

ATMOSPHERIC AIR AND THE VACUUM.

The origin of the first pneumatic apparatus, the syringe, is unknown. The fact that the piston of the syringe could not be withdrawn without the cylinder becoming filled with air, water, or some other liquid, constituted one of the experimental proofs of the theory of the "horror vacui" accepted by ancient philosophers. The Greek observed that combustion, taking place in a vessel rarefied the air. By means of the introduction of a burning light into a bell-shaped vessel and then pressing the latter to the skin, they applied cupping glasses in the same way as it is done at the present day. This being an inconvenient method, however, they looked for some different means. Hero, of Alexandria, in the 56th chapter of his celebrated "Treatise," describes "the construction of a cup sucking without the aid of heat." The closed end of this cupping bell was separated from the mouth by a transverse partition situated near the latter. Into the closed end was inserted a tube with a stopcock. The partition also was provided with a valve, by which the two compartments could be brought into communication at will. With the valve between the compartments shut, the air was sucked out of the upper compartment through the tube, and the stopcock closed. The bell was then applied firmly to the skin, and the valve opened; the air within the entire bell was thus rarefied, and the skin consequently raised by aspiration.

This same idea was brought out, after a lapse of many centuries, by Otto von Guericke. He used a hollow sphere with tube and stopcock, from which the air was removed by a pump. Otto von Guericke, born in 1602, was burgo-master of Magdeburg, in Germany, and spent his hours of leisure, which his duties as a public officer and his frequent diplomatic missions allowed him, to study and experiment on scientific matters. His attention being first called to the problem of creating an entirely empty space by a treatise on that subject, he set out to experiment at once. He tried, at first, to remove the air from a tightly closed cask. For this purpose he used a pump, provided with the necessary stopcocks, reaching to the bottom of the cask. The latter being filled with water, he commenced to work the pump, but as he removed the water the outside air forced its way into the cask by minute openings in the wood, causing a noise as if the water within was boiling. He next used a hollow sphere of copper provided with a tube and stopcock, which was screwed airtight to a powerful pump, after being filled with water. It required two stout men to operate the pump and remove the water. Then the stopcock was closed and the copper globe detached. The stopcock being now opened, the air rushed into the hollow sphere with such force that anything coming within reach was caught by it, and the hand held over the opening was severely injured.

These experiments were repeated at Ratisbon, in 1654, before the German Diet, the Emperor, and the most celebrated statesmen and scientists. The Archbishop of Mayence became so interested in them that he induced Otto von Guericke to leave Magdeburg and bring his apparatus to his palace at Würzburg. At the latter place the celebrated mathematician Schott, a Catholic priest, and several other *se-vants*, assisted Guericke.

The latter's researches obtained publicity for the first time under the title of "The Magdeburg Experiments," in Schott's work, "Ars Hydraulico-pneumatica," and later, by introduction, into the work of the same author, "Technica Curiosa" (lib. i., "De Mirabilibus Magdeburgicis.")

The book containing the most complete account of the discovery, however, was published in 1672, at Amsterdam, under the title "Ottonis de Guericke Experimenta Nova (ut vocantur) Magdeburgica, de Vacuo Spatio," of which the author is unknown. The pneumatic machines were not very portable, and as Guericke wished to repeat all his experiments in a comprehensive way before his sovereign, the Elector of Brandenburg, he constructed an apparatus possessing a marked improvement on his former machines.

It consisted of a vertical cylinder of brass or iron, supported by a tripod made of iron (Fig. 1). At its lower end the cylinder had a stopcock, while within a piston and rod could be moved up and down by means of a stout lever fastened to one of the legs of the tripod. The piston was provided with a valve. On the upper extremity was

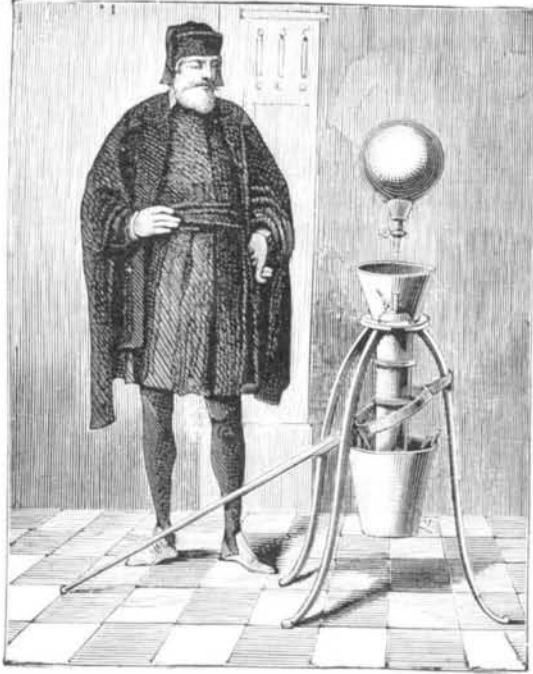


Fig. 1.—OTTO VON GUERICKE'S ORIGINAL AIR PUMP.

fastened a hollow sphere of stout glass provided with a tube and stopcock, similar to the copper globe previously used. This machine being very exact and powerful, a prolonged series of experiments were then made. One of the most

celebrated is that with the so called "Magdeburg Hemispheres," used in schools at the present day, and constructed substantially the same as those made by Guericke. They consist of hollow brass hemispheres, as shown in Fig. 2. The two hemispheres were pressed together and attached to the pump, by which a vacuum was created; when the apparatus was detached from the pump the two hemispheres adhered with great force.

After his first experiment with this apparatus, in 1656, Guericke stated that six powerful men could not separate the two parts. Afterwards, in 1657-64 ("Technica Curiosa," Schott), he said that a more complete vacuum was attained and the diameter of the sphere increased, so that he could hitch twelve horses to each side, and have them pull at their full power without being able to effect a separation. These experiments created a profound sensation. It was conceived gradually that it was the pressure or weight of the atmosphere that produced such astonishing effects. Calculating the pressure exerted on the surface of the two hemispheres, accepting the vacuum as perfect, we find it equal to the weight of a column of mercury of barometrical height, having a base with an area found by the formula πR^2 , R being the radius of the sphere. The weight exerted will be $\pi R^2 \times 76 \times 13.6$.

A great variety of experiments were made. By allowing the air to enter slowly, by opening the stopcock slightly, the adherence of the hemispheres was rapidly diminished, and soon ceased altogether. Otto von Guericke said regarding this: "How is it, that a mere breath of air can accomplish what was impossible to do by the power of 24 horses?"

The separation may be effected also in a different way, of which the learned burgo-master did not think. When the hemispheres are joined together, and the vacuum within as nearly as possible complete, they are suspended under a glass bell, in which a vacuum is then also created. As soon as this is done the weight of the lower hemisphere will be sufficient to separate it from the upper one. Guericke attached one hemisphere to a hook fastened in the body of a gallows, and the other to a chain, running over pulleys, and carrying at the end a platform on which weights could be placed. When a sufficient load was placed on the platform the hemispheres separated, with a report similar to that of a cannon. Separation was also produced by men pulling on ropes running over a compound system of pulleys. Guericke also constructed an apparatus which he described as a "glass globe capable of moving 50 men against their will." It consisted of a cylinder resting on a support, and provided at the base with a coupling and stopcock. Within was contained a piston with a long rod. The piston was drawn out as far as possible, and the 50 men attached to the rod by ropes running over pulleys. To the lower end of the cylinder was now screwed a big glass globe previously deprived of air. As soon as the stopcocks were opened the air contained in the cylinder was suddenly diffused throughout the glass globe, thereby creating a partial vacuum in the cylinder. The piston was consequently forcibly drawn into the cylinder, while the men attached to the ropes were suddenly jerked forward in spite of their resistance. This experiment was afterwards modified by attaching the cylinder to a chain hitched to a platform bearing a great weight. When the air was removed from the cylinder, as shown in Fig. 3, the platform was lifted from the ground and held in suspension in spite of its weight.

RECENT investigations indicate that the great kidney worm (*Strongylus gigas*) which exists in the kidneys of the horse, dog, and sometimes in man, lives in fishes in its young state; and the observations of Dr. Bertolus almost furnish proof that people contract the Swiss or broad tapeworm (*Bothriocephalus latus*) by feasting on imperfectly cooked trout. According to Professor Van Beneden, however, the latter parasite is at present known to occur only in Russia, Poland, and Switzerland. All full grown fishes sold in the shops as food are liable to contain entozoa.

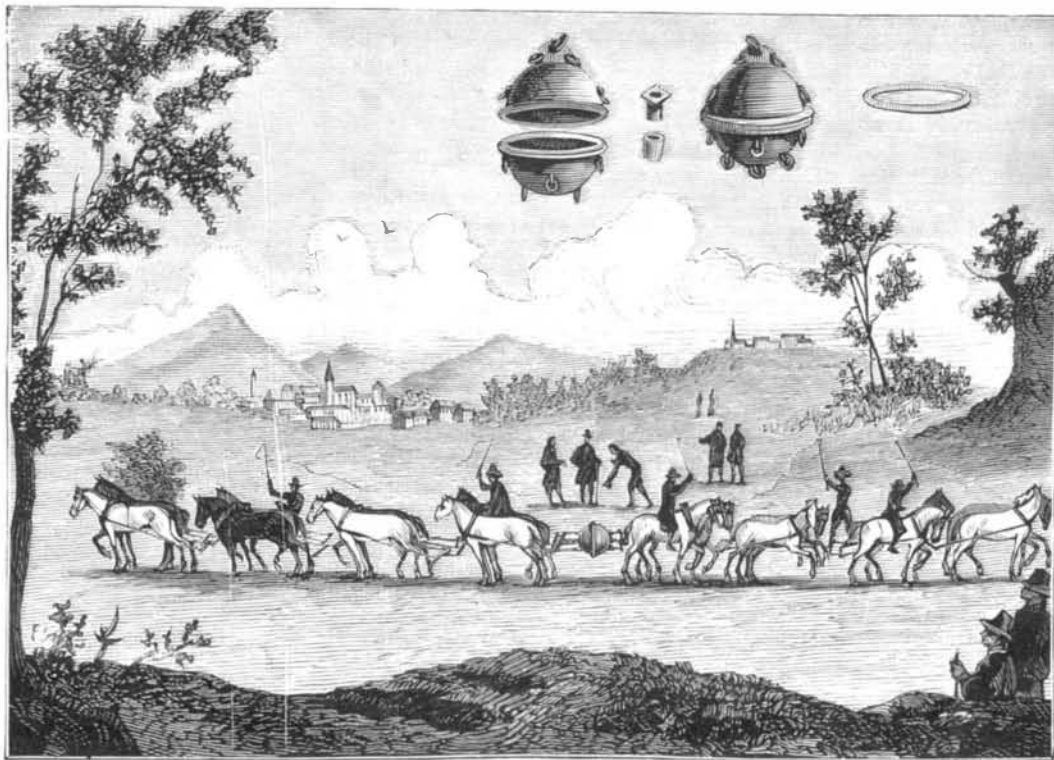


Fig. 2.—ATMOSPHERIC PRESSURE EXHIBITED BY THE HEMISPHERES.

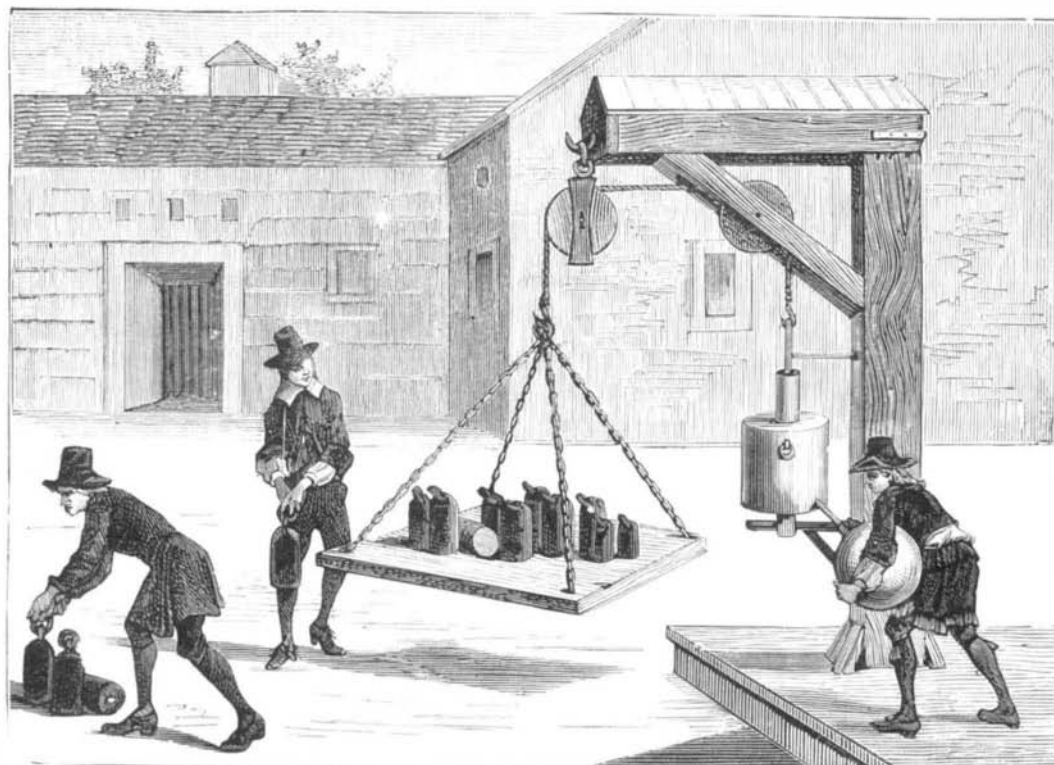


Fig. 3.—AIR EXHAUSTED FROM A CYLINDER BY MEANS OF A VACUUM BALL.