# Evangelista Torricelli | Encyclopedia.com

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(*b*. Faenza, Italy, 15 October 1608; *d*. Florence, Italy, 25 October 1647)

*mathematics, physics*.

Eldest of the three children of Gaspare Torricelli and the former Caterina Angetti, Torricelli soon demonstrated unusual talents. His father, a textile artisan in modest circumstances, sent the boy to his uncle, the Camaldolese monk Jacopo (formerly Alessandro), who supervised his humanistic education. In 1625 and 1626 Torricelli attended the mathematics and philosophy courses of the Jesuit school at Faenza, showing such outstanding aptitude that his uncle was persuaded to send him to Rome for further education at the school run by Benedetto Castelli, a member of his order who was a mathematician and hydraulic engineer, and a former pupil of Galileo's. Castelli took a great liking to the youth, realized his exceptional genius, and engaged him as his secretary.

We have direct evidence on the scope and trend of Torricelli's scientific studies during his stay at Rome in the first letter (11 September 1632) of his surviving correspondence, addressed to Galileo on behalf of Castelli, who was away from Rome. In acknowledging receipt of a letter from Galileo to Castelli, Torricelli seized the opportunity to introduce himself as a mathematician by profession, well versed in the geometry of Apollonius, Archimedes, and Theodosius; he added that he had studied Ptolemy and had seen "nearly everything" by Brahe, Kepler, and Longomontanus. These studies had compelled him to accept the Copernican doctrine and to become "a Galileist by profession and sect"; he had been the first in Rome to make a careful study of Galileo's *Dialogo sopra i due massimi sistemi*, published in February of that year (1632).

After this letter there is a gap in the correspondence until 1640, and it is not known where Torricelli lived or what he did during this period. The most likely hypothesis so far advanced is that from the spring of 1630 to February 1641, he was secretary to Monsignor Giovanni Ciampoli, Galileo's friend and protector, who from 1632 was governor of various cities in the Marches and Umbria (Montalto, Norcia, San Severino, Fabriano). In 1641 Torricelli was again in Rome; he had asked Castelli and other mathematicians for their opinions of a treatise on motion that amplified the doctrine on the motion of projectiles that Galileo had expounded in the third day of the *Discorsi e dimostrazioni matematiche intorno a due nuove scienze* . . . (Leiden, 1638). Castelli considered the work excellent; told Galileo about it; and in April 1641, on his way from Rome to Venice through Pisa and Florence, after appointing Torricelli to give lectures in his absence, submitted the manuscript to Galileo, proposing that the latter should accept Torricelli as assistant in drawing up the two "days" he was thinking of adding to the *Discorsi*. Galileo agreed and invited Torricelli to join him at Arcetri.

But Castelli's delay in returning to Rome and the death of Torricelli's mother, who had moved to Rome with her other children, compelled Torricelli to postpone his arrival at Arcetri until 10 October 1641. He took up residence in Galileo's house, where Vincenzo Viviani was already living, and stayed there in close friendship with Galileo until the latter's death on 8 January 1642. While Torricelli was preparing to return to Rome, Grand Duke Ferdinando II of Tuscany, at Andrea Arrighetti's suggestion, appointed him mathematician and philosopher, the post left vacant by Galileo, with a good salary and lodging in the Medici palace.

Torricelli remained in Florence until his death; these years, the happiest of his life, were filled with the greatest scientific activity. Esteemed for his polished, brilliant, and witty conversation, he soon formed friendships with the outstanding representatives of Florentine culture; the painter Salvatore Rosa, the Hellenist Carlo Dati, and the hydraulic engineer Andrea Arrighetti. In fact, the regular meetings with these friends gave rise to the "Accademia dei Percossi," to whom Torricelli apparently divulged the comedies he was writing, which have not survived but were explicitly mentioned in the memoirs dictated on his deathbed to Lodovico Serenai (*Opere*, **IV** ,88).

In 1644 Torricelli's only work to be published during his lifetime appeared, the grand duke having assumed all printing costs. The volume, *Opera geometrica*, was divided into three sections: the first dealt with *De sphaera et solidis sphaeralibus libri duo*; the second contained *De motu gravium naturaliter descendentium et proiectorum* (the writing submitted to Galileo for his opinion); and the third section consisted of *De dimensione parabolae*. The work, soon known throughout Italy and Europe, had intrinsic value and, through its clear exposition, diffused the geometry of Cavalieri, whose writings were difficult to read.

The fame that Torricelli acquired as a geometer increased his correspondence with Italian scientists and with a number of French scholars (Carcavi, Mersenne, F. Du Verdus, Roberval), to whom he was introduced by F. Niceron, whom he met while in Rome. The correspondence was the means of communicating Torricelli's greatest scientific discoveries but also the occasion for fierce arguments on priority, which were common during that century. There were particularly serious polemics with Roberval over the priority of discovery of certain properties of the cycloid, including quadrature, center of gravity, and measurement of the solid generated by its rotation round the base. In order to defend his rights, Torricelli formed the intention of publishing all his correspondence with the French mathematicians, and in 1646 he began drafting *Racconto d'alcuni problemi proposti e passati tra gli matematici di Francia et il Torricelli ne i quattro anni prossimamente passati* (*Opere*, III, 1-32). But while he was engaged in this work he died of a violent illness (probably typhoid fever) lasting only a few days. In accordance with his wish he was buried in the Church of San Lorenzo in Florence, but the location of his tomb is unknown.

Mathematical research occupied Torricelli's entire life. During his youth he had studied the classics of Greek geometry, which dealt with infinitesimal questions by the method of progressive elimination. But since the beginning of the seventeenth century the classical method had often been replaced by more intuitive processes; the first examples were given by Kepler, who in determining areas and volumes abandoned Archimedean methods in favor of more expeditious processes differing from problem to problem and hence difficult to imitate. After many years of meditation, Cavalieri, in his geometry of indivisibles (1635), drew attention to an organic process, toward which Roberval, Fermat, and Descartes had been moving almost in the same year; the coincidence shows that the time was ripe for new geometrical approaches.

The new geometry considered every plane figure as being formed by an infinity of chords intercepted within the figure by a system of parallel straight lines; every chord was then considered as a rectangle of infinitesimal thickness—the indivisible, according to the term introduced by Galileo. From the assumed or verified relations between the indivisibles it was possible to deduce the relations between the totalities through Cavalieri's principle, which may be stated as follows: Given two plane figures comprised between parallel straight lines, if all the straight lines parallel thereto determine in the two figures segments having a constant relation, then the areas of the two figures also have the same relation. The principle is easily extended to solid figures. In essence Cavalieri's geometry, the first step toward infinitesimal calculus, replaced the potential mathematical infinity and infinitesimal of the Greek geometricians with the present infinity and infinitesimal.

After overcoming his initial mistrust of the new method, Torricelli used it as a heuristic instrument for the discovery of new propositions, which he then demonstrated by the classical methods. The promiscuous use of the two methods—that of indivisibles for discovery and the Archimedean process for demonstration—is very frequent in the *Opera geometrica*. The first part of *De sphaera et solidis sphaeralibus*, compiled around 1641, studies figures arising through rotation of a regular polygon inscribed in or circumscribed about a circle around one of its axes of symmetry (already mentioned by Archimedes). Torricelli observes that if the regular polygon has equal sides; one of its axes of symmetry joins two opposite vertices or the midpoints of two opposite sides; if, on the other hand, it does not have equal sides, one of its axes of symmetry joins a vertex with the midpoint of the opposite side. On the basis of this observation he classifies such rotation solids into six kinds, studies their properties, and presents some new propositions and new metrical relations for the round bodies of elementary geometry. The second section of the volume deals with the motion of projectiles, about which more will be said later.

In the third section, apart from giving twenty demonstrations of Archimedes' theorem on squaring the parabola, but without adding anything new of importance, Torricelli shows that the area comprised between the cycloid and its base is equal to three times the area of the generating circle. As an appendix to this part of the work there is a study of the volume generated by a plane area animated by a helicoid motion round an axis of its plane, with the demonstration that it equals the volume generated by the area in a complete rotation round the same axis. Torricelli applies this elegant theorem to various problems and in particular to the surface of a screw with a square thread, which he shows to be equal to a convenient part of a paraboloid with one pitch.

As Torricelli acquired increasing familiarity with the method of indivisibles, he reached the point of surpassing the master—as Cavalieri himself said. In fact he extended the theory by using curved indivisibles, based on the following fundamental concept: In order to allow comparison of two plane figures, the first is cut by a system of curves and the second by a system of parallel straight lines; if each curved indivisible of the first is equal to the corresponding indivisible of the second, the two figures are equal in area. The simplest example is given by comparison of a circle divided into infinitesimal concentric rings with a triangle (having the rectified circumference as base and the radius as height) divided into infinitesimal strips parallel to the base. From the equality of the rings to the corresponding strips it is concluded that the area of the circle is equal to the area of the triangle.

The principle is also extended to solid figures. Torricelli gave the most brilliant application of it in 1641 by proving a new theorem, a gem of the mathematical literature of the time. The theorem, published in *Opera geometrica*, is as follows (*Opere*, 1, 191–213): take any point of an equilateral hyperbola (having the equation $xy = 1$) and take the area comprised by the unlimited section of the hyperbola of asymptote $x$, asymptote $x$, and the ordinate of the point selected. Although such area is infinite in size, the solid it generates by rotating round the asymptote, although unlimited in extent, nevertheless has a finite volume, calculated by Torricelli as $\pi/a$, where $a$ is the abscissa of the point taken on the hyperbola.

Torricelli's proof, greatly admired by Cavalieri and imitated by Fermat, consists in supposing the solid generated by rotation to be composed of an infinite number of cylindrical surfaces of axis $x$, all having an equal lateral area, all placed in biunivocal correspondence with the sections of a suitable cylinder, and all equal to the surfaces of that cylinder: the principle of curved indivisibles allows the conclusion that the volume of this cylinder is equal to the volume of the solid generated by rotation of the section of the hyperbola considered. In modern terms Torricell's process is described by saying that an integral in Cartesian coordinates is replaced by an integral in cylindrical coordinates. Still using curved indivisibles, Torricelli found, among other things, the volume of the solid limited by two plane surfaces and by any lateral surface, in particular the volume of barrels. In 1643 the results were communicated to Fermat, Descartes, and Roberval, who found them very elegant and correct.

The example of the hyperbola induced Torricelli to study more general curves, defined today by equations having the form $x^m y^n = C^n$, with $m$ and $n$ positive whole numbers and $m \neq n$. He discovered that their revolution round an asymptote could generate an infinitely long solid with finite volume and that, under particular conditions, the area comprised between the asymptote and the curve could also be finite. Torricelli intended to coordinate all these results, communicated by letter to various mathematicians in 1646 and 1647, in a single work entitled *De infinitis hyperbolis*, but he died before it could be completed. Only after publication of the *Opere* was it possible to reconstruct the paper from scattered notes.

The geometry of indivisibles was also applied by Torricelli to the determination of the center of gravity of figures. In a letter to Michelangelo Ricci dated 7 April 1646, he communicated the "universal theorem," still considered the most general possible even today, which allows determination of the center of gravity of any figure through the relation between two integrals. Among particular cases mention should be made of the determination of the center of gravity of a circular sector, obtained both by the classic procedure and by the method of indivisibles. Torricelli arrived at the same result, perhaps known to him, that Charles de La Faille had reached in 1632.

Torricelli also directed his attention to rectification of arcs of a curve, which Descrates in his *Géométrie* of 1637 had declared to be impossible, after having learned from Mersenne that Roberval had demonstrated the equality of length of particular arcs of a parabola and of arcs of an Archimedean spiral. Having conceived the logarithmic spiral, which he termed "geometric," he taught a procedure allowing rectification with ruler and compass of the entire section comprised between any point on the curve and the center, to which the curve tends after an infinite number of revolutions. Torricelli further demonstrated that any Archimedean spiral-or "arithmetic spiral," as he called it-can always be made equal to any particular arc of a suitable parabolic curve.

In addition to these contributions to the integral calculus, Torricelli discovered many relationships of differential calculus. Among the applications he made to the concept of derivative, drawn from the doctrine of motion (see below), mention should be made of his research on maxima and minima. He showed that if the sum $x + y$ is constant, the product $x^m y^n$ is maximum if $x$ $y$ have the same relation as the exponents. He also determined the point still known as Trorricelli's point on the plane of a triangle for which the sum of the distances from the vertices is minimum: the problem had been proposed by Fermat.

Torricelli made other important contributions to mathematics during his studies of mechanics. In *De motu gravium* he continued the study of the parabolic motion of projectiles, begun by Galileo, and observed that if the acceleratory force were to cease at any point of the trajectory, the projectile would move in the direction of the tangent to the trajectory. He made use of this observation, earring Galileo's congratulations, to draw the tangent at a point of the Archimedean spiral, or the cycloid, considering the curves as described by a point endowed with two simultaneous motions. In unpublished notes the question is thoroughly studied in more general treatment. A point is considered that is endowed with two simultaneous motions, one uniform and the other varying, directed along two straight lines perpendicular to each other. After constructing the curve for distance as a function of time, Torricelli shows that the tangent at any point of the curve forms with the time axis an angle the tangent of which measures the speed of that moving object at the point. In substance this recognizes the inverse character of the operations of intergration and differentiation, which from the fundamental theorem of the calculus, published in 1670 by Isaac Barrow, who among his predecessors mentioned Galileo, Cavalieri, and Torricelli. But not even Barrow understood the importance of the theorem, which was first demonstrated by Newton.

Full mastery of the new geometrical methods made Torricelli aware of the inherent dangers, so that his manuscripts contain passages against infinities. His unpublished writings, in fact, include a collection of paradoxes to which the doctrine of indivisibles leads when not applied with the necessary precautions.

In *De motu gravium* Torricelli seeks to demonstrate Galileo's principle regarding equal velocities of free fall of weights along inclined planes of equal height. He bases his demonstration on another principle, now called Torricelli's principle but known to Galileo, according to which a rigid system of a number of bodies can move spontaneously on the earth's surface only if its center of gravity descends. After applying the principle to movement through chords of a circle and parabola, Torricelli turns to the motion of projectiles and, generalizing Galileo's doctrine, considers launching at any oblique angle—whereas Galileo had considered horizontal launching only. He demonstrates in general from Galileo's incidental observation that if at any point of the trajectory a projectile is relaunched in the opposite direction at a speed equal to that which it had at such point, the projectile will follow the same trajectory in the reverse direction. The proposition is equivalent to saying that dynamic phenomena are reversible—that the time of Galileo's mechanics is ordered but without direction. Among the many theorems of external ballistics, Torricelli shows that the parabolas corresponding to a given initial speed and to different inclinations are all tangents to the same parabola (known as the safety parabola or Torricelli's parabola, the first example of an envelope curve of a family of curves).

The treatise concludes with five numerical tables. The first four are trigonometric tables giving the values of sine $2\alpha$, sine$^2\alpha$, ½tan $\alpha$, and sine $\alpha$, respectively, for every degree between 0° and 90°; with these tables, when the initial speed and angle of fire are known, all the other elements characteristic of the trajectory can be calculated. The fifth table gives the angle of inclination, when the distance to which the projectile is to be launched and the maximum range of the weapon are known. In the final analysis these are firing tables, the practical value of which is emphasized by the description of their use in Italian, easier than Latin for atillerymen to understand. Italian is also the language used for the concluding description of a new square that made it easier for gunners to calculate elevation of the weapon.

The treatise also refers to the movement of water in a paragraph so important that Ernst Mach proclaimed Torricelli the founder of hydrodynamics. Torricelli's aim was to determine the efflux velocity of a jet of liquid spurting from a small orifice in the bottom of a receptacle. Through experiment he had noted that if the liquid was made to spurt upward, the jet reached a height less than the level of the liquid in the receptacle. He supposed, therefore, that if all the resistances to motion were nil, the jet would reach the level of the liquid. From this hypothesis, equivalent to a conservation principle, he deduced the theorem that bears his name: The velocity of the jet at the point of efflux is equal to that which a single drop of the liquid would have if it could fall freely in a vacuum from the level of the top of the liquid at the orifice of efflux. Torricelli also showed that if the hole is made in a wall of the receptacle, the jet of fluid will be parabolic in form; he then ended the paragraph with interesting observations on the breaking of the fluid stream into drops and on the effects of air resistance. Torricelli's skill in hydraulics was so well known to his contemporaries that he was approached for advice on freeing the Val di Chiana from stagnant waters, and he suggested the method of reclamation by filling.

Torricelli is often credited—although the idea is sometimes attributed to the Grand Duke Ferdinando II—with having converted Galileo's primitive air thermoscope to a liquid thermometer, at first filled with water and later with spirits of wine. On the other hand, there is very good evidence of his technical ability in working telescope lenses, a skill almost certainly acquired during his stay in Florence. By the autumn of 1642 he was already capable of making lenses that were in no way mediocre, although they did not attain the excellence of those made by Francesco Fontana, at that time the most renowned Italian telescope maker. Torricelli had set out to emulate and surpass Fontana. By 1643 he was already able to obtain lenses equal to Fontana's or perhaps even better, but above all he had come to understand that what is really important for the efficiency of a lens is the perfectly spherical machining of the surface, which he carried out with with refined techniques. The efficiency of Torricelli's lenses was recognized by the grand duke, who in 1644 presented Torricelli with a gold necklace bearing a medal with the motto "Virtutis praemia."

The fame of Torricelli's excellent lenses quickly became widespread and he received many requests, which he fulfilled at a good profit. He attributed the efficiency of telescopes fitted with his lenses to a machining process that was kept secret at the time but was described in certain papers passed at Torricelli's death to the grand duke, who gave them to Viviani, after which they were lost. An elaborate story has sometimes been woven round this "secret" but from the surviving documents it seems possible to reconstruct the whole of Torricelli's "secret" — which, apart from the need to enhance the merits of his production in the grand duke's eyes, consisted mainly in very accurate machining of the surfaces, in selecting good quality glass, and in not fastening the lenses "with pitch, or in any way with fire," But this last precaution—which, according to Torricelli, was known only to God and himself—had been recommended by Hireonymus Sirturi in his *Telescopium* as far back as 1618. In any event, one of Torricelli's telescope lenses, which is now preserved together with other relics at the Museo di Storia della Scienza, Florence, was examined in 1924 by Vasco Ronchi, using the diffraction grating. It was found to be of exquisite workmanship, so much so that one face was seen to have been machined better than the mirror taken as reference surface, and was constructed with the most advanced technique of the period.

The lectures given by Torricelli on various occasions, and collected by Tommaso Bonaventuri in the posthumous volume *Lezioni accademiche*. were by preference on subjects in physics. They include eight lectures to the Accademia della Crusca, of which he was a member (one lecture of thanks for admission to the academy, three on the force of impact, two on lightness, one on wind, and one on fame): one in praise of mathematics, given to the Studio Fiorentino; two on military architecture at the Academy of Drawing, and one of encomium for the "golden century," the fabled epoch of human perfection, delivered to the "Accademia dei Percossi."

From the point of view of physics, the lectures on the force of impact and on wind are of particular interest. In the former he said that he was reporting ideas expressed by Galileo in their informal conversations, and there is no lack of original observations. For example, the assertion that "forces and impetus" (what we call energy) lie in bodies was interpreted by Maxwell in the last paragraph of *A Treatise on Electricity and Magnetism* (1873) as meaning that the propagation of energy is a mediate and not remote action. In the lecture on wind Torricelli refuted the current theory on the formation of wind, which was held to be generated by vaporous exhalations evaporating from the damp earth; on the other hand, he advanced the modern theory that winds are produced by differences of air temperature, and hence of density, between two regions of the earth.

But Torricelli's name is linked above all to the barometric experiment named after him. The argument on vacuum or fullness goes back to the first Greek philosophical schools. In the Middle Ages, Catholic theology replaced Aristotle's doctrine that a vacuum is a contradiction in logic by the concept that nature abhors a vacuum (*horror vavui*) During the Renaissance the argument between supporters of vacuum and those of fullness flared up again. Galileo, joining the rationalist philosophers Telesio and Bruno, opposed Aristotle's arguments against the vacuum and about 1613 experimentally demonstrated the weight of air. But like the majority of his contemporaries, he believed that an element does not have weight in itself; hence, on the basis of the ascertained weight of air, he was unable to deduce pressures within atmospheric air. To explain the phenomenon that in suction pumps the water does not rise more than eighteen *braccia* (about nine meters), as observed by the Florentine well diggers, Galileo advanced the hypothesis of a force—the "force of vacuum" —that occurred inside the pump and was capable of balancing a column of water eighteen *braccia* high.

In 1630, when Giovanni Battista Baliani asked him why a siphon that was to cross a hill about twenty-one meters high did not work, Galileo replied by reiterating his theory of the force of vacuum. Baliani retorted that in his opinion the failure of the siphon was due to the weight of the air, which by pressing on all sides supported the column of water not under pressure in the top part of the siphon, from which the air had been expelled by the water poured in to fill it. But Galileo did not accept Baliani's ideas, and in the *Discorsi* (1638) he continued to uphold the theory of the force of vacuum. After Galileo's death the discussion continued between his followers in Rome and Florence; and it is probable that the former turned to Torricelli to get his opinion on the working of suction pumps or on a similar experiment that Gasparo Berti is said to have carried out at Rome in 1640 for the purpose of showing that the water in suction pumps rose to more than eighteen *braccia*.

Torricelli, who was perhaps acquainted with Baliani's concept, proceeded to repeat Berti's or Baliani's experiment, using progressively heavier liquids such as seawater, honey, and mercury, which was mined in Tuscany. The use of mercury also allowed him to simplify the filling process by replacing Baliani's or Berti's siphon with a simple glass tube about one meter long. He planned to fill it to the rim with mercury, to close it with one finger and overturn it, and to immerse the open end in mercury in a bowl. To make such a long tube capable of withstanding the weight of mercury was not an easy task at that time (only in 1646 was Mersenne able to obtain a sufficiently strong tube from the French glassworks); viviani to make one, and hence the later was the first to perform the experiment.

In a letter of 11 June 1644 to Michelangelo Ricci, Torricelli described the experiment and, rejecting the theory of the force of vacuum, interpreted it according to Baliani. But even before carrying out the experiment he was aware of the variations in atmospheric pressure, since in the letter he says that he "wished to make an instrument that would show the changes of air, now heavier and denser, now lighter and thinner." According to a fairly well founded hypothesis, he had acquired a knowledge of the variations in atmospheric pressure through skillful observation of the behavior of hydrostatic toys, perhaps invented by him and later called "Cartesian devils," According to Torricelli the force that supports the mercury column is not internal to the tube but external, produced by the atmosphere that weighs on the mercury in the bowl. If,instead of mercury, the tube had contained water, Torricelli predicted that the height of the column would have been greater by the proportion that the weight of mercury exceeds that of water, a result verified by Pascal in 1647. In confirmation of the hypothesis that the cause of support of the mercury is outside and not inside the tube, Torricelli describes other experiments with tubes blown into a sphere at the top, with which equal heights of the mercury column were obtained, so that the force was not due to the volume of vacuum produced and therefore was not a "force of vacuum."

In his reply to Torricelli's letter Ricci put forward three objections showing how difficult it was for contemporaries to understand the transmission of pressure in air: (1) If the bowl is closed with a lid, the air weighs on the lid and not on the mercury, which should therefore fall in the bowl; (2) The weight of the air acts in a vertical direction from top to bottom, so how can it be transmitted from bottom to top inside the tube? (3) Bodies immersed in a fluid are subject to Archimedes' thrust, so the mercury should be pushed upward by a force equivalent to an equal column of air. Torricelli replied in a letter of 28 June 1644, carefully refuting the objections as follows: (1) If the lid does not change the "degree of condensation" of the air locked between the lid itself and the mercury in the bowl, things remain as before–this is shown by the example of a wood cylinder loaded with a weight and cut crosswise by an iron plate, in which the lower part remains compressed as before; (2) Fluids gravitate downward by nature, but "push and spurt in all directions, even upward" (3)The mercury in the tube is not immersed in air. In substance Torriicelli's two letters elaborate the theory of atmospheric pressure, with a hint at what was to be Pascal's principle.

According to the writings of his contemporaries, Torricelli, after succeeding in the experiment, sought to observe the conditions of life of small animals (fish, flies, butterflies) introduced into the vaccum. The results obtained were almost nil, however, because the creatures were crushed by the weight of the mercury before reaching the top part of the tube: and attempts to ascertain whether sound is propagated in a vacuum also appear to have been unsuccessful. In testimony of his great appreciation Grand Duke Ferdinando II issued a decree prasing this experiment of Torricelli's very highly.

Copies of Torricelli's two letters were circulated among Italian scientists and were sent to Mersenne, who, traveling to Italy in October 1644, passed through Florence and obtained a repetition of the experiment from Torriecelli himself. On his return to France, he informed his friends of Torricelli's experiment giving rise to flourishing experimental and theoretical activity. Discovery of the barometer, Vincenzo Antinori wrote, changed the appearance of physics just as the telescope changed that of astronomy: the circulation of the blood, that of medicine; and Volta's pile, that of melecular physics.

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1813); and “sopra la bonificazione della Valle di Chiana,” in *Raccolta d' autori che trattano del moto delle acque*, IV (Florence, 1768). Other short writing were published in historical works, mentioned below.

The majority of Torricelli's MSS, after complicated vicissitudes and some losses, as recounted in the intro to the *Opere*, are preserved at the Biblioteca Nazionale Centrale, Florence: Angiolo Procissi, in *Evangelista Torricelli nel terzo centenario della morte* (Florenc, 1951), 77–109, gives an accurate catalogue raisonné The autograph works, except for one, and the souvenirs kept at the Torricelli Museum in Faenza were destroyed in 1944.

There are two oil portraits of Torricelli in the Uffizi Gallery in Florence; another portrait, engraved by Pietro Anichini, is reproduced on the frontispiece of the *Lezioni accademiche*.

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