Otto von Guericke (1602–1686) and His Pioneering Vacuum Experiments

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HARSCH V. *Otto von Guericke (1602–1686) and his pioneering vacuum experiments.* **Aviat Space Environ Med 2007; 78:1075–7.**

The German scholar Otto von Guericke (1602–1686) is regarded as one of the most prominent figures of the scientific revolution in the 17th century. A politician, physicist, engineer, and natural philosopher, von Guericke invented the world's first air pump in 1650. By performing and interpreting some pioneering vacuum experiments, he made important contributions to the basic principles of the physics of fluids and gases. He is most recognized for his so-called Magdeburg experiments, in which two copper hemispheres were placed together, the interior evacuated, and two teams of horses were unable to pull the evacuated hemispheres apart until the air was readmitted. In this way in 1654 he first demonstrated the enormous power of the atmosphere. Through this and other experiments, Otto von Guericke significantly contributed to the understanding of high altitude physiology, and was the first to experiment with an artificial vacuum. However, it took more than three centuries before his pioneering book, *Experimenta Nova Magdeburgica de Vacua Spatio* (1672), was translated into English in 1994, bringing his genius, scientific ideas, and philosophical understanding to a wider audience.

Keywords: Otto von Guericke, vacuum experiments, air pump, history of aerospace medicine.

OTTO VON GUERICKE was born Otto Gericke on November 20, 1602, as the son of a patrician family who had been residing in Magdeburg for three centuries. He attended the city school and was also given private tuition. At the age of 15, he entered the Faculty of Arts at the University of Lipsia. Thereafter he studied in Helmstedt and Jena. In Leiden, Netherlands, he studied mathematics and started to deal with engineering problems (3,6,8). In 1631, he was appointed as a construction engineer to help rebuild Magdeburg after it had been severely damaged during the Thirty Years' War (**Fig. 1**). In 1646, he was elected mayor of Magdeburg, a post he held until 1678. On January 4, 1666, Otto Gericke was elevated to the peerage by the emperor Leopold I, in recognition of his political and scientific contributions, and was thereafter called Otto von Guericke. In 1681 he left Magdeburg and moved to live with his son in Hamburg, where he died on May 11, 1686 (3,6).

Von Guericke's time was largely filled by the burdens of public life. However, he remained interested in experimental science. He was aware of the new developments in the debate regarding atmospheric physics. His research in astronomy lead him to successfully predict the periods of the return of comets, and he invented an early version of an electric generator, which was recognized by the Royal Society. Von Guericke's main achievements were in the field of establishing an experimental vacuum, thereby contributing to the philosophical understanding of the structure of the universe (3,6).

The Italian physicist and mathematician Evangelista Torricelli (1608–1647) was the first to produce a vacuum experimentally in 1643. Blaire Pascal (1623–1662), who in 1648 conducted the same experiment as Torricelli, demonstrated that the column of mercury was lower on the 1465-m Mount Puy de Dôme than at sea level, as the atmosphere was thinner there. Von Guericke's invention of the world's first air pump in 1650 catalyzed the subsequent progress of science in high altitude research. Although his first pumps were not very efficient, they were adequate to demonstrate the capacity of the atmosphere to do work. Thus, von Guericke decisively refuted the long-held notion that it was impossible for a vacuum to exist.

Von Guericke's first evacuation pump from 1650 worked with a piston and was capable of pumping entire vessels empty. He began by experimenting with this pump on water placed in a beer and a wine barrel, but found that when the water was drawn off, the air permeated the wood (**Fig. 2**). He, therefore, continued by using glass vessels and containers made out of copper or brass (3). In extensive experiments of evacuating the air from the vessels, he showed that a ringing bell could not be heard, that candles would not burn, and that different species of birds and fish could not live in very low air pressure (3). Using hollow copper spheres and an air pump of his own construction, he demonstrated that a partial vacuum could be created by pumping the air out of the sphere (6). In conducting the same experiments as Torricelli and Pascal, von Guericke knew about the barometric change from sea level to the top of mountains as well. This indicated that a limited amount of air is trapped on the Earth and he, therefore, deduced that a

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This manuscript was received for review in June 2007. It was accepted for publication in August 2007.

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DOI: 10.3357/ASEM.2159.2007

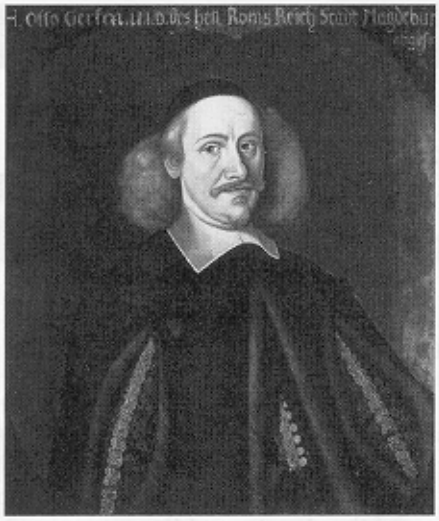

Fig. 1. Portrait of Otto von Guericke (1602–1686). Picture from the Otto von Guericke Museum at the Magdeburg Lukasklause, Germany. Painting by Lucia Maria Lauch in Wien, Austria around 1650.

vacuum outside our atmosphere does exist (3). In his experiments, von Guericke noticed the effects of temperature on gaseous volume, later known as the Law of Charles, the effects of altitude on pressure change as noticed before by Blaire Pascal, and the relation of pressure and volume also known as Boyle's Law (3,8).

On May 8, 1654, von Guericke performed his first vacuum experiment before the emperor, Ferdinand III (1608–1657). During the Diet of Regensburg, he demonstrated the tremendous force exerted by atmospheric pressure by pumping out the air inside two closely fitting hemispheres of copper and showing that two teams of horses were unable to pull the evacuated hemispheres apart until the air was readmitted (**Fig. 3**). Thereafter, Kaspar Schott was ordered by Ferdinand III to go on with these experiments using von Guericke's instruments. In 1657 Schott published his book *Mechanica Hydraulico-Pneumatica*, mentioning the instruments and achievements of Otto von Guericke in a supplement. This was also reported by Robert Boyle (1627–1691) and Robert Hooke (1635–1709) in the proceedings of the British Royal Society (6,8).

That same year, in 1657, von Guericke's demonstration was repeated at the emperor's court in Vienna and again in Berlin in 1663. At the court of the Elector, Friedrich Wilhelm the Great, in Berlin, two bronze hemispheres, each around 50 cm in diameter, were put together and a vacuum was produced between them. Not even the combined force of 30 horses, pulling in opposite directions, was enough to separate the two parts (3,6).

Robert Boyle constructed his own pump with the assistance of Robert Hooke, paving the way for research activities in Oxford (2) during the latter half of the 17th century (3,5,7,8). Without the knowledge of von Guericke's invention, scientific progress would have been delayed. Von Guericke, who originally did not want to publish his results, was motivated to write about his experiments due to the ever-growing public interest and scientific discussion and recognition. He finished his book *Experimenta Nova Magdeburgia De Vacuo Spatio* in 1663, but it took another decade to get it published (3). His "New Magdeburg Experiments About the Vacuum" was finally published in Amsterdam in 1672 when he was 70 years old. He sent one of his books to the Royal Society. The 301-page book consisted of 7 chapters dealing with the following topics: 1) the world and its structure (Die Welt und ihr Bau); 2) empty space (Der leere Raum); 3) [my] own experiments (Eigene Versuche); 4) the cosmic effects (Die kosmischen Wirkkraefte); 5) the 'blue planet' and its composition, the moon (Der Erdwasserball und sein Begleiter, der Mond); 6) our solar system (Unser Sonnensystem); and 7) the fixed stars and their limits (Die Fixsternwelt und ihre Grenze) (3–5). Out of the 37 experiments he described in chapter 3, the most famous are the so-called Magdeburg experiments. This book is a significant contribution to the scientific community of the 17th century, increasing the understanding of the physics of atmosphere and high altitude physiology.

Von Guericke's invention of the air pump in 1650 catalyzed research on topics related to low air pressure and was important for later high altitude and applied hypoxia studies. Though his pioneering vision and experiments cannot be overrated, it remains an irony of history that

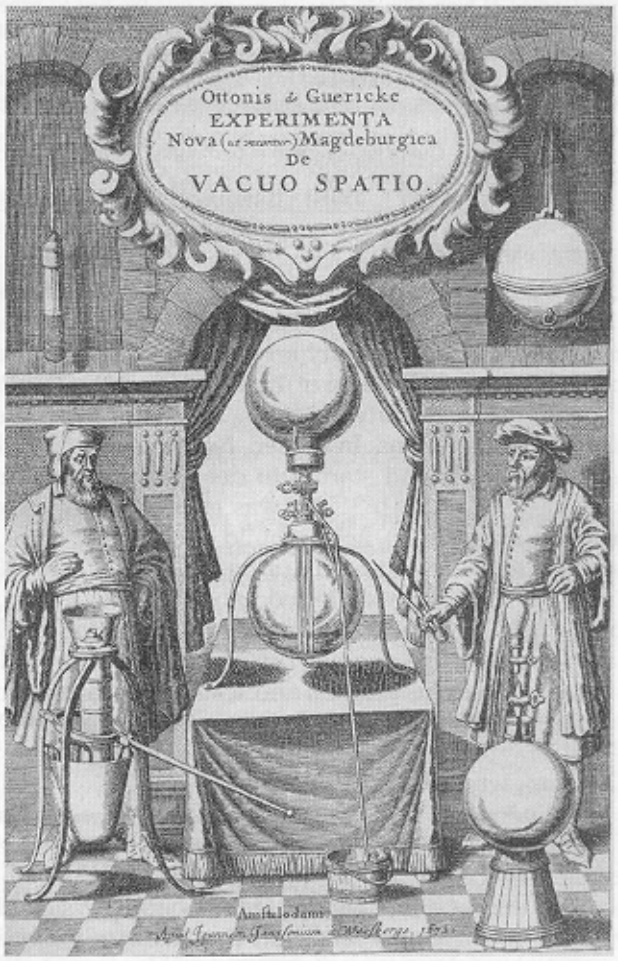

Fig. 2. Otto von Guericke's vaccum experiments with glass vessels and his air pump. From *Experimenta Nova (ut vocantur) Magdeburgica De Vacuo Spatio*, Amsterdam, Netherlands, 1672 (Ref. 3).

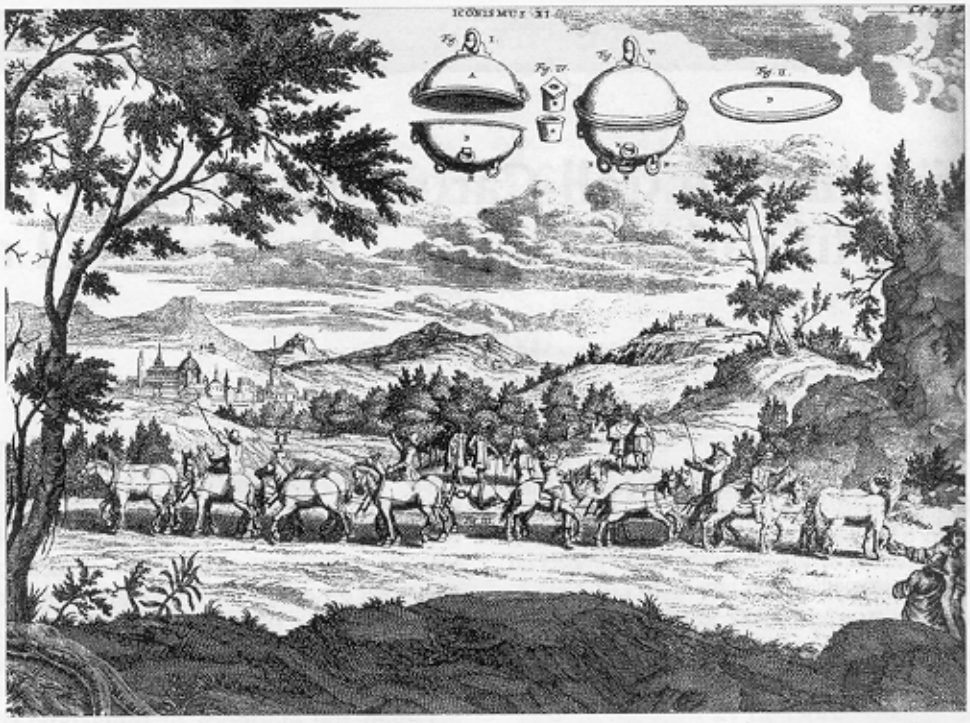

Fig. 3. Two teams of horses trying unsuccessfully to pull apart vacuum-filled copper spheres during the Magdeburg demonstration for Emperor Ferdinand III. From *Experimenta Nova (ut vocantur) Magdeburgica De Vacuo Spatio*, Amsterdam, Netherlands, 1672 (Ref. 4).

the delay of his publication by one decade was not the only one. More than two centuries later the first German translation of his third book, *Ueber eigene Versuche*, with his most famous vacuum experiments, was published in 1894, and the first British translation did not appear until another century later in 1994 (1,3). The Otto von Guericke Society currently displays his most important contributions in an informative museum located in Magdeburg at the Lukasklause, a historic building by the Elbe River (9).

REFERENCES

1. Ames GF. The new (so-called) Magdeburg experiments by Otto von Guericke. Archives Internationales d'Histoire des Idées. Dorchrecht/Boston: Kluwer Academic Press; 1994.
2. Boyle R. New experiments physico-mechanical, touching the spring of the air, and its effects. Oxford: Hall for T. Robinson; 1660.
3. Dannemann F, ed. Otto von Guericke's new (so-called) Magdeburg experiments on the empty space (Neue "Magdeburgische" Versuche ueber den leeren Raum). Third book: own experiments (Drittes Buch: Ueber eigene Versuche). German translation from Latin. Leipzig: Verlag von Wilhelm Engelmann, 1894.
4. von Guericke O. The new (so-called) Magdeburg experiments (Neue [sogenannte] Magdeburgische Versuche über den leeren Raum). Duesseldorf: VDI Publishing; 1996:1–301.
5. Harsch V. Robert Hooke, Inventor of the Vacuum Pump and the First Altitude Chamber (1671). Aviat Space Environ Med 2006; 77:867–9.
6. Krafft F. Otto von Guericke in his time (Otto von Guericke in seiner Zeit). Duesseldorf: VDI Publishing, 1996: XI–LXXXV.
7. Waller R. The life of Dr. Robert Hooke (1705). In: Gunter RT, ed. Early sciences in Oxford. Vol. VII. London: Dawson of Pall Mall; 1968:1–68.
8. West JB. High life. A history of high-altitude physiology and medicine. Oxford: Oxford University Press; 1998.
9. Otto von Guericke Society. Magdeburg. Retrieved August 1, 2007, from: http://www.uni-magdeburg.de/org/ovgg/deutsch/museum/welcome.html.