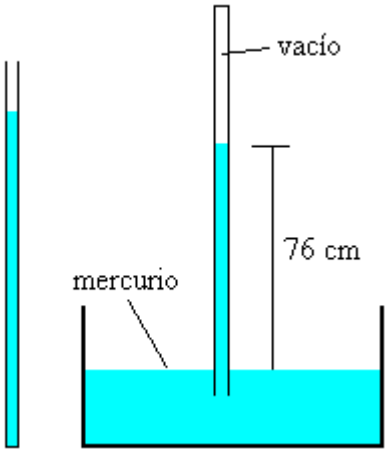


Evangelista Torricelli (1609-1647)

"We live submerged at the bottom of an ocean of air."

Torricelli…

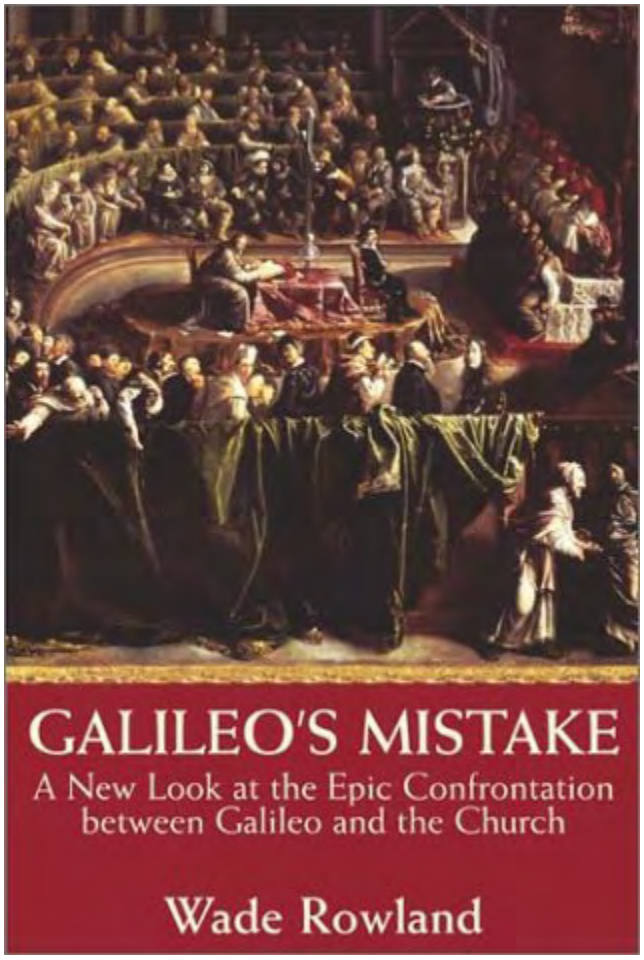
- Torricelli was born in Faenza, then part of the Papal States.
- He was left fatherless at an early age and educated under the care of his uncle, a monk, who first entered young Torricelli in a Jesuit College in 1624 to study mathematics and philosophy until 1626,
- His uncle sent Toricelli to Rome in 1627 to study science under Castelli, professor of mathematics in Pisa.

Torricelli

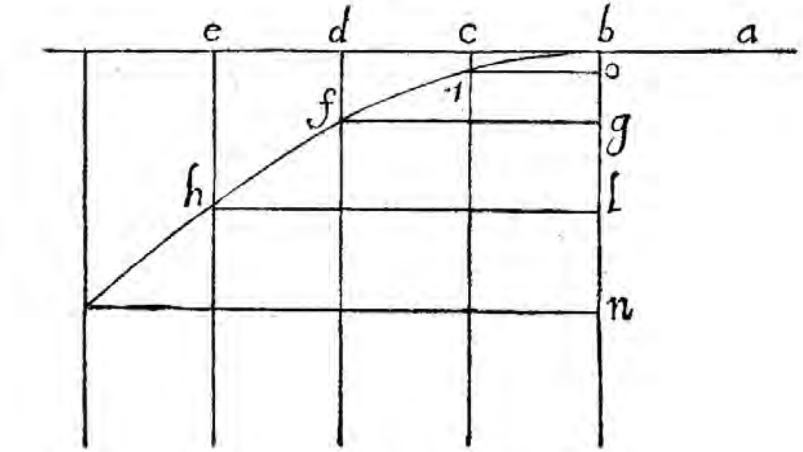
In 1632, shortly after the publication of Galileo's *Dialogue concerning the Two Chief World Systems*, Torricelli wrote to Galileo:

I have read your book with delight, having already practiced all of geometry most diligently ….and having studied Ptolemy and seen almost everything of Tycho Brahe, Kepler and Longomontanus, finally, forced by the many congruences, came to adhere to Copernicus…

- The Vatican condemned Galileo in June 1633, and this was the only known occasion on which Torricelli openly declared himself to hold the Copernican view.

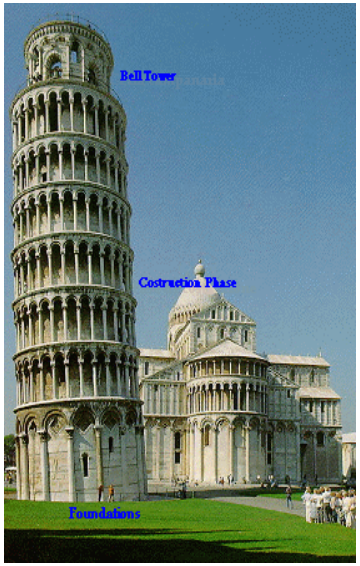


- Aside from several letters, little is known of Torricelli's activities in the years between 1632 and 1641,
- Castelli sent Torricelli's monograph of the “path of projectiles” to Galileo (then a prisoner in a villa at Arcetri).
- Although Galileo promptly invited Torricelli to visit, he did not accept until just three months before Galileo's death.

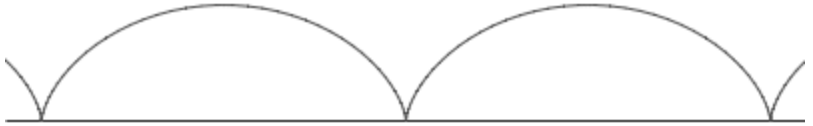


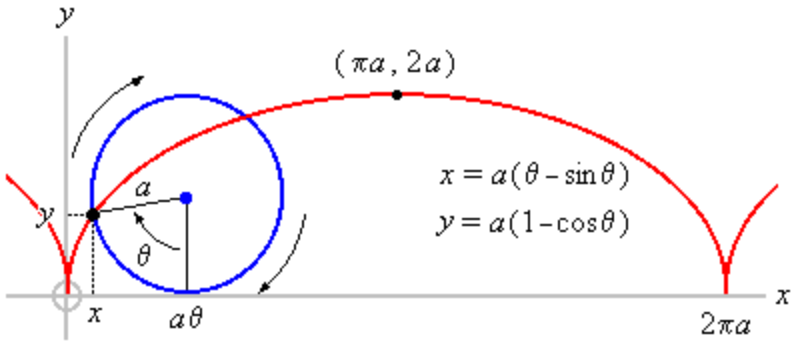
- During his stay, however, he wrote out Galileo's Discourse of the Fifth day.

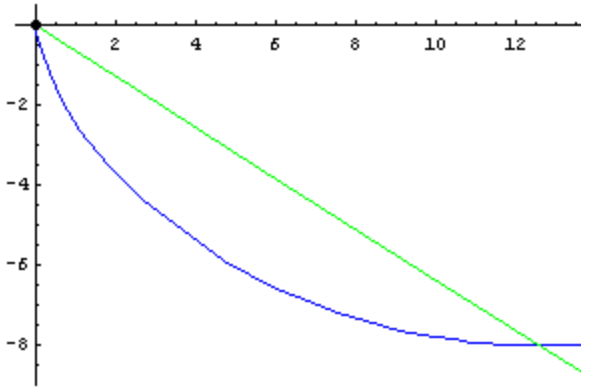
- After Galileo's death on January 8, 1642, Grand Duke Ferdinando II de' Medici asked him to succeed Galileo as the grand-ducal mathematician and professor of mathematics in the University of Pisa.



Torricelli…







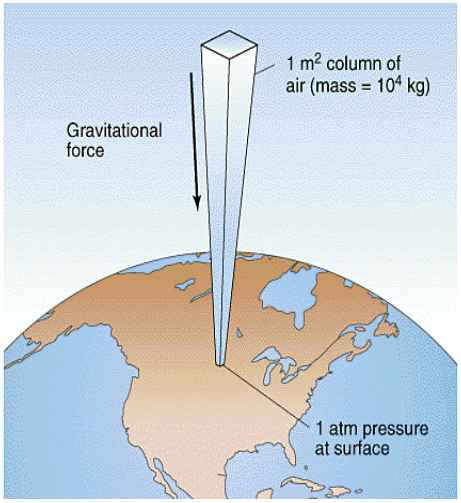
In Pisa he solved some of the great mathematical problems of the day, such as finding a cycloid's area and center of gravity.

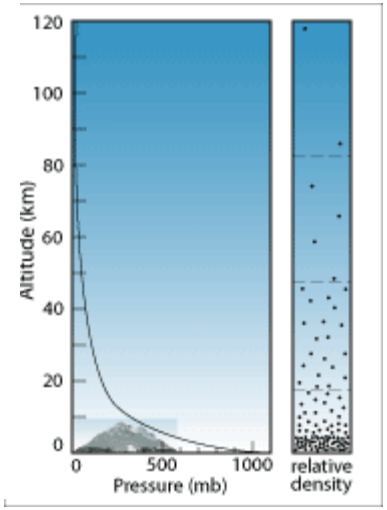
Torricelli

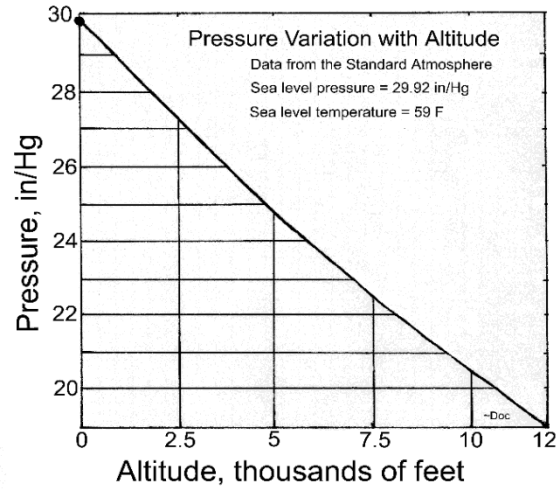
- He also designed and built a number of telescopes and simple microscopes; several large lenses, engraved with his name, are still preserved at Florence.

- In 1644, he famously wrote in a letter:

  "We live submerged at the bottom of an ocean of air."







Torricelli died in Florence a few days after having contracted typhoid fever, and was buried in San Lorenzo. An asteroid was named in his honor.

Torricelli's statue in the Museo di Storia Naturale di Firenze.


3

Measuring the “weight of the atmosphere”

- Galileo was the first to record that miners told him that it was impossible to raise water more than about 30 feet by “suction”. He thought that “the force of vacuum” was responsible for the suction effect.

- His student, Torricelli, however, argued that it was “the weight of the atmosphere” that supported the column of mercury. He said that the mercury would only rise to a little over 30 inches.

- Using Galileo’s value for the density of air, Torricelli estimated the height of the atmosphere.

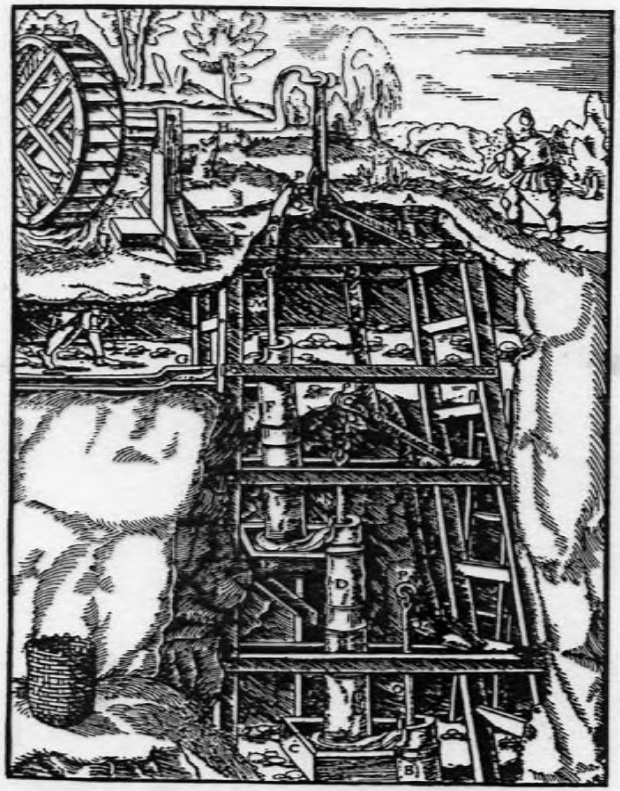
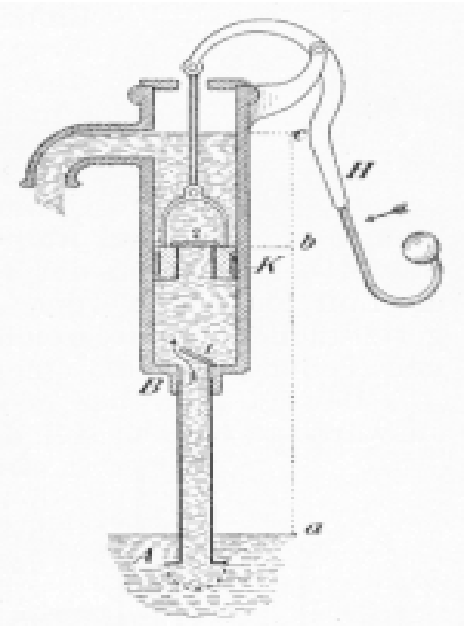


Figure 2-4. An illustration from Agricola's sixteenth-century book on mining, showing the use of pumps for removing water from mines.

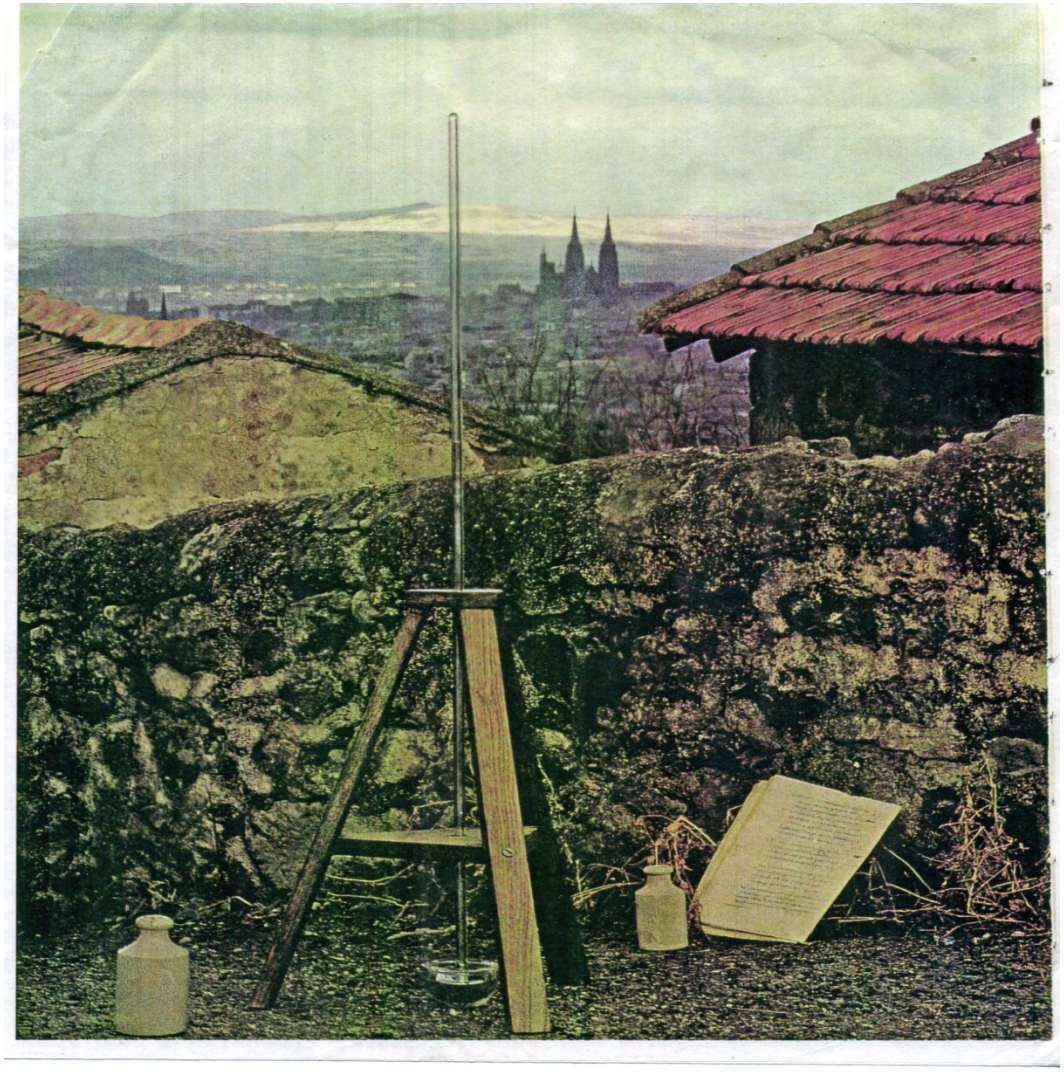
The Torricellian Experiment 31

Measuring the “weight of the atmosphere”

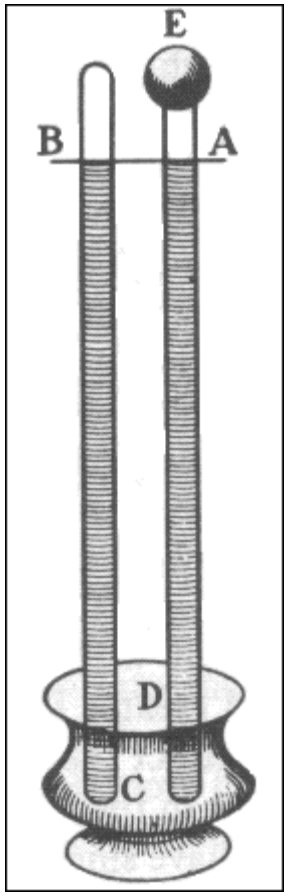
- **The phenomenon of siphoning**
- **Problem of drainage of mines**
- **Development of pumps to raise water**
- **Aristotle law: “Nature abhors vacuum”.**
- **Pascal’ law : “Nature abhors vacuum but only up to 30 feet”.**
- **Stinner’s law: “Nature does not suck”.**

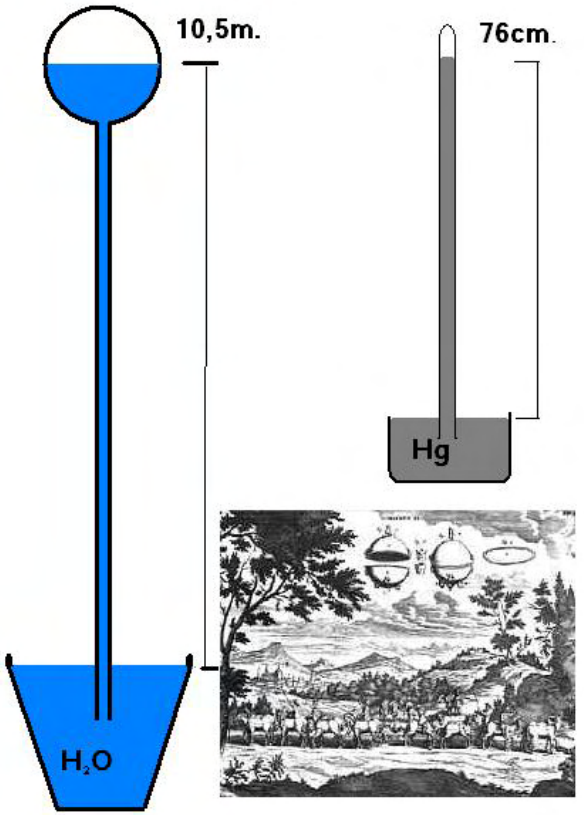


The Torricelli experiment

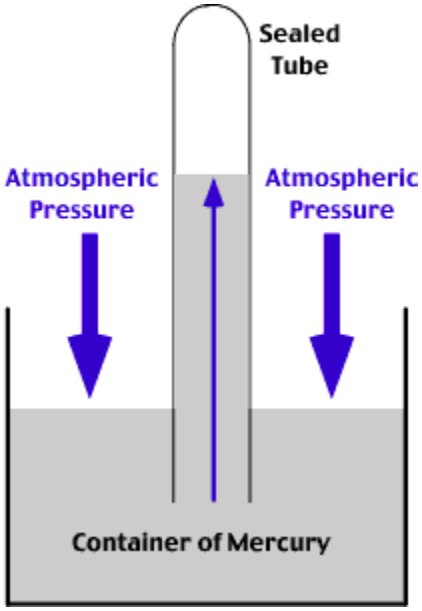


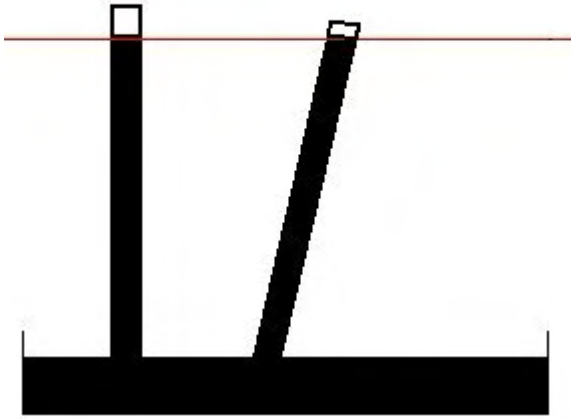
The Torricelli experiment





The Torricelli experiment





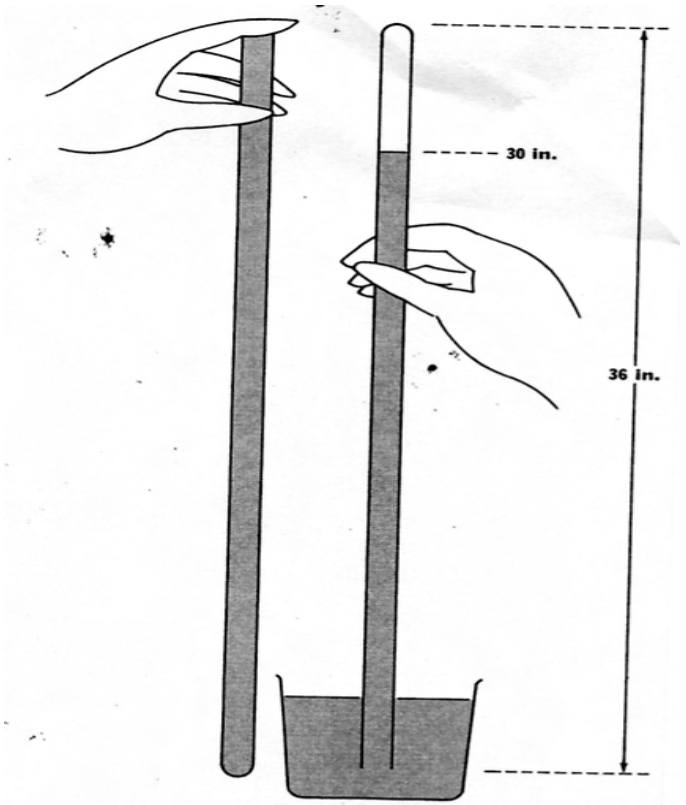


Figure 2-5. In the Torricellian experiment, the tube is completely filled with mercury. The open end is sealed with a finger and the tube is inverted and placed with the "open" end in a dish of mercury. When the finger is removed, the mercury drops until the column is about 30 inches high.

The Torricelli experiment

- In Paris, Pascal finds out about these calculations and was very impressed.
- Pascal then asked his brother-in-law, Monsier Perier, to take a tube of mercury up the Puy-de-Dome and make measurements of the height of mercury in the tube.
- The results of the controlled experiment confirmed Torricelli's hypothesis.

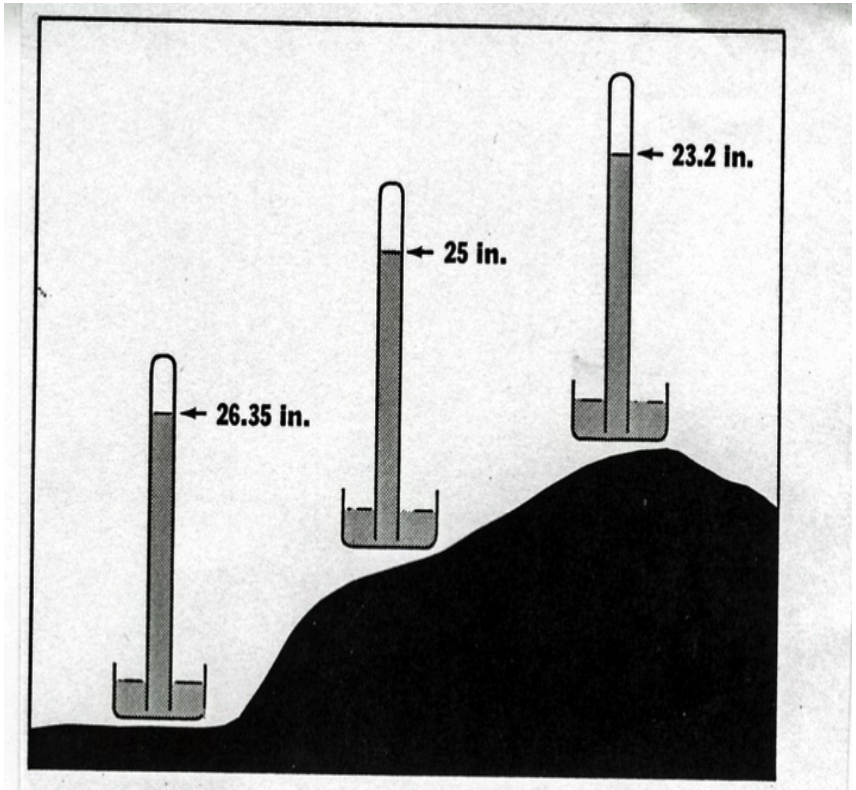


Figure 2-6. Diagram of Monsieur Perier's experimental findings.

f the Great Experiment on the Weight of the Mass of Air **3**

What did Torricelli's contemporaries say?

	YES	NO
Does air pressure hold the mercury up?	Descartes Pascal	Aristotelians Roberval
Is there a vacuum above the mercury?	Pascal Roberval Boyle	Descartes Aristotelians Galileo Hobbes

Table 1 Seventeenth-century Opinions on Air Pressure and the Vacuum

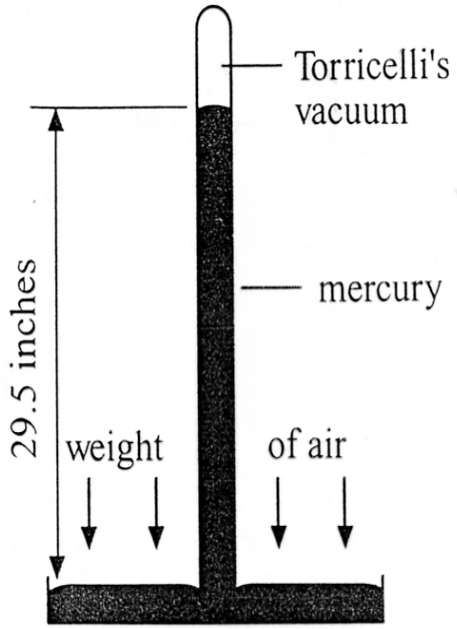
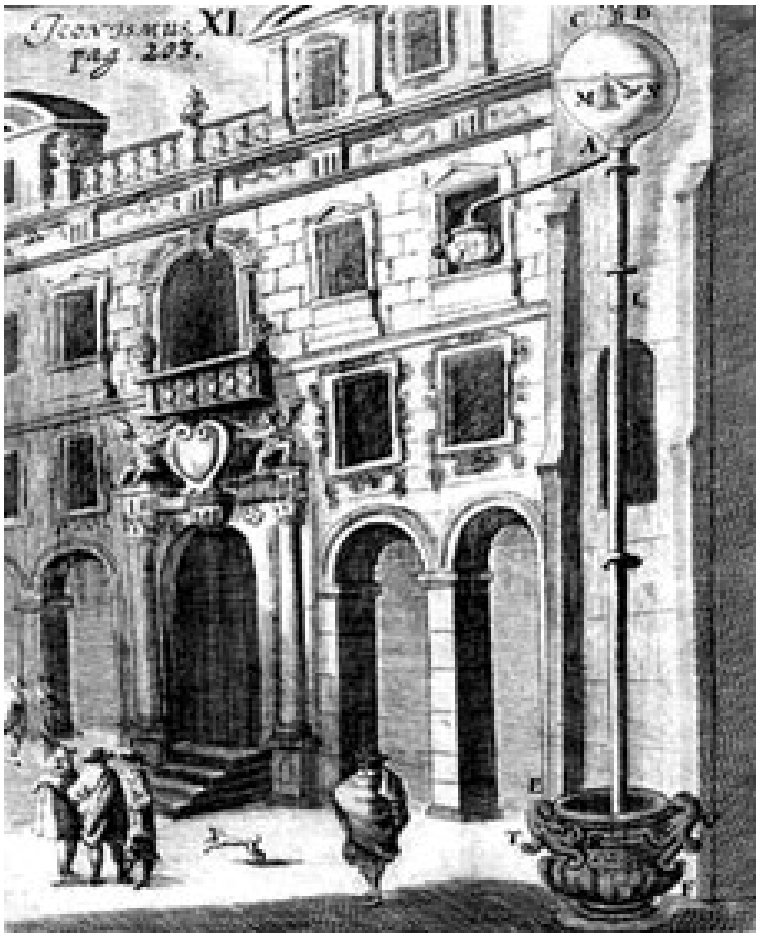


FIG.1 Torricelli's Barometer

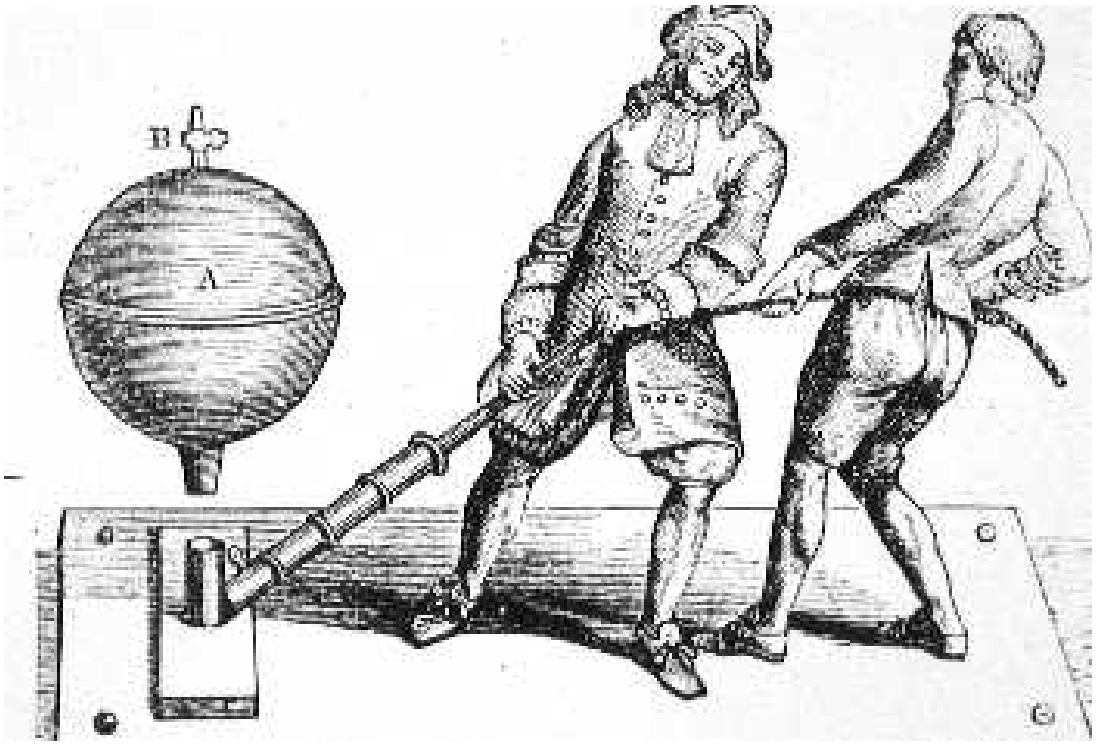
1) What holds the column of mercury up?
2) Is there anything in the space above the mercury in the column?

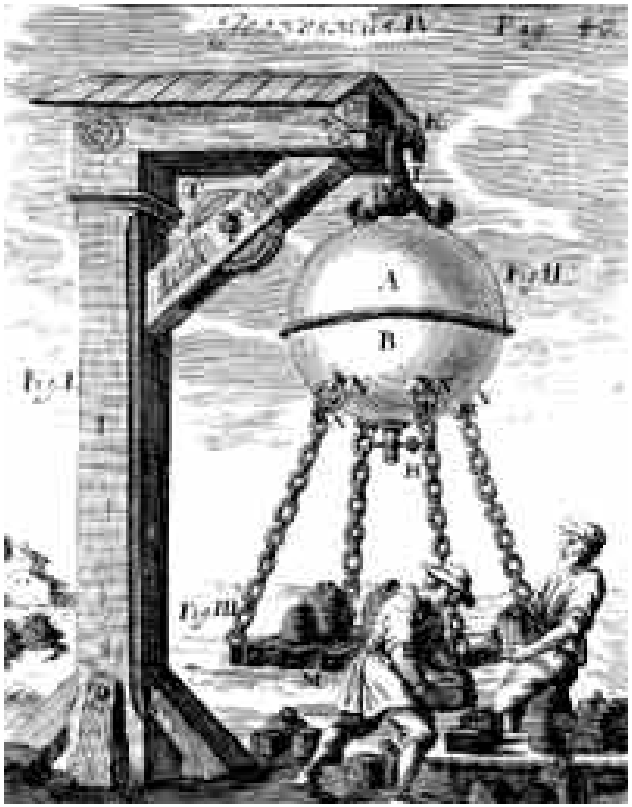
First sustained vacuum, created by means of an 11 m. high column of water. Demo in Rome, 1664

Vacuum by means of a mercury column. Florence, 1644.



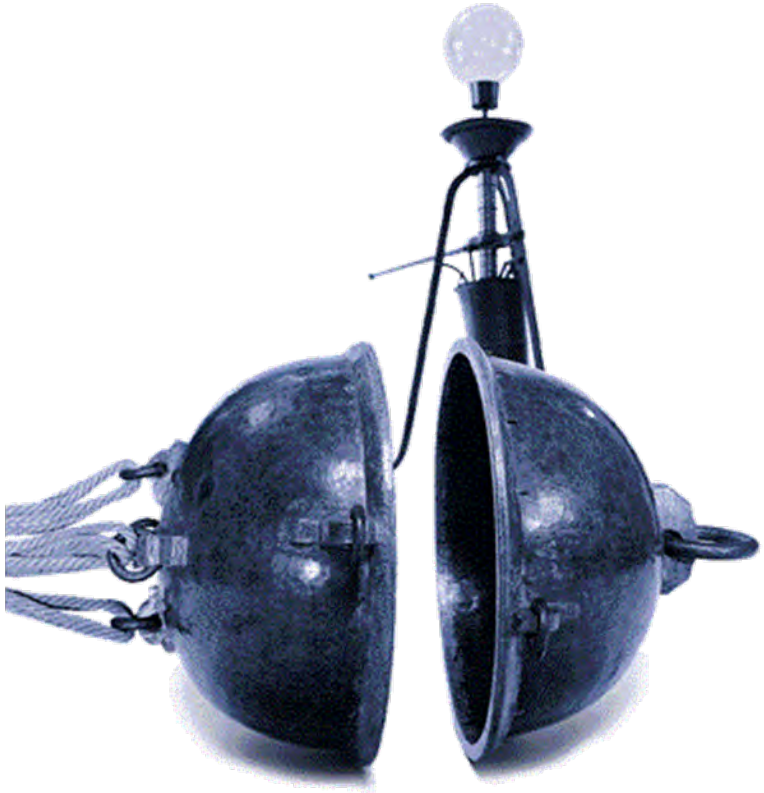
Creating a “vacuum”





Guericke's "Halbkugel" in the Deutsches Museum

Guericke's hemispheres: about 36 cm in diameter



Torricelli triumphs

- Two copper bowls would be joined to form a hollow sphere. After the air was removed from this sphere, two teams of horses were hitched to pull on the two bowls in order to separate them – which they would fail to do. When air was again allowed into the sphere, the bowls would come apart by themselves.

Torricelli triumphs

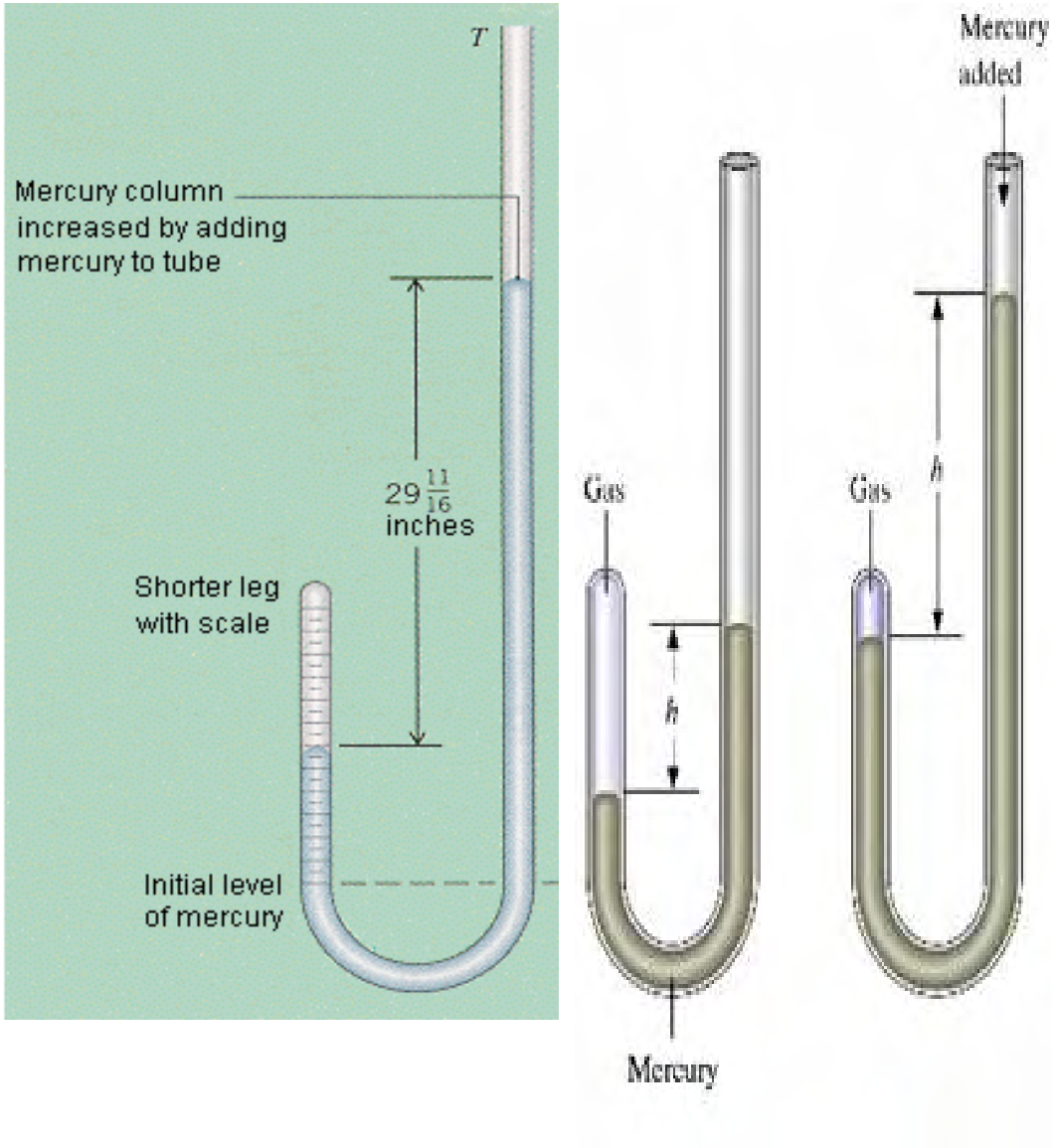
Re-enactment of Von Guericke's performance (April 25, 2004, Ulman, Missouri).

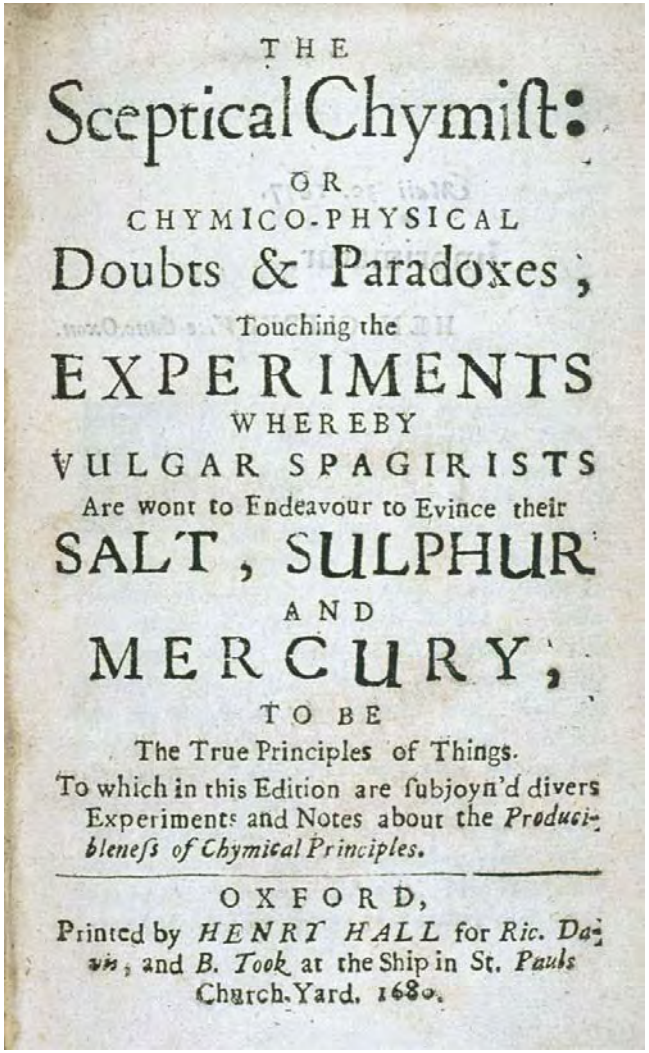
- Robert Boyle also investigated whether small animals survive in a vacuum, with very clear negative results.

- Boyle's experiment became part of the standard repertoire of the eighteenth-century "travelling scientists".

- A home theatre performance of this sort is shown on this famous picture by Joseph Wright of Derby ("An Experiment on a Bird in the Air Pump", 1768).

Boyle's experiment




THE
Sceptical Chymist:
OR
CHYMICO-PHYSICAL
Doubts & Paradoxes,
Touching the
EXPERIMENTS
WHEREBY
VULGAR SPAGIRISTS
Are wont to Endeavour to Evince their
SALT, SULPHUR
AND
MERCURY,
TO BE
The True Principles of Things.
To which in this Edition are subjoyn'd divers Experiments and Notes about the *Producibleness of Chymical Principles.*
OXFORD,
Printed by *HENRY HALL* for *Ric. Davis*, and *B. Took* at the Ship in St. *Pauls* Church-Yard. 1680.

Boyle's experimental notes

A table of the condensation of the air.

A	*A*	*B*	*C*	*D*	*E*
48	12	00	Added to 111 makes	29 1/8	29 1/8
46	11 3/4	01 1/12		30 2/12	33 4/12
44	11	02 11/12		31 10/12	31 10/12
42	10 1/2	04 2/12		33 2/12	33 1/2
40	10	06 4/8		35 1/8	35 - -
38	9 1/2	07 6/8		37	36 11/12
36	9	10 1/12		39 1/8	38 1/2
34	8 1/2	12 2/12		41 10/12	41 1/12
32	8	15 1/12		44 1/8	43 4/8
30	7 1/2	17 11/12		47 1/8	46 1/2
28	7	21 1/8		50 1/8	50 - -
26	6 1/2	25 1/8		54 1/8	53 10/12
24	6	29 11/12		58 10/12	58 1/2
23	5 1/2	32 2/8		61 2/8	60 11/12
22	5 1/2	34 11/12		64 1/8	63 1/2
21	5 1/2	37 2/8		67 1/8	66 1/2
20	5	41 2/8		70 10/12	70 - -
19	4 1/2	45 - -		74 1/8	73 10/12
18	4 1/2	48 11/12		77 10/12	77 1/2
17	4 1/2	53 1/12		82 1/12	82 1/12
16	4	58 1/8		87 1/8	87 1/2
15	3 1/2	63 1/12		92 1/12	93 1/2
14	3 1/2	72 1/8		100 1/8	99 1/2
13	3 1/2	78 1/12		107 1/12	107 1/2
12	3	88 1/12		117 1/12	116 1/2

AA. The number of equal spaces in the shorter leg, that contained the same parcel of air diversly extended.

B. The height of the mercurial cylinder in the longer leg, that compressed the air into those dimensions.

C. The height of the mercurial cylinder, that counterbalanced the pressure of the atmosphere.

D. The aggregate of the two last columns *B* and *C*, exhibiting the pressure sustained by the included air.

E. What that pressure should be according to the hypothesis, that supposes the pressures and expansions to be in reciprocal proportion.

For the better understanding of this experiment, it may not be amiss to take notice of the following particulars:

1. That the tube being so tall, that we could not conveniently make use of it in a chamber, we were fain to use it on a pair of stairs, which yet were very lightsome, the tube being for preservation's sake by strings so suspended, that it did scarce touch the box presently to be mentioned.

2. That lower and crooked part of the pipe was placed in a square wooden box, of a good largeness and depth, to prevent the loss of the quicksilver, that might fall aside in the transfusion from the vessel into the pipe, and to receive the whole quicksilver in case the tube should break.

3. That we were two to make the observation together, the one to take notice at the bottom, how the quicksilver rose in the shorter cylinder, and the other to pour in at the top of the longer; it being very hard and troublesome for one man alone to do both accurately.

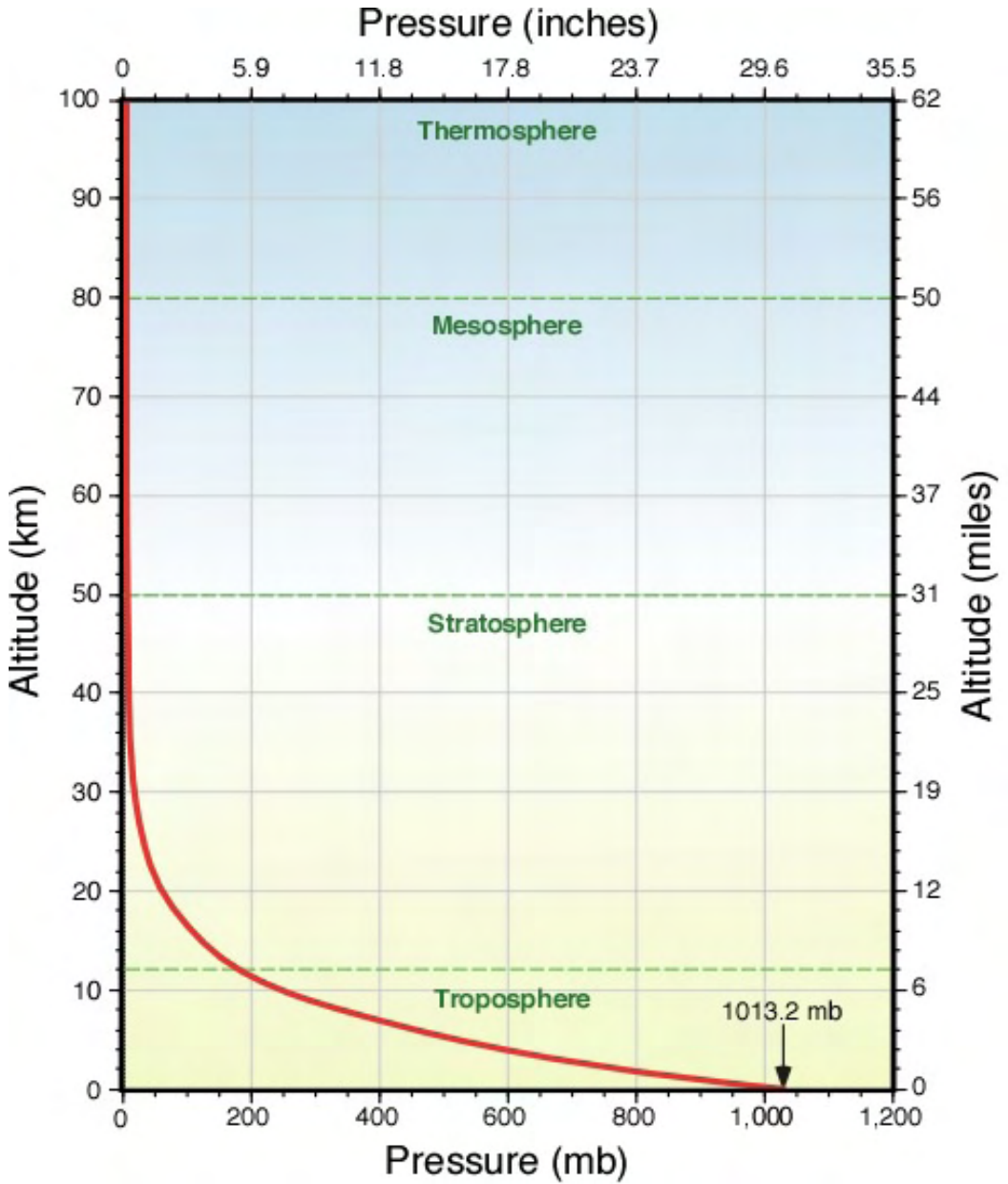
4. That the quicksilver was poured in but by little and little, according to the direction of him that observed below; it being far easier to pour in more, than to take out any, in case too much at once had been poured in.

5. That

Atmospheric pressure

Change in average atmospheric pressure

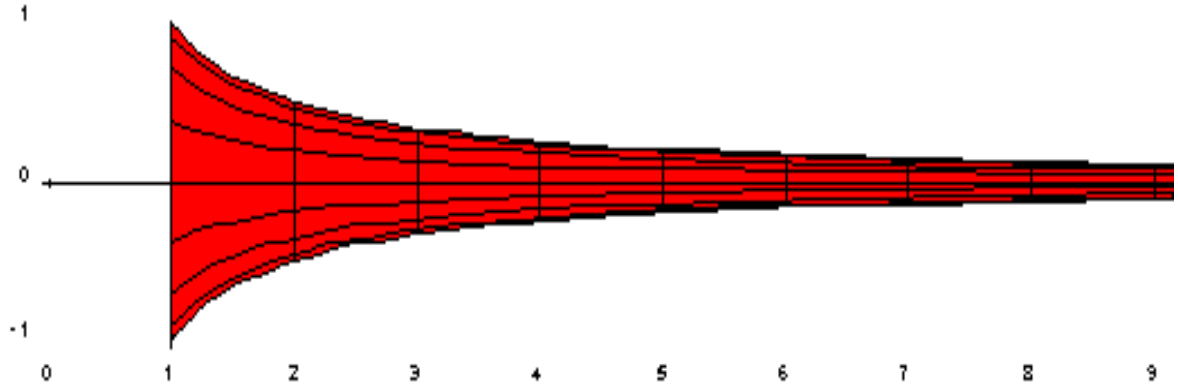
with altitude.



Torricelli’s Paradox

Gabriel's Horn (also called **Torricelli's trumpet**) is a figure invented by Evangelista Torricelli which has infinite surface area, but finite volume.

The name refers to the tradition identifying the archangel Gabriel with the angel who blows the horn to announce Judgement Day, associating the infinite with the divine.



Modern use of mercury

Testing atmospheric pressure in Turkey

We tested Torricelli's "Weight of the atmosphere", descending from the observatory.

Arthur Stinner and Michael Eckert of the Deutsches Museum, Munich. Braving cold winds when climbing to the Bakirliteppe observatory.