

# Making **SIMPLE AUTOMATA**

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# ACKNOWLEDGEMENTS

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*Canoe with Birds.* A simple automaton, made by the author in driftwood.

# INTRODUCTION

## WHAT ARE AUTOMATA?

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*Automata* is the plural of the Greek word *automaton*, meaning a thing that moves of itself. The plural can also be *automatons*, but it is less common. Rather more common, but not strictly correct, is the use of *automata* for the singular. Modern dictionaries give a broad spectrum of definitions and usage. Sometimes the word has a narrow specialized application, such as in the mathematical concept of a cellular automaton. It can be applied to a person, or to a living creature in general, when it suggests a possibly efficient, but merely mechanical action, without thought or feeling. One of the common usages of the word focuses on the notion of a mechanical device that moves, is usually intended as a toy or amusement, and often imitates the action of a living creature. There may be reference to a concealed mechanism and motive power. Although *automata* can be quite complicated machines, mimicking the movements of human beings or animals, even performing complex actions such as drawing a picture or writing, the Oxford English Dictionary gives a clockwork mouse as an example.

This book deals with the design and construction of small scale, simple mechanical devices made for fun. I shall call them *automata*, although in many, the mechanism, rather than being *concealed*, is in full view and intended to be part of the overall effect. The source of motive power and its transmission are also often clearly visible. Power

may be provided directly by turning a drive shaft with a crank handle, or less directly, for instance by raising a weight or winding a spring.



**The oxford english dictionary suggests a clockwork mouse as an example of an automaton.**

## **THE HISTORY OF AUTOMATA**

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That the OED gives a clockwork mouse as an example of an automaton indicates that it is pretty impossible to disentangle the history of automata from the history of moving or mechanical toys, not to mention that of puppets and dolls, of kinetic sculpture, of theatrical devices, of conjuring or of robotics.

If you look at such histories you will find the same passages from classical authors, and the same museum objects, claimed as early references to, and early examples of, automata, or of moving toys, or of dolls, or of puppets and so on.



***Figure Kneading dough.*** An ancient moving toy, operated by pulling a string. egypt, around 2000BCE.

It is well worth following these histories. Since prehistoric times the urge to represent living things by animating them has been a significant factor in the development of technology.

Among the toys, or toy-like objects, found in ancient Egyptian tombs are a variety of jointed figures with movable limbs, and animals with moving jaws, operated by pulling a string. One notable example that survives in the Egyptian Museum in Cairo is an ivory sculpture of three dancing dwarves mounted on a base: strings can be pulled to rotate the figures (a fourth figure from the group is in the Metropolitan Museum, New York).

A number of moving toys, including wheeled toys, dolls with

movable limbs and figures operated by pulling a string, survive from ancient Greece, and also from earlier civilizations, such as those in Mesopotamia and the Indus valley.

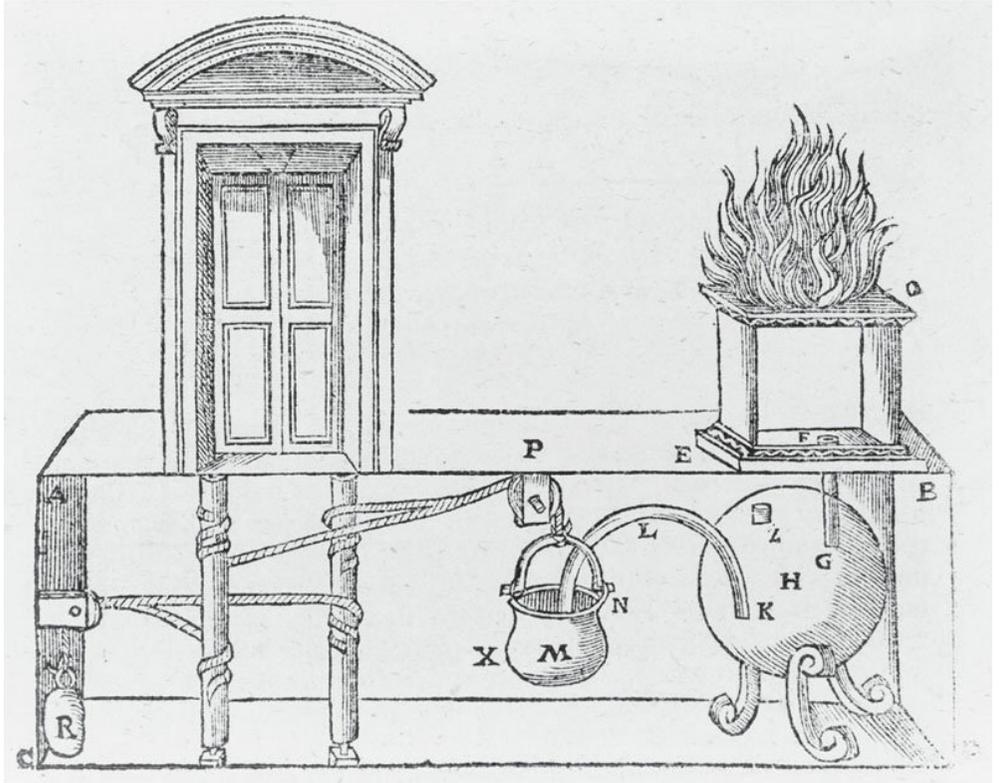
References to automata, moving toys and puppets in classical texts are sparse, and often difficult to interpret with any certainty, but they do suggest that such things were familiar objects in ancient Greece. For example, in Chapter 7 of *The Republic*, in the well-known allegory of the cave, Plato pictured puppets, with their operators hidden behind a wall below, casting shadows on the wall. Aristotle, in *De motu animalium*, compared the movement of animal limbs to automata (by which he probably meant some sort of puppet, or mechanical theatrical device) and also to a strange-sounding toy cart, which runs in a circle because the wheel, or wheels, on one side are smaller than on the other.

Solid descriptions of more complex automata first appear in the second and first centuries bce in the works of the Alexandrian school, and particularly of Ctesibius, Philo and Hero. A wide variety of hydraulic, pneumatic and mechanical devices are described in the texts that survived. Some of these, such as clepsydrae (water-clocks), are machines with a really practical purpose, but they often incorporate moving figures, singing birds and, literally, bells and whistles. In addition, many are really just automata – intended to mystify theatre-goers and temple-goers, or simply to amuse.

These texts survived because they were transcribed by Byzantine and Arab scholars. They subsequently had a considerable impact on Renaissance Europe when Latin translations appeared during the sixteenth and seventeenth centuries.



*Woman with Rolling Pin*, by a modern maker, Edessia Aghajanian. In the British Museum there is a terracotta string-pull toy from Rhodes, dating from 450bce, showing the same timeless domestic task.



**Hero's device for automatically opening temple doors when a fire is lit on the altar. From Giambattista Aleotti's work of 1647.**

Under Harun al-Rashid, the fifth caliph of the Abbasid dynasty, who succeeded in 786ce, and under his successors, Baghdad became an important centre of learning, not least in mathematics and science. Scholars at the House of Wisdom actively sought Greek texts, such as Euclid's *Elements*, to translate into Arabic. Among them were the three Banū Mūsā brothers who produced the *Book of Ingenious Devices* including an array of hydraulic and pneumatic automata including trick vessels, automatic fountains and music machines. They drew heavily on the work of Philo and Hero, but introduced many original features of their own.

Another important figure in the history of automata is the brilliant engineer Al-Jazari, who, in the late twelfth century was in the service of three successive Artuqid rulers in the city of Āmid, now Diyarbakir in Eastern Turkey. His amazing *Book of Knowledge of Ingenious Mechanical Devices* appeared in 1206CE. It also draws heavily on the Alexandrians, and on the Banū Mūsā brothers' developments. It has numerous coloured drawings of automata and other hydraulic, pneumatic and mechanical constructions, many involving delicate control mechanisms, and highly sophisticated water clocks and a boat with four mechanical musicians operated through a camshaft. The drawings are detailed, if sometimes difficult to interpret. Al-Jazari's designs use mechanical devices, such as crankshafts and camshafts, and are technologically advanced in the use of segmental gears, and of conical valves with the seats and plugs ground down to give a watertight fit.



Al-Jazari's design for a candle clock, with a system of weights and pulleys, releasing twelve balls to mark the hours.

Grottoes, fountains and mechanical theatres

Translations of Hero and Philo started to appear in Europe at the beginning of the sixteenth century. The hydraulic and pneumatic devices that they described were used enthusiastically in princely pleasure gardens with ever more elaborate fountains and grottoes with mechanical music, moving figures and automated scenes. The motive power was provided by flowing water, but the mechanical elements became more and more complex, using pulley systems, camshafts and crankshafts to animate individual figures and even whole theatrical scenes.

These garden embellishments were the preserve of the seriously rich and powerful – they were expensive to build and difficult to maintain. Many of the more intricate mechanical elements did not last. However, a famous example of these waterworks was installed early in the seventeenth century at Schloss Heilbrunn near Salzberg and many of the effects survive, although the hydraulic mechanisms are not original. In the eighteenth century the Nuremberg craftsman Lorenz Rosenegge installed an extraordinary model theatre, which is also still in working order.



**Lorenz rosenegge's water-driven mechanical theatre added to the attractions in the gardens at schloss Hellbrunn, salzberg, in the mid-eighteenth century.**

## Clockwork

In 807 one of the gifts that Harun al-Rashid presented to Charlemagne was a clepsydra (water clock) in which twelve horsemen appear in turn and twelve balls fall onto cymbals to strike the hours. There were plenty of other opportunities for the advancing technologies used in clepsydrae (water clocks) in the Arab world to pass into Europe, principally through Muslim Spain. Complicated water clocks became widely used in medieval Europe, and usually they would include various automata, such as figures to strike a bell to mark the hours. From the end of the thirteenth century weight driven *clocks*, with an escapement mechanism to control the fall of the weight, started to

replace them. The word clock comes from the French *cloche*, Latin *clocca*, meaning *bell*, and the earliest had no hands, indicating the passage of time by the ringing of a bell. The principal purpose, for these mechanical clocks, as for the clepsydrae that preceded them, was to measure the fixed canonical hours of prayer. They were substantial structures, and typically mounted on a tower. Just as the makers of clepsydrae often incorporated animated figures, opening doors and singing birds, the mechanical clock makers incorporated animated strikers of the bell to be operated by the weight-driven clockwork mechanism. These were known as jacks of the clock, or jaquemarts.

By the late fourteenth century dials were being added to the clocks. At first the dial rotated and a fixed hand indicated the time, but soon a rotating hand sweeping around a fixed dial became the norm. Mechanical clocks developed rapidly. There would be more than one jack to strike the bell, and different sets of figures might appear through doors at the hour and at the quarters, circling around at the front. During the fifteenth and sixteenth centuries many churches also had automata associated with the organ, and mechanical figures of Christ on the cross, or of devils and angels, were not uncommon.