farnese was hit in an Allied bombing raid, which wrecked the seating and other woodwork of the interior. Today this has all been restored but left unpainted, and the theatre has become in effect an exhibit in the National Gallery of Parma, of which it forms part. Nothing survives of the machines or sets. The legacy of Aleòtti's masterpiece is to be found elsewhere: in the pivotal role of the building itself in the evolution of theatre architecture, and in the profound influence of its stage machinery throughout Europe, until the introduction of electricity.

Buontalenti's Uffizi Theatre and the Teatro Farnese mark the origins of the modern proscenium theatre and its equipment. The Farnese's special adaptation to the needs of the tournament was a historical peculiarity, as we have seen. Later court theatres were still designed with central arenas for dancing. But in the commercial theatres catering to public audiences that were built from the 1630s in Padua and Venice, the floor of the auditorium was shortened and filled up with seats or space for standing spectators. Meanwhile the stepped gallery seating was replaced by boxes, stacked up on several levels. In this way the social classes could be decently segregated. The stage machines remained unchanged, however.

There was a large audience for the opera in Venice.[75] The lack of a central court theatre in the Republic meant that the important families acquired prestige instead by patronising public opera. And there were great numbers of tourists – John Evelyn and Philip Skippon among them – especially during Carnival. By the end of the century there were ten opera houses in the city.

Francesco Guitti worked as a set designer in several other cities besides Parma and Ferrara, and is reported as being in Venice in 1637, where he may have been involved in a production of Benedetto Ferrari's *Andromeda* in that year.[76] This was the first opera put on in Venice's first public opera house, the Teatro San Cassiano. One of Guitti's scene painters on *Mercury and Mars*, Alfonso Chenda, also moved to Venice in 1639, and designed scenery for another production of *Andromeda*.[77] Little is known of Giacomo Torelli's early years, but he too arrived in Venice at around this time, and in 1641 became stage designer at the Teatro Novissimo, a building of which he was the architect and which he may have helped to finance.[78] This had a chariot system, flying machines and all the other Aleòttian paraphernalia. There are suggestive similarities between Torelli's first scenery and the sets for *Andromeda*.[79]

Torelli rapidly built a reputation for his spectacular shows throughout Italy and beyond – although oddly Evelyn's is one of only a few eyewitness accounts known, besides the printed *Descriptions*. Nobody, however, seems to have noticed the significance of a reference to chariots in the *Description* of *Bellerofonte*, put on in 1642 with sets by Torelli. The author writes of 'the artifice of a great wheel which controls many scenic flats at one time'. This is 'banal, and once well known to all base mechanics, [yet] remained entirely neglected and used in no other place, until it was installed last year at the Teatro Novissimo'.[80] If this is Torelli writing anonymously, he must have very quickly changed his story.

In 1645 Queen Anne, Regent of France, asked Duke Odoardo of Parma – whose initiation into acting in *Mercury and Mars* as a young man had made him a lifelong opera enthusiast – to recommend a stage designer.[81] Odoardo named Torelli, who moved from Venice to Paris, where he first worked in a converted hall at the Hôtel du Petit Bourbon. He then took charge at the Théâtre du Palais Royal, later the home of the Académie Royale de Musique, which became the Paris Opera. The high point of Torelli's triumphant French career was a production of Pierre Corneille's 'machine play' *Andromède*, of 1650, which resurrected the flying gods of the classical theatre.

A century later Torelli's technical drawings were published in Diderot and D'Alembert's *Encyclopédie* in the section on 'Machines de Théâtre', spreading their influence further across Europe and beyond.[82] Figure 8.17 shows the many drums below stage at the Palais Royal for moving chariots and other devices. Figure 8.18 is a cross-section illustrating a gallery in the roof with a windlass carrying pulleys of several diameters for lowering clouds at different rates, straight out of the repertoire of Aleòtti and Guitti. Details of two scenes are inset: cloud effects 'preceding the arrival of a god' and the chariot of Medea.

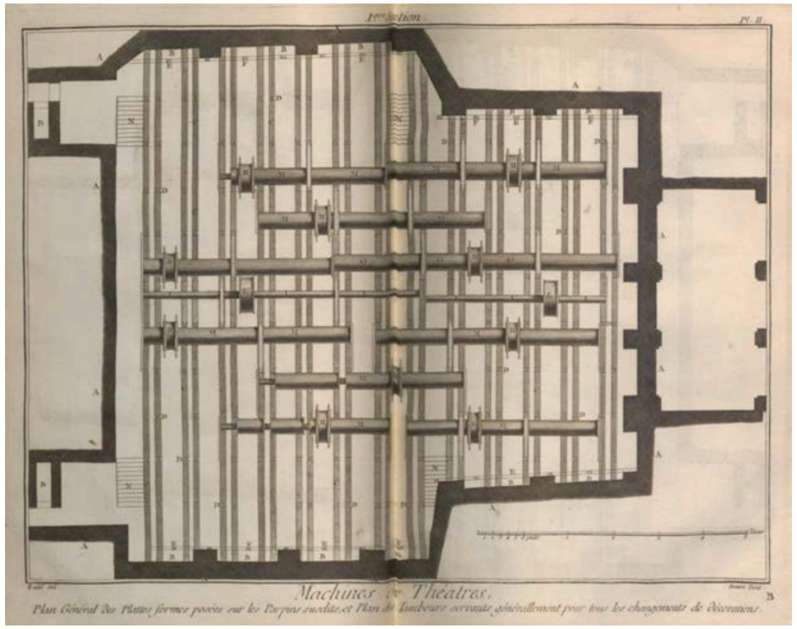

Figure 8.17 Plan showing drums below stage for moving chariots and other devices at the Théâtre du Palais Royal in Paris; from the section on 'Machines de Théâtre' in Diderot and d'Alembert's *Encyclopédie*.

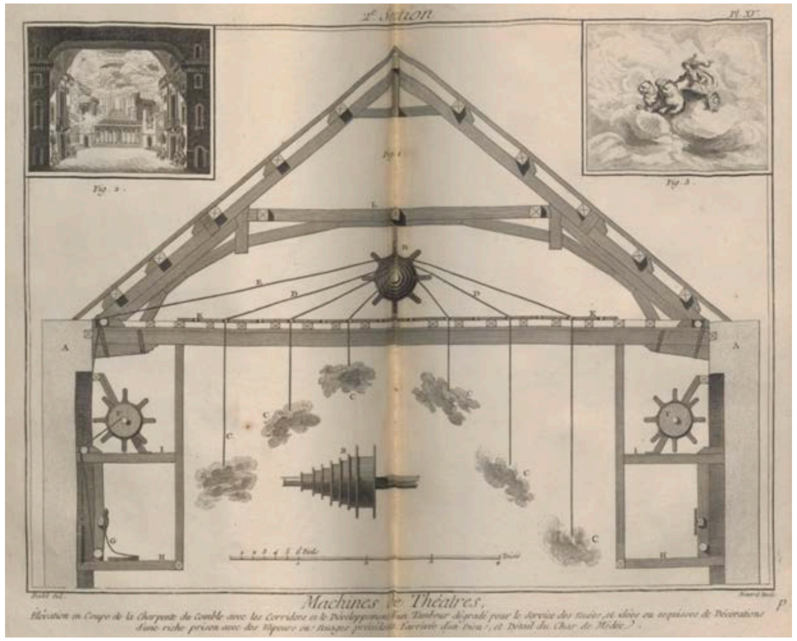

Figure 8.18 Cross-section of the Théâtre du Palais Royal showing a windlass in the roof carrying pulleys of various diameters for lowering clouds at different rates; from the section on 'Machines de Théâtre' in Diderot and d'Alembert's *Encyclopédie*.

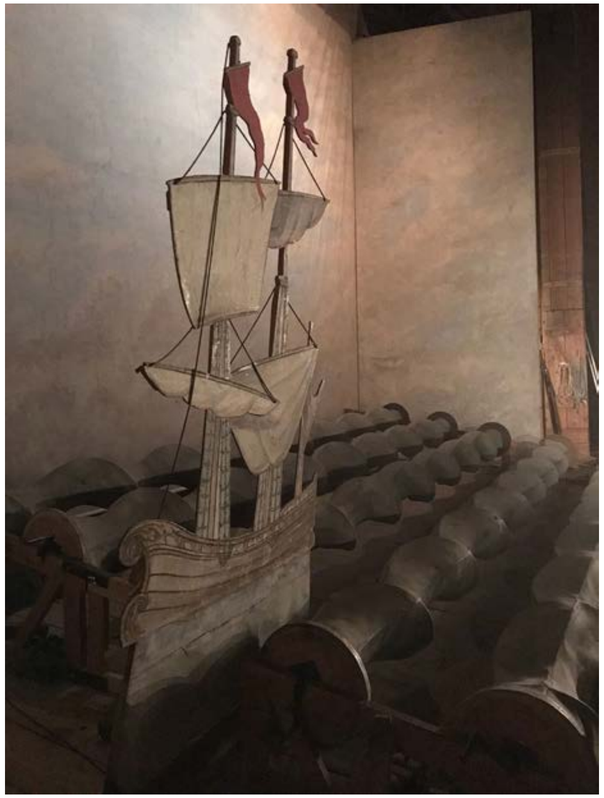

Figure 8.19 Wave machine at the Slottsteater at the Royal Palace of Drottningholm near Stockholm. The cut-out boat moves along a track. By kind permission of Drottningholms Slottsteater.

No machinery survives from any seventeenth-century theatre. But there are three eighteenth-century court theatres where machines in this tradition have been preserved virtually intact.[83] The best known of these is the Slottsteater at the Royal Palace of Drottningholm near Stockholm. The others are at Gripsholm, also in Sweden, and at Český Krumlov in Bohemia, now the Czech Republic. All three theatres have chariots, moveable borders and backdrops, flying machines and the original fittings for stage lighting. The Slottsteater also has automatic trapdoors, a wind machine and a thunder machine. Figure 8.19 shows the theatre's wave machine with a cut-out ship running on a track between the waves. In 1975 the director Ingmar Bergman built an exact reconstruction of the sets and machines at Drottningholm for his film of Mozart's *The Magic Flute*, which features a thunderstorm, a fire-breathing dragon and three boys who descend in a balloon.[84]

The final scene of *Mercury and Mars* was not the last actual inundation in theatrical history. In 1638 Gianlorenzo Bernini mounted his own play *The Flooding of the Tiber* in the Palazzo Barberini in Rome.[85] The set was a perspective view of the city, in which real water in the river 'rose ingeniously'. Passengers were ferried across. Concerned officials came to study the situation. Then the defences failed, and the water rushed towards the audience. They really would have got wet, had Bernini not arranged for another barrier to rise up at the front of the stage just in time to save them.

Notes

1 There are numerous books and papers about the Teatro Farnese and *Mercury and Mars*. Glauco Lombardi first published letters from Aleòtti to Duke Ranuccio about the building of the theatre and its machines in 'Il Teatro Farnesino di Parma', *Archivio Storico per le Province Parmensi*, new series, 9 (1909): 1–52. Stuart Reiner published 'Preparations in Parma – 1618, 1627–28', *The Music Review*, 25 (1964): 273–301. Irving Lavin included further unpublished correspondence in 'On the Unity of the Arts and the Early Baroque Opera House', in B. Wisch and S. S. Munshower (eds), *'All the World's a Stage': Art and Pageantry in the Renaissance and the Baroque* (University Park: Pennsylvania State University Press, 1990), Part 2, pp. 518–79. This paper was first published in French in 1964. The official account of the festivities in 1628 was by Marcello Buttigli, *Descrittione dell'Apparato Fatto per Honorare la Prima e Solenne Entrata in Parma della Serenissima Prencipessa Margherita di Toscana, Duchessa di Parma, Piacenza* (Parma: Viotti, 1629). Alois Nagler gives an account of *Mercury and Mars,* drawing on Buttigli, in *Theatre Festivals of the Medici 1539–1637* (New Haven, CT, and London: Yale University Press, 1964), pp. 139–61. The building of the theatre and the performance in 1628 are described in detail in a splendidly illustrated volume, Luca Ronconi, Marzio Dall'Acqua, Pompeo de Angelis and Claudio Gallico (eds), *Lo Spettacolo e la Meraviglia: Il Teatro Farnese di Parma e la Festa Barroca* (Turin: Edizioni Rai, 1992). This contains pictures of scenes and machines, and essays by Marzio Dall'Acqua ('The Teatro Farnese in Parma'), Claudio Gallico ('Monteverdi at the Gran Teatro Farnese in Parma') and Pompeo de Angelis ('Machines and Allegories for the Wedding Festivities of Odoardo Farnese and Margherita de Medici (1628)'), with parallel texts in Italian, French and English. The English translations quoted here are by Richard Kamm.

2 Buttigli, *Descrittione*, p. 271. Francesco Mazzi in a letter to Enzo Bentivoglio of 8 December 1627 (transcribed in Lavin, 'Early Baroque Opera House', p. 537) gives a figure of 2,400.

3 Camillo Giordano, letter published by A. Saviotti, 'Feste e spettacoli nel seicento', *Giornale Storico della Letteratura Italiana*, 41 (1903): 49; cited and translated by Nagler, *Theatre Festivals*, p. 161.

4 There are two collections of drawings for scenes and stage machinery in Parma. One is a portfolio in the Biblioteca Palatina that contains 38 drawings, 24 of which show machines. The index says that some of these were probably for the Teatro Farnese. Many of these are reproduced (rather poorly) in Orville K. Larson, 'Italian Stage Machinery, 1500–1700', PhD thesis, University of Illinois (1956). The second collection is in the Archivio di Stato in Parma. Seven of these are reproduced by C. Thomas Ault, 'Baroque Stage Machines for Venus and Mars from the Archivio di Stato, Parma', *Theatre Survey*, 28/2 (1987): 27–39. Since none of the drawings is dated or signed, and no details of theatres or productions are given, there has been much debate about their provenance, as discussed in the text. Some historians have argued that many or all date from the eighteenth century, but the general opinion is now that they are seventeenth-century. Edward Carrick ('Theatre Machines in Italy, 1400–1800, Part II', *Architectural Review*, 70 (1931): 31–6 and plates 2 and 3) believed that the Biblioteca Palatina drawings were all Venetian and attributed them to Gasparo Mauro. Elena Povoledo published a further set of eight machine drawings from the private collection of Alberto Sciolla in Rome in 'Macchine e ingegni del teatro Farnese', *Prospettive*, 7/19 (1959): 49–55. Povoledo connects these explicitly with *Mercury and Mars*. They are closely similar to drawings in the Parma State Archive. Minute examination, however, shows that they are not identical. None of the Parma designs is reproduced in seventeenth- or eighteenth-century books on stagecraft. One wonders whether some of the more complex machines were ever built. Yet more drawings have only recently been rediscovered in Ferrara.

5 This history has only recently been fully unravelled by Giuseppe Adami in *Scenografia e Scenotecnica Barocca tra Ferrara e Parma (1625–1631)* (Rome: 'L'Erma' di Bretschneider, 2003), chapter 3, pp. 39–85.

6 For a schematic plan by Aleòtti, see Adami, *Scenografia e Scenotecnica*, p. 66, Figure 13. The building burned down in 1679. In 1930 Franz Rapp published what he proposed were drawings for the Teatro degli Intrepidi, contained in a portfolio of theatrical drawings by Aleòtti in the Biblioteca dei Comune in Ferrara. ('Ein Theater-Bauplan des Giovanni Battista Aleotti', *Neues Archiv fur Theatergeschichte*, 41 (1930): 79–125.) These, however, bear little resemblance to what is now known of the Intrepidi from other sources. The designs in Rapp's paper are more similar to commercial opera houses of the later seventeenth century. The same collection does nevertheless include Oliviero Gatti's engraving of what is definitely the proscenium of the Intrepidi.

7 Dall'Acqua, 'The Teatro Farnese', English translation, p. 332.

8 See Armando Fabio Ivaldi, 'G. B. Aleotti architetto e scenografo teatrale', *Atti e Memorie della Deputazione Prov. Ferrarese di Storia Patria*, 27/3 (1980): 187–225, for an account of Aleòtti's various theatres and his work with Bentivoglio in Ferrara.

9 Dall'Acqua, 'The Teatro Farnese', English translation, p. 326.

10 For this reason the theatre is often called in Parma the Salone della Pilotta.

11 Lombardi, 'Teatro Farnesino', p. 8.

12 The building was bombed on 13 March 1944, and much of the seating and decorations were destroyed. The painted ceiling had been lost earlier. Armando Quintavalle includes photos of the damage in 'Il Teatro Farnese di Parma', *Rivista di Studi Teatrali*, 5 (January–March 1953): 3–32, with 16 plates.

13 The letters are printed in Lombardi, 'Teatro Farnesino', pp. 26–31.

14 Lombardi, 'Teatro Farnesino', letter of 18 March 1618, pp. 29–30.

15 Letter from Cremona Visdomini to Ranuccio, 3 August 1618; quoted in Ronconi et al., *Lo Spettacolo e la Meraviglia*, pp. 337–8.

16 Claudio Achillini, *Intermezzo di Mercurio e Marte* (Parma: Viotti, 1629). Achillini was helped by Cesare Abelli.

17 Giuseppe Massera, 'Mecanica, musica, idraulica nella festa farnesiana del 1628', *Avrea Parma, Rivista di Storia, Letteratura e Arte*, 63/2 (1979): 99–119; see 112–13.

18 Gallico, 'Monteverdi', English translation, p. 362.

19 Massera, 'Mecanica, musica, idraulica', p. 102.

20 Gallico, 'Monteverdi', English translation, p. 360.

21 Povoledo, 'Macchine e ingegni': see in particular pp. 51–4.

22 Ronconi et al., *Lo Spettacolo e la Meraviglia*.

23 Adami, *Scenografia e Scenotecnica*, which contains many pages from Floriani's 'codices α and β' in facsimile.

24 Adami, *Scenografia e Scenotecnica*, plates 32 to 51.

25 Adami, *Scenografia e Scenotecnica*, pp. 163–4, plate 34.

26 Eighteenth-century drawings of the theatre however show five banks: see Ronconi et al., *Lo Spettacolo e la Meraviglia*, pp. 92–3. The flat wings designed by Francesco Guitti for Torquato Tasso's *Aminta* in Parma in 1628 were discussed in Chapter 1 (see Figure 1.20).

27 See Larson, 'Italian Stage Machinery', pp. 198–203.

28 The eighteenth-century art historian Francesco Milizia said that Torelli 'invented a wonderful machine for shifting all the settings in an instant'. Official Venetian sources said much the same thing: see Orville K. Larson, 'Giacomo Torelli, Sir Philip Skippon, and Stage Machinery for the Venetian Opera', *Theatre Journal*, 32/4 (1980): 448–57; see 448.

29 Per Bjurström, *Giacomo Torelli and Baroque Stage Design* (Stockholm: Almqvist and Wiksell, 1961), pp. 108–12.

30 Pierre Sonrel, *Traité de Scénographie* (Paris: Librarie Théâtrale, 1984), pp. 162–7; see p. 163, Figure 37.
31 Several pairs of flats could be readied on chariots at the start of the performance, and stagehands would reconnect the ropes for each scene change; or stagehands could replace flats on chariots during the show.
32 Fabrizio Carini Motta, *Costruzione de teatri e machini teatrali*, 1688, ms in Biblioteca Estense, Modena; trans. C. Thomas Ault and Orville K. Larson and published in *The Theatrical Writings of Fabrizio Carini Motta* (Carbondale and Edwardsville: Southern Illinois University Press, 1987), plate 3, p. 81 and plate 7, p. 94.
33 Carini Motta, *Costruzione de teatri*, p. 77.
34 Larson, 'Giacomo Torelli', p. 454 and plate 2.
35 Skippon's diaries are included in A. Churchill (ed.), *A Collection of Voyages and Travels* (London: John Walthoe et al., 1732), vol. 4, pp. 359–736; his visit to the Venetian opera is recorded on pp. 506–8.
36 *Il Cannochiale per la Finta Pazza dell Strozzi delineato da N.B.-G. di C. in Venetia MDCXXXXI per Gio. Battista Surain*, p. 8: quoted in translation in Larson, 'Giacomo Torelli', p. 450.
37 Letter of 18 March 1618 from Aleòtti to Ranuccio, in Lombardi, *Teatro Farnesino*, pp. 29–30; my translation.
38 Lombardi, 'Teatro Farnesino', p. 38, quoted in translation by Larson, 'Italian Stage Machinery', p. 202.
39 Lavin, 'Early Baroque Opera House', p. 535: letter from Francesco Mazzi, who assisted with the stage design, to Enzo Bentivoglio, 26 November 1627.
40 Adami, *Scenografia e Scenotecnica*, pp. 200–1 and plate 57.
41 Adami, *Scenografia e Scenotecnica*, pp. 203–4 and plate 63.
42 Lavin, 'Early Baroque Opera House', p. 533: 'Istrutione' attached to letter from Francesco Mazzi to Enzo Bentivoglio, 23 November 1627.
43 Adami, *Scenografia e Scenotecnica*, pp. 156–7, plate 32.
44 Adami, *Scenografia e Scenotecnica*, pp. 197–200, plates 55, 56.
45 Adami, *Scenografia e Scenotecnica*, plates 19, 24, 25, 26 and 27.
46 Adami, *Scenografia e Scenotecnica*, pp. 158–63, plate 23.
47 As Adami points out (*Scenografia e Scenotecnica*, pp. 159–60), this would imply a Galilean rather than a Ptolemaic model of the cosmos, with the sun at the centre, a bow towards the new Florentine science. Duke Cosimo II was Galileo's pupil and patron.
48 Buttigli, *Descrittione*, p. 279.
49 Adami, *Scenografia e Scenotecnica*, pp. 164–7, plate 35.
50 Adami, *Scenografia e Scenotecnica*, pp. 167–8, plate 36.
51 Buttigli, *Descrittione*, p. 285 uses the word *isodomine*, meaning a straight level wall, but then says the shape has many equal faces. I assume he means a rectangle.
52 Adami, *Scenografia e Scenotecnica*, pp. 168–72, plates 37, 38.
53 Nagler, *Theatre Festivals*, plate 131.
54 Adami, *Scenografia e Scenotecnica*, pp. 172–4, plate 39.
55 Buttigli, *Descrittione*, p. 294.
56 Adami, *Scenografia e Scenotecnica*, pp. 174–5, plate 40.
57 In *Applausi Festivi*, 1658: see Jean Jacquot and Günter Schöne, 'Note sur quelques dessins du Louvre et un tournoi de Munich (1658), in Jean Jacquot (ed.), *Les Fêtes de la Renaissance*, 3 vols (Paris: Editions du Centre Nationale de la Recherche Scientifique, 1973–5), vol. 3, pp. 411–19, plate 3.
58 Jacquot, *Fêtes de la Renaissance*, pp. 131–3, plates 6, 7.
59 Dall'Acqua, 'The Teatro Farnese', English translation, p. 335, says that this set 'was to appear as a huge window, opening to the outside' showing the real Garden Palace outside – not in the actual direction in which it would be seen, but as though in a mirror. The palace was planned by Vignola and was for summer pleasures only – it was not for year-round occupation.
60 Adami, *Scenografia e Scenotecnica*, pp. 186–7, plate 46.
61 Buttigli, *Descrittione*, p. 345.
62 The letter was published by Lombardi, 'Teatro Farnesino'. Extracts are given in Massera, 'Mecanica, musica, idraulica', p. 117; translations by Richard Kamm and myself.
63 Letter from Guitti to Bentivoglio, 18 February 1628, in Lavin, 'Early Baroque Opera House', p. 529.
64 Buttigli, *Descrittione*, p. 363, uses the Vitruvian word *orchestra* to refer to this position for the players. Irving Lavin says that there were musicians behind a parapet in front of the stage for a production by Giulio Parigi in Florence in 1621: 'Early Baroque Opera House', pp. 523–4: see also Gallico, 'Monteverdi', English translation, p. 363. Eugene Johnson, *Inventing the Opera House: Theater Architecture in Renaissance and Baroque Italy* (Cambridge: Cambridge University Press, 2018), p. 199, reproduces a sketch plan, possibly by Aleòtti, for a theatre in the Ducal Palace in Pesaro, also of 1621, with an 'orchestra for musicians' labelled as such.
65 Described by Guitti in a letter to Bentivoglio on 22 September 1627, reprinted in Lavin, 'Baroque Opera House', p. 528. Guitti uses the word *burchielli* or 'little barges'.
66 Adami, *Scenografia e Scenotecnica*, pp. 189–94, plates 49, 50, 51.
67 Nagler, *Theatre Festivals*, plate 132. Cesare Molinari, on the other hand ('Disegni a Parma per uno spettacolo Veneziano', *Critica d'Arte*, 70 (1965): 47–64), believed that it shows the finale of *Divisione del Mondo* at the Teatro San Salvatore in Venice in 1675.
68 For example, Pietro de Lama, *Descrizione del Teatro Farnese di Parma* (Bologna: Annesio Nobile, 1818), see p. 18.
69 Giovanni Battista Aleòtti, *Della Scienza et dell'Arte del ben Regolare le Acque* (Modena: Panini, c.2000).
70 Giovanni Battista Aleòtti, *Gli Artificiosi et Curiosi Moti Spiritale di Herone* (Bologna: Carlo Zenero, 1647), p. 98.
71 Massera, 'Mecanica, musica, idraulica', p. 118.
72 Francesco Mazzi discusses the sizing and positions of the tanks in a letter to Bentivoglio of 16 November 1627 (Lavin, 'Early Baroque Opera House', p. 532). He gives more details of their taps, the openings from which the water will emerge and the reinforcement of the floor in a letter of 31 December 1627 (Lavin, 'Early Baroque Opera House', p. 539).
73 Dall' Acqua, 'The Teatro Farnese', English translation, p. 346.
74 Dall' Acqua, 'The Teatro Farnese', English translation, p. 347.
75 For a historical account see Bjurström, 'Venice in the Early 17th Century', in *Giacomo Torelli*, pp. 29–46.
76 Adami, *Scenografia e Scenotecnica*, p. 23. Others have suggested that the designer was Alfonso Chenda: see Johnson, *Opera House*, p. 209.
77 This was at the Teatro Santi Giovanni e Paolo: see Johnson, *Opera House*, p. 210 and Bjurström, 'Venice in the Early 17th Century', in *Giacomo Torelli*, p. 44.
78 Bjurström, 'Giacomo Torelli in Venice', in *Giacomo Torelli*, pp. 47–52; also Johnson, *Opera House*, p. 213.
79 Bjurström, 'Giacomo Torelli in Venice', in *Giacomo Torelli*, p. 49.
80 Quoted in Bjurström, *Giacomo Torelli*, p. 110. Oddly, Bjurström cites this passage as evidence of the 'importance of this invention' (by Torelli). Translation by Gregorio Astengo.
81 Bjurström, 'Torelli in Paris', in *Giacomo Torelli*, pp. 122–33.
82 Denis Diderot and Jean le Rond d'Alembert (eds), *Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des metiers* (Paris: 1751–72): 'Machines de Théâtre', première section, vol. 10, 1772. Plates 2 and 15 are reproduced here. The text says that these are machines in use at the Opéra de Paris. But Arnold Aronson and Donald Roy, in Martin Banham (ed.), *Cambridge Guide to Theatre* (Cambridge: Cambridge University Press, 2nd edn, 1988), p. 1117, say that they are drawings by Torelli from the Petit-Bourbon.
83 Frank Mohler, 'Survival of the Mechanized Flat Wing Scene Change: The Court Theatres of Gripsholm, Český Krumlov and Drottningholm', *Theatre Design and Technology*, 35 (Winter 1999): 46–56.
84 Several videos online give extracts from the film. Others show the real Slottsteater in use.
85 Robert Fahrner and William Kleb, 'The Theatrical Activity of Gianlorenzo Bernini', *Educational Theatre Journal*, 25/1 (1973): 5–14; see p. 8.

Reprise: Hero as unlikely hero

Garden historians and historians of science have been exploring the influence of Hero's *Pneumatics* on the designs of automata and music machines installed in Renaissance gardens and grottoes – although there is surely still more to be learned. The inspiration that Renaissance designers of table fountains found in Philo, Hero and Islamic sources, touched on here in Chapter 5, has not received so much attention.

Italian designs for grottoes and automata spread across Europe, although only for the century or so that the fashion for Renaissance gardens lasted. There is an irony – as remarked in Chapter 7 – that Buontalenti's more lasting influence so far as garden and landscape architecture is concerned was arguably on the English romantic style that swept many Renaissance gardens away. On the other hand, Aleòtti and Buontalenti's theatre designs and systems of stage machinery, with their debts to Hero, survived essentially unchanged and were reproduced worldwide until the end of the nineteenth century.

The Teatro Farnese as a Heronian machine

The comedies of the sixteenth century, and even more so the *intermezzi*, called for many changes of setting, meaning that their scenery had to be mobile. The ancient *periaktos*, described by Vitruvius, was seized on immediately as a means for changing scenes at speed, to be replaced in time by sliding or rolling flats, which proved yet more flexible. This changeable scenery, and the machinery for the special effects demanded by the *intermezzi* and the opera, all needed to be hidden behind the stage frames of Buontalenti and Aleòtti's new type of proscenium

theatre. What has not previously been discussed, beyond a few hints and oblique allusions, is the 'startling resemblance' that Victor Prou saw between Hero's automaton theatres and the theatrical machines of Buontalenti and Aleòtti: their use of cables and drums of varying diameters, their counterweights, the chariot system, their apparatus to make people and vehicles fly, their creatures, characters and scenic elements rising from below stage.

I have suggested that Buontalenti and Aleòtti drew ideas for their theatre designs and machinery from Hero's *On Automata-Making*. With the rediscovery of Floriani's drawings of Aleòtti's and Guitti's machines, we can now see more of what Prou meant. At the Uffizi Theatre and the Teatro Farnese, mobile scenery is concealed behind the proscenium and is brought in from the sides and above, as in Hero's theatre. The most 'startling resemblance' is the use by both Hero and Aleòtti of systems of cords or ropes wound on drums, pulled by weights, to shift the different scenic elements. Hero's stage floor seems to have been cut with slots along which the figure of Athena was pulled back and forth with cords. I wonder if this arrangement might have given Aleòtti the inspiration for scenic chariots and their slots.

In the standard chariot system, the flat wings are moved simultaneously at the same speed, since they are all connected to the one central cylinder. In other machinery both Aleòtti and Hero employ drums and pulleys of different diameters to pull the respective ropes or cords at different speeds. We saw this in the Parma cloud machine of Figure 8.9 and in the arrangement for lowering the clouds surrounding Venus's boat in Figure 8.14. Two of Floriani's sketches of chariot mechanisms, no doubt designed by Guitti, show tapered drums, or wheels of graduated sizes on a common axle, for pulling the wings.[1] These would have the effect of making the flats at the back of the scene move faster than those nearer the front. From all being aligned in the wings, the flats would thus move inwards at different rates to create the typical staggered and tapering scene of the perspective stage.

In Hero's theatres, cylinders and cords like these provided the central system by which the timing of all the various mechanical actions was controlled. The machinery of the seventeenth-century stage was of course only partly automated, and still depended – unlike Hero's theatre – on the coordinated actions of many human operatives. Rather it was the script and music that gave the stage crew their cues and determined the timing of the great 'Heronian machine' that was the Baroque theatre. Hero was Buontalenti and Aleòtti's hero, and the improbable hero of the story told in this book.

Note added in April 2020

A previously unknown album of Buontalenti drawings

The rediscovery has recently been announced, by the Italian Ministry for Cultural Assets and Activities, of a large and previously unknown album of drawings from the workshop of Bernardo Buontalenti with the title *Libro di Meccanica ed Ornato* [*Book of Machines and Decor*]. This had been preserved in a private collection in a castle near Milan, and will now pass to the State Archive in Florence. The album is of 80 pages, in large format, and many of the drawings are coloured. They depict a variety of subjects. One large group is devoted to designs for scenery and machines by Buontalenti for theatrical productions including *L'Amico Fido* (1585) and *La Pellegrina* (1589) in the Uffizi Theatre. There are drawings of Vulcan's Forge and automated figures of Lucifer and Pegasus. A few examples have been published online, including a drawing of machinists working winches above stage to control groups of celestial personages flying on clouds.[2] Another shows a fountain operating on Heronian principles, alongside Alberti's diagram reproduced here as Figure 5.6.

The volume is being studied by the art historian Orietta Lanzarini and is not (in 2020) available to other scholars. Clearly it will transform our knowledge of Buontalenti's machinery for the Florentine *intermezzi*, about which little was previously known – as noted in Chapter 1. More light will also doubtless be thrown on Buontalenti's designs of automata and fountains, for Pratolino and elsewhere. This is extremely exciting and tantalising, but, regrettably, too late for the present book.

Notes

1 Giuseppe Adami, *Scenografia e Scenotecnica Barocca tra Ferrara e Parma (1625–1631)* (Rome: 'L'Erma' di Bretschneider, 2003), plates 9, 53.

2 https://www.movio.beniculturali.it/asmi/patrimonioincammino/it/35/cerchia-di-bernardo-buontalenti-libro-di-meccanica-ed-ornato.

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Renaissance Fun is about the technology of Renaissance entertainments in stage machinery and theatrical special effects; in gardens and fountains; and in the automata and self-playing musical instruments that were installed in garden grottoes. How did the machines behind these shows work? How exactly were chariots filled with singers let down onto the stage? How did mechanical birds imitate real birdsong? What was 'artificial music', three centuries before Edison and the phonograph? How could pipe organs be driven and made to play themselves by waterpower alone? And who were the architects, engineers and craftsmen who created these wonders?

Renaissance Fun is offered as an entertainment in itself. But behind the show is a more serious scholarly argument, centred on the enormous influence of two ancient writers on these subjects, Vitruvius and Hero. Vitruvius's *Ten Books on Architecture* were widely studied by Renaissance theatre designers. Hero of Alexandria wrote the *Pneumatics*, a collection of designs for surprising and entertaining devices that were the models for sixteenth- and seventeenth-century automata. A second book by Hero, *On Automata-Making* – much less well known, then and now – describes two miniature theatres that presented plays without human intervention. One of these, it is argued, provided the model for the type of proscenium theatre introduced from the mid-sixteenth century, the generic design which is still built today.

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