A report by

l'AnticoPédie

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The inventions and technology of the ancient Greeks

I. Introduction

When ancient Greece is mentioned, people immediately think of its sculptures and temples, and - almost two inseparable words - Greek art. They will then mention the great philosophers and Athenian democracy, probably the Greek theater, and poetry perhaps.

We also know that Greece shone in science. In mathematics, we still have memories of the theorems of Pythagoras or Thales, of Euclid's geometry, of the "Sieve of Eratosthenes" in arithmetics. And then of course in physics, Archimedes' principle. In astronomy, thinking of the names of the planets is enough to remind us of Greek culture.

More than a thousand years ahead, the Greeks had discovered that the Earth was round, calculated its diameter and the distance from the Earth to the Moon. But what do we know about the technology of the ancient Greeks, the machines, the appliances, the instruments they used ? Huge surprises are to be expected in this field. Ancient Greece was also swarmed with engineers and inventors, some were as creative as Leonardo da Vinci, except that their achievements actually worked and sometimes still work today.

It seems obvious nowadays that scientific progress is based on technological tools, and conversely, technology is based on the progress of science. Of course, it was already so at that time. The Greeks used screws, nuts, hydraulic cylinders, pumps, machine tools, gears, they had repeating arms, they knew static electricity and even some bases of computer science : the letters of their messages could be coded in two bits, and the Antikythera mechanism, which was discovered in 1901, deserves the name of the first analog computer in history.

You may be surprised to learn that Plato and Aristotle had alarm clocks, that Hero of Alexandria created not only the first steam turbine, but also automata and animated shows, that Philo was served wine by a robot maid, that Archytas was flying a jet dove, that Alexander's army had repeating arms, that the door of a temple could be equipped with an alarm system, its opening could be automatic, there could be inside an automatic holy water vending machine, some musicians played the organ etc.

And we may begin to dream : what would be the world today if by the fall of the Greek world and of the Roman Empire, all this knowledge and skill had not been forgotten for almost a millennium ? Where would we be at today ? Could the industrial revolution have happened two thousand years before ?


the Aeolosphere of Hero of Alexandria, the first steam turbine

Maybe. Not sure. For the Greeks, science and technology were not intended for mass-production and marketing. Apart from a few exceptions (i.e. when Archimedes built machines to defend the city of Syracuse, besieged by the Romans), scientific research was rarely intended for practical applications, and never for selling them. Nobody would have thought to claim intellectual property rights on his inventions or to produce them in factories. Anyway the notion of factory did not even exist and at the time, a workshop having about forty workers was already a big business. Greeks did not take repetitive manufacturing in high esteem, and did they really need machines, since slaves and metics were easily available ? Anyway, no one can help beeing amazed when discovering the creativity of Hero of Alexandria, Philo of Byzantium, Ctesibius, Hipparchus, Archimedes and so many others, even if their main purpose was often precisely... to amaze their contemporaries.

The technological inventions presented here have been selected using the work of Kostas Kotsanas, who has worked for over twenty years to make them revive. He rebuilt hundreds of machines and instruments that are now displayed at the "Museum of the Ancient Greek Technology" and the "Museum of Ancient Greek musical instruments and toys & games", located in Katakolon, the small port where cruise ships stop for the visit of the archaeological site of Olympia. Visit his website www.kotsanas.com !

II. Technology and entertainment

The Greeks loved art, beauty, music, theater, poetry. Their engineers invented the entertainment technology, creating automata which were maybe not really useful, but amazed their audience. For theatrical performance, they created stage machinery, but also small automatic programmed shows, with animated characters and sound effects, where they used all their ingenuity.

They studied the physical laws that govern music, investigating what makes a sound beautiful and studying harmony. Lastly, in the field of sport, their sense of fairness called on technology : how to observe a fair race start without any risk of argument ?

2.1 Automata, robots and wonders

You'll not be wrong if you think that Hero of Alexandria and Philo of Byzantium, the brilliant engineers, were also illusionist at heart. Philo built an automaton where birds were singing near an owl, but stopped as soon as the owl periodically turned to them. In another one, an animal was drinking while Pan turned away, a dragon whistled when Hercules hit him with his arrow, a horse continued to drink though its head had been cut.

Both took inspiration from "rigged vessels" which allow to pour both water and wine, to turn water into wine or to keep a crater full no matter how much people drew wine from it. The best example is probably the robot-servant which poured wine first, then water, and stopped when you withdrew your cup. Or the cup of Pythagoras, which emptied completely if a too greedy drinker tried to overfill it..

Hero of Alexandria also described a system which automatically opened the doors of a temple – see opposite figure – while sacrifice was performed (the heat of the sacred fire activated the mechanism), a burglar alarm system that sounded when a door was opened, a vending machine – the first in history - that gave the visitor a measure of holy water when he inserted a coin.

He also used the power of steam to run his "Eolipyle" (the first steam turbine in history), or levitate a sphere above a jet of steam. A particularly strange wonder is Archytas' dove, a bird made of light wood, containing an animal bladder that was inflated with steam or compressed air. Once released, the bird rushed away in the air, propelled by reaction. This is the first self propelled flying device, if not the first jet aircraft !

2.2 Technologies in the antique entertainment

Theater inspired the ancient engineers in two ways. First, they created small automatic theaters, with self-opening doors, displaying several scenes with moving panorama, animated characters, special effects and even sound effects, denoting an exceptional talent in animation and programming (opposite picture). Some of these shows were mobile, mounted on wheels, and came in front of the audience on their own.

Secondly, they changed the architecture of the theaters and equipped them with stage machinery that added special effects like the descent of characters from the sky (the *deus ex machina*), instantaneous scenery changes, turning stages and movable carts.

2.3 Musical instruments, games and toys

For the Greeks, music was a major art. They had even organs (the hydraulis). Ctesibius' one required the musician to be accompanied by two assistants who pumped air like in the harmoniums of last century.

They had wind, strings and percussion instruments, which evolved over time. Among the best known, the lyre, zither and harp had plucked strings ; the aulos (a kind of oboe) and diaulos (double flute) ; a sort of bagpipe (the askaulos), the pan flute, the trumpet (salpinx), tambourines and cymbals ; the sistrum, xylophone, clappers, chimes, etc.

Their functioning has been studied in a scientific way, i.e. by Pythagoras and Ptolemy who defined the rules of musical harmony, scales and pitches, and the effects of string length and tension.

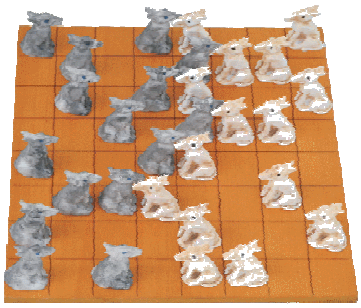
the lyre

the zither

the diaulos

Ctesibius' organ

Greek children played of course. They had dolls, rolling animals, jacks, tops, hoops. The adults played too : ball games, sports games of course, dice (and some were cheating !), and also strategy games like the Polis (a kind of chess) and geometric games looking like puzzles, like the Ostomachion where the player had to build up various shapes using fragments of a square.



2.4 Sports technology in ancient Greece

Sports held an important place in ancient Greece, like at the Olympic and Delphic games, the Nemean and the Isthmian games in Corinth, and many others. For ensuring that runners observed the rules, they had to line up behind the hysplex, a barrier that was lowered for starting. Similarly, for horses and chariots races, another starting system looking like our current starting gates was set up, with offset starting places so that all competitors had the same chance to win.

III. Technology in everyday life

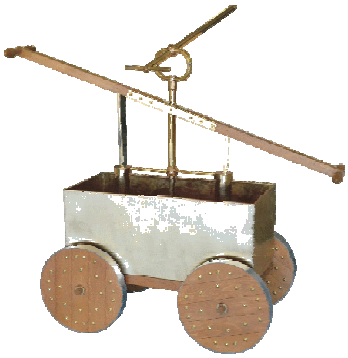
3.1 Lifting and building machinery

The Greeks had a large range of advanced technologies to build their monuments. They had different kinds of cranes, pulleys, winches and capstan hoists, block and tackle systems which could lift huge stones with minimal effort, lifting tongs and lewis for a safe and easy handling. Archimedes designed a winch using a gearbox with which he moved the heaviest loads using only one hand. The way Greeks built piers (below) was particularly clever.

An ancient overhead crane

This crane was mounted on a mobile platform. Capstan winches allowed to tilt it forward or backward and to lift the load. The stone was grabbed on one side, lifted, tilted to the other side, and dropped off. For building a pier, the crane was moved forward before handling the next one. Two cranes could be used together to build parallel walls, then the space between both was filled in.

3.2 Hydraulic technology

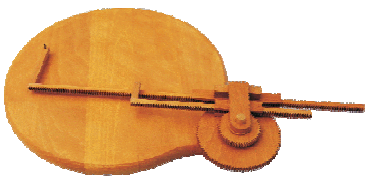


The Greeks had water mills but used also special type with an horizontal turbine, well suited for fast flows of small rivers. They used water to operate the bellows of the "hydraulis" (an organ equipped with a keyboard and pipes like today), but much more, they developed a wide range of pumping systems for domestic needs or irrigation.

The Archimedes screw pump is well known, others used the noria or advanced waterwheel systems with bucket chains and even piston pumps. Doesn't this fire pump invented by Hero, look quite like the ones we used 2.000 years later ?

3.3 Machines and tools

For building their machines, the Greeks needed basic components. Well, those were the same than ours today : screws, nuts, levers, gears, cylinders and pistons, pumps, etc. They had developed special machine tools to produce them : drills, lathes, thread cutting machines, etc.

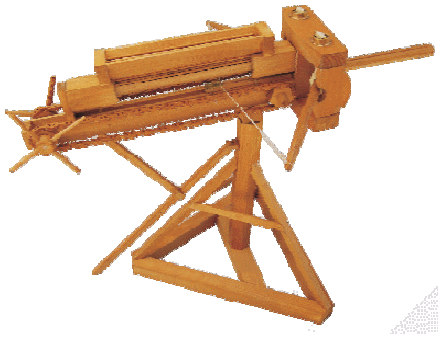


This picture shows the drawing device used by Hero of Alexandria to duplicate his drawings, and even reduce and enlarge them : that's not far from reprography !

3.4 Weapons, telecommunication and shipbuilding

The Greeks realized early that the value of soldiers is one thing, the technology another. The weapons must have longer ranges than those of the enemy, messages must be delivered very quickly, ships must be faster and more maneuverable, siege engines must be able to destroy fortifications or higher than the city's walls .

It was difficult to design portable weapons that could be more powerful than bows and slings, but the Greeks invented a great range of siege engins throwing arrows (catapults) and balls which easily bear comparison with those of the Middle Ages. Dionysios of Alexandria even created a "repeater crossbow" – an early machine gun !



The "polybolos" was an automatic repeating straight-spring catapult which had the possibility of launching heavy arrows in succession at long distance. It was equipped with an ammunition magazine. By turning a winch or a crank, the same motion drew the crossbow and at the same time loaded an arrow from the magazine.

The Greeks used different kinds of battering rams to destroy walls (keep in mind that at the time the stone of the walls were simply piled up without mortar), a highly effective flamethrower against wooden fortifications, "armored vehicles" sheltering the soldiers while they handled the ram, filled the ditches or undermined the wall's footings, and impressive siege towers, especially the one built by Epimachos which had 9 floors !

For defense, Archimedes created a whole range of devices to destroy the ships besieging Syracuse. He also designed a steam cannon, indeed the first in history.

For military communication, the Greeks used shrewdly encrypted messages, but also beacons relay leagues (fire signals, opposite picture) where each letter was codified by a combination using a minimum of torches (computer engineers would say that each letter was coded using 2 bits in a base-5 system). Aeneas the Tactician, an engineer of Alexander the Great, also developed a stunning hydraulic telegraph system.

Lastly, the Greeks who had always been sailors and traders understood early that they had to turn the heavy merchant ships into fine and fast galleys. The triaconter (a 30 oared galley mentioned in the Iliad) evolved into the bireme (two rows of oarsmen on each side) and especially triremes (three rows) which led to the great victory of the battle of Salamis.

3.5 Textile, agricultural machinery and medical devices

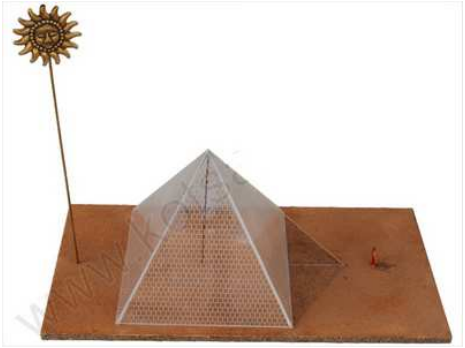
In a world where everything was hand-crafted, the Greeks used very early horizontal and vertical looms, swing ploughs, water mills and draft animals mills, and developed screw presses to produce their valuable olive oil.

In the medical field, they used pliers, scalpels, and even this kind of syringe.

3.6 Measuring lengths and distances

The Greeks manufactured reduction gearboxes (including gears and wormdrives) and used some to measure road distances. Their odometer was mounted on a cart, and computed the number of revolutions of the wheels. It was also the first taximeter, since some models stroke regularly the distance units they had traveled.

Some measurements required some skill. How to measure the height of a tree, the distance from a ship to the shore ? How to estimate the distance and height of the enemy city wall without approaching it, in order to use catapults? The Greeks were masters in the art of solving problems by geometry, and if possible using only the ruler and the compass. All were not so easily solved, but even with all the means we have today, some solutions may still be surprising.



How high is the Great Pyramid ?

At one point in the day, the sun is precisely in the pyramid's north-south axis. You just need to stand on the north side with a stick and measure the length of its shadow. The triangle formed by the stick and its shadow is similar to the one made by the pyramid's axe and its shadow. Simply measure the length of the shadow at its foot and add it to the half of its width...

3.7 Measuring time and other physical values

In the ancient worlds, an hour had not the same meaning as today. The system of "temporary hours" divided the day (defined as the period between sunrise and sunset) in 12 hours. Their durations varied therefore each day over the seasons. Days, as hours, became longer from winter to summer, and than shortened again. And vice versa for the night's 12 hours.

For measuring time, the Greeks used two main devices : sundials and a steady fluid flow (mainly water clocks, the clepsydra).

Sundials

The Greeks obviously knew the sundial, but they studied it most thoroughly and developed a large number of variations : the shadow of a point (the gnomon) or a sunbeam passing through a hole showed the time on a spherical, conical, cylindrical or flat surface. These surfaces could be horizontal or vertical. Of course, the flat vertical sundial is the most convenient to passersby. The Greeks did the required computation to develop sundials that could face any direction and not only the south, so that they could be mounted on any wall. The famous "Wind tower" of Athens, an octagonal building, displays a vertical sundial on each of its faces.

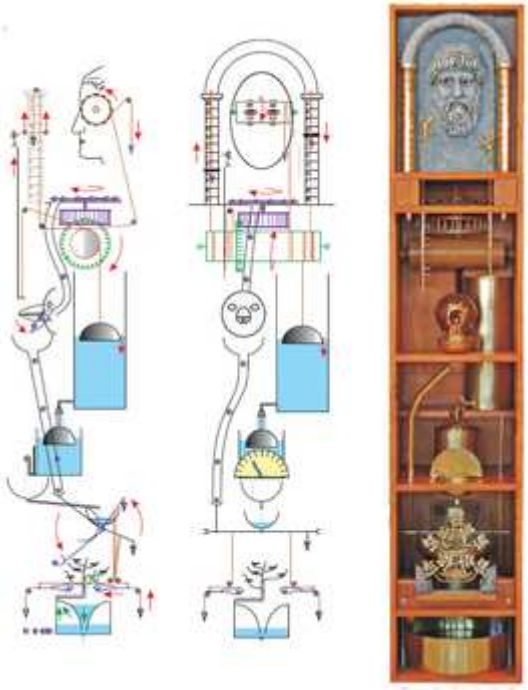
When traveling, the Greeks could carry small portable sundials. The one designed by Parmenion could work under 4 different latitudes (for 4 different cities), and is so attractive that it is still to be found in some shops !

The water clock (clepsydra)

This clock did not need the sun, it worked by measuring a fluid flow leaking from a container at constant pace - although that is not so easy to get : if you drill a hole at the bottom of a bucket, the water flow will decrease constantly, since the pressure decreases with the water level inside.

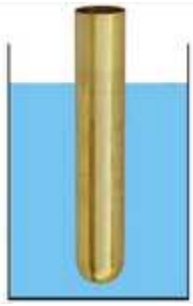
Greek engineers get out very well, inventing the level regulating valve (like the one we still use in flushing systems !). They also knew the siphon principle, which allows to implement complex mechanisms : some clocks could strike the hours, took into account their daily change of duration according to the season, and worked as an alarm clock.

Aristotle's alarm clock was quite simple. That of Plato (opposite picture) was more "bucolic" and imitated the chirping of a bird to wake him up gently...



Archimedes reached a height in clocks automation. This model (left) may be compared to the astronomical clocks of the Middle Ages. At the top of this water clock, moving along two small columns, two statuettes showed the time and the remaining number of hours of the day.

Every hour, the iris of the mask's eyes changed color and a raven let a small ball fall from its beak, striking the hour. At the bottom, two small snakes then slid towards birds, which began to chirp with fear.



Archimedes invented also a density meter (right), still used today by winemakers for measuring the alcohol concentration. According to his famous principle, in a liquid of higher density, the top of this floating device should stand higher over the liquid surface.The density can thus be easily read on the scale.

IV. When technology assists Science

4.1 Geometrical tools

When the Greek geometricians encountered a problem, they always tried to solve by using the ruler and compass, but this did not always work, so they built devices to simulate the statement and seeked solutions by successive approximations.

Proclos designed a device for drawing ellipses, Plato and Eratosthenes found solutions to the Delos problem (what is the side of a cube which has twice the volume of another ?) and Nicomedes to the trisection of an angle.

Proclos' Ellipsographos | Plato's Cubist | Nicomedes' Trisector | Eratosthenes' Mesolabe

4.2 Astronomical instruments

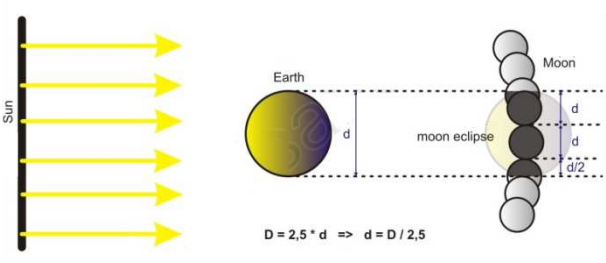
The height of Greek technologiy was reached with the "Antikythera mechanism", which stunned its discoverers. It took a long time to understand its function and operation, using dozens of gears. We could only reconstitute it very recently, and it is indeed the first astronomical analog computer in the world.

The Antikythera calculating mecanism (left) was used to determine and forecast important astronomical and calendar events, and even eclipses.

Studying the stars, Hero of Alexandria and Ptolemy created astronomical observation instruments to record their precise position through their angular coordinates.

Hipparchus, who knew that the earth was spherical, measured the latitude of any place using a quadrant (a quarter circle with a graduated angular scale in degrees) and a plumb line.

Eratosthenes computed the circumference of the Earth with less than 2% error. Columbus, 1.700 years later, was far to know as much as him ! Archimedes measured the apparent angle of the Moon. During a lunar eclipse, he noted that the Moon remains in the shade of the Earth while moving 2.5 times its diameter. If the shade thrown by the Earth was cylindrical, the diameter of the Earth was therefore 2.5 times that of the Moon.



But Hipparchus discovered that the Sun is much larger than the Earth, and the shade area is therefore conical. The Moon is thus much smaller. He calculated that it was actually four times smaller than the Earth, which is not far from the true value. Knowing the Moon's apparent angle and its diameter, it was then easy to calculate how far it was.

The Greeks also wanted to understand how the universe is working. Therefore, Ptolemy and Eudoxus built different mechanisms that simulated the motion of the planets. Although Ptolemy still believed that the Sun turns around the Earth, the model (right) did not display just planets turning in circles around the Earth. Each one had an eccentricity on its orbit, thanks to a secondary epicycloîdal revolution motion added to their orbit. This simulated quite well their apparent path around the Earth, which itself was not quite in the center of the system. The approximation this system gave was accurate enough to remain unchallenged for 1.500 years, until the works of Copernicus. Is this not a great result ?

For any additional information on these devices, machines and technologies
we recommend that you refer to the website

www.kotsanas.com