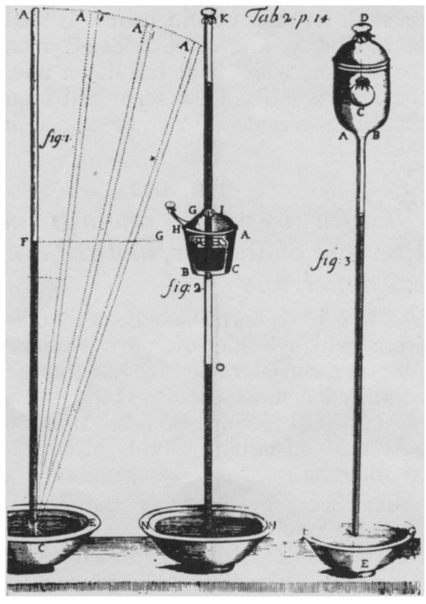
CLASSIC INVENTIONS: Torricelli's Vacuum

Physics

This is Torricelli's famous experiment, the first demonstration that Nature's abhorrence of a vacuum" is limited, and the elaboration of the experiment by Torricelli's pupils.

ESSAYES OF NATURAL EXPERIMENTS Made in the Academie del Cimento, Under the Protection of the Most Serene Prince Leopold of Tuscany. Written in Italian by the Secretary of that Academy. Englished by Richard Waller, Fellow of the Royal Society. London, Printed for Benjamin Alsop at the Angel *and* Bible *in the* Poultrey, *over-against the* Church. 1684.

An Experiment, *Suggesting to* Torricelli *the first* Inventor *thereof, that it might be the natural external* Pressure of the Air *which sustains the* Mercury, *or any other* Fluid, *at a determinate Height in the* empty *space of a Cane,* &c.



TAB. 2

Provide a glass Cane about 46 Inches long, *Heremetically* sealed at one end, and open at the other, represented by A B C. Fill this with *Mercury,* and stop the mouth C close, either with your Finger, or a moistened Bladder tyed over it; invert it, and gently immerse it into the Vessel of Stagnant Quick-silver D E then untie the mouth C and immediately the *Mercury* in the Cane will subside for the whole space AF where meeting with its Level, or Counterpoise after some Fluctuations, it rests immovable: and the Cilinder of Quick-silver sustained E B which bears upon the superficies of the Stagnant *Mercury* D E shall be about the length of 28-6/10 Inches, which length is found to vary, though but little, from External Accidents of *Heat* and *Cold;* and something more from the divers seasons of the *Air,* as appears plainly from a long Series of our Observations. Nevertheless, these variations being very little, it will be always about the before-mentioned Height of 28-6/10 Inches, or near it.

The space A F shall contain no *Air,* which is manifest by inclining the Cane about the Point C as a *Center,* when you will find the internal Level F successively move towards A, but never rise above the *horizontal* prickt line F G, drawn from the point F, the first height of the *Quick-silver,* when the Cane was *perpendicular;* and if the end A be inclined quite to the line F G, the Cane will be full of *Quick-silver,* except a very little at A, whither still above the level of the included *Mercury,* gathers together either some *air* wherewith perhaps it is impregnated, or some other invisible *affluvia* exhaling there from. This is most conspicuous, when a small quantity of Water is in the Cane, which in making the *Vacuum* gets above the *Mercury,* and discovers in their passage through the midst of it, that several small Bubbles rise out of the *Mercury* towards the empty space; as may be shewn hereafter.

This Vacuity of *Air* may likewise be proved by *Water* poured upon the *Quick-silver* in the Vessel D E, for lifting the Mouth of the Cane C out of the *Quick-silver,* as soon as it is every way encompassed with the *Water,* the *Mercury* will fall down, raising the *Water* in its place to the top of the Cane; provided it exceeds not the length of 33 Feet 25 Inches, to which (as may be elsewhere discoursed) it is usual for *Water* to be sustained; probably from the same power that bears up the *Mercury* to 28-6/10 Inches; and indeed, there will be no great quantity of *Air* at the top of the Cane; since there is onely some thin *Effluvia* forced into an almost invisible space, which (as we said) rise from the *Quick-silver,* or is some other subtil Matter capable of penetrating thither.

Upon this ground we shall call (as before for brevity sake) the space A F, (and any other left by the subsiding *Mercury* in a like Vessel) the *vacuum,* or *void space,* (*i. e*) empty, and void of *Air;* at least such as unaltered, and in its Natural State encompasses the Cane; not presuming here to exclude *Fire, Light,* or the *Ether,* or any other very thin Bodies, which are either in part dispersed with little *vacuities* interposed, or wholly filled the space, which we call the *vacuum,* being stretcht and attenuated as some think. Nevertheless, 'tis our intent in this place, onely to discourse of the Space fill'd with *Mercury,* and endeavor to find the true cause of that wonderful Counterpoise of this Weight, without entering into any Dispute with the deniers of a *Vacuity.* And since many Experiments have been made for this end, (as well what is related by others, as what has been invented by our *Academy*) the success shall be faithfully set down; our Custome being always to deliver the Matter *Historically,* and not to defraud the *Inventors* either of their Invention, or due *praise.*

An Experiment *Of Mr.* Robervals *in favour of the* Airs Pressure *upon Inferior Bodies, tryed in our* Academy.

Let there be a glass Vessel A, to the bottom of which B C perforated at D; let the Cane D E 46 Inches long be affixt, over this hols set the square glass F, then close the Vessel A with the glass Cover G H, having an open nose H I, and a hole at G, through which let the Cane K I be put open at each end, and about 46 inches long, or not less then 30; let this down into the Glass F, but not quite to touch the bottom; and fasten it there with Mastic, or other Cement at the fire, to the hole in the Cover G; this Cement, or Paste, is made of Brick reduced to an impalbable Powder, and incorporated with Turpentine, and Greek Pitch; 'tis admirable to stop Glasses to exclude the *Air;* let it be luted close with the same, round about where the said Cover and Vessel joyn; and cover the lower mouth E with a Bladder; Then pour in at the upper end K so much *Mercury,* till running over the Glass F it falls upon the bottom B C, and thence by the hole D fills the lower Cane E D, and after that the whole Vessel A, the *Air* having its way out by the open Nose H I, which when the *Mercury* be- (*Turn to next page*)

Torricelli's Vacuum—*Continued*

gins to run through it, close well with the Bladder I, and lift up the whole Cane to K till a little runs over, that not the least *Air* may remain when closed, which do with the Bladder K. Lastly, open the other Bladder at the Mouth E under the Superficies of the Stagnant *Mercury* M N, into which the Cane is immersed, an dimmediately the upper Cane K L, and the Vessel A will empty themselves; the Glass F and O P, part of the Cane D E being about 28½ Inches above the Level, M N remaining full. This done, the ingress of the External *Air* upon opening, or pricking the Bladder I, will immediately suppress the *Cilinder* of *Mercury* O P into the lower Vessel, and raise up another Q R from the *Mercury* in the glass Cup F into the Cane L K equal to the former O P, and therefore 28½ Inches long; and this *Cilinder* will not subside until the External *Air* entering at the top K, rushes in upon it through the Cane L K.

If in this Vessel A, a little Bladder be enclosed, taken carefully out of a *Fish*, the *Air* that is Naturally therein being first expressed, so as very little be left in the folds thereof, and then the Orifice well tyed together, as soon as ever (by the subsiding of the *Mercury*) the Bladder shall be in *vacuo*, that little *Air* remaining in it will swell, and distend it; nor will it shrink again, till by opening the Vessel at K the External *Air* gets in to press upon it.

But we have observed more clearly the like Expansion of *Air in vacuo*, in a Vessel made after another manner, as A D B, wherein a Lambs Bladder squeezed together, and almost wholly discharged of *Air*, is inclosed thus; fill the Vessel with *Quicksilver* by the mouth D, and tye it over with a Bladder, the lower Mouth E being before stopt with the Finger, then immersing it into the *Quicksilver*, in the Vessel F G, open the Mouth E, and let the *Quick-silver* subside; then will the Bladder C hung by a Thread in the empty Vessel A D B swell it self, and so continue, till by opening the Mouth D, the External *Air* enters at the Top, which at the same time will bear down the *Cilinder* of *Mercury* into the Vessel at the bottom F G, and press together the Bladder.

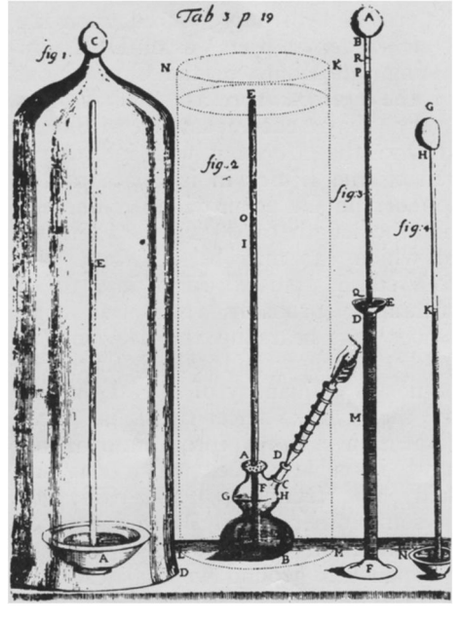
Likewise, if in closing the Mouth D, there be put upon the *Mercury* a little froth made with *whites* of *Eggs*, or *Soap-suds*, still as the Vessel A D B empties it self, the *Air* imprisoned in these small *bubbles* will so swell them, that at length breaking through its thin Confinements, it shall be at liberty, and quite released from the Liquor, which will fall down upon the *Mercury* like Dew separated from that fine streame of *Air* contained in the *froth*.

Experiments *Alledged by some against the* Pressure of the Air, *and the Answer thereto.*

There have been Two Experiments, from which some of our *Academy* judged a considerable *Argument* might be raised against the *Pressure of the Air* upon Inferior Bodies, and the Effect of sustaining Fluids attributed to something else.

One was, by covering the Vessel A, and likewise the Cane with a great *Bell* of Glass B C D pasted down close to a Table round the edges: for then they imagine, that if it were true, that the weight of the whole incumbent *Atmosphere of Air* did protrude the *Mercury* into the Cane, and counterpoise it with its weight; by defending (with this Cover of Glass) the Stagnant *Mercury* from so great a *Pressure*, the small, and scarce sensible weight of the little portion of *Air* included within the Bell, must of necessity be unable to keep the *Quicksilver* at the same height whereto the *momentum* of so vast a space of *Air* had raised it; but notwithstanding this, they never observed it to subside a jot from the usual height E G.

The Second *Experiment* was of the same Nature, but more Artificial.



TAB. 3

We fill'd with *Mercury* a small Vessel A B (which at first was made without the Beak C D, added afterwards for another Experiment) and plunged into it when full, the Cane E F, and making the usual *Vacuum*, there was poured out from the Vessel A B a small quantity of *Quick-silver*, so that a little *Air* might be in the space A H to bear upon the *Stagnant* Level H G, and then the Weight and *Pressure* of the External *Air* was kept off, by closing carefully with the afore-named Cement, the round space A between the Neck of the Vessel, and the Cane; and yet in this case, when the bulk of the External *Air* was so lessened to nothing almost, we saw no sensible abatement of the *Mercurial Cilinder* I F below the usual height.

But the Assertors of the *Airs Pressure* answer these Experiments thus. That these Events on the contrary greatly favour their *Opinion;* for the immediate cause (as they say) that forces, and powerfully sustains the *Mercury*, to the height of 28½ inches, is not the weight of the Incumbent *Air;* which indeed is taken off by the Bell in the *first* Experiment, and by the Cement in the *second*, but is in reality an effect of Compression, which was produced and wrought in the *Air* (contained in B C D *Fig.* 1 and in A H *Fig.* 2) by that weight before they were Cemented close: whence 'tis no wonder, that the *Quicksilver* subsides not from its usual height, the *Air* keeping in the same state of Compression as 'tis forced to do, from the resistance made by the glass Bell, and Cement, which supplies the place of all that vast Tract of Incumbent *Air*.

And because 'tis yet believed by some, that the force of a supposed *Spring* in the *Air* acts wholly in this Effect, so as without it by no means it could happen; 'twas therefore attempted to insinuate the contrary, by the following Experiment.

Taking the same Vessel A B, with its Cane E F (before we poured off any of the *Mercury*, as was directed in the former Experiment, or stopt up the Mouth of the Vessel at A with Cement) and then setting all in a great Vessel full of *Water* K L M N, the *Quick-silver* was observed to be sensibly deprest from A to G H; and on the contrary, raised in the Cane from I to O: this Ascent being about the *fourteenth* part of the whole height of the (*Turn to next page*)

Astronomer Forecasts English Rains

Meteorology

Storms which hampered the early days of the Boy Scouts' jamboree in England are but a forecast of a return to normal rainfall for the second half of 1929, after an exceedingly dry six months, according to predictions of Dr. Dinsmore Alter, professor of astronomy at the University of Kansas.

A test prediction by Dr. Alter, published in the U. S. Monthly Weather Review for June, 1927, forecast the dry season through which the British Isles have just passed. If the observed rainfall follows the prediction for the next six months as closely as it has in the past several years, England may look for approximately normal rainfall the rest of the year. After a damp spring in 1930, the prediction indicates, England may experience two years of sub-normal rainfall.

Dr. Alter has published a dozen papers on periodicity of rainfall, basing his studies on records from many sections of the world. The British Isles and the Pacific Coast of North America, with their purely marine types of weather, and the purely continental types as found in the Punjab of India, and in Siberia, gave the most consistent results when mathematical formulae were applied.

The British Isles predictions, for example, were based on a study of data from six different places in the Isles, covering the years from 1834 to 1924. From these data, a periodogram was computed with a dozen or more peaks, the four principal of which were applied in producing the chart published in the United States two years ago, and making test predictions up to 1940.

Actual reports received since the test prediction was published have been charted, and found to have a high correlation. The predicted excess of rainfall by 12 per cent., in the spring of 1926, was found actually to be 18 per cent. excess of normal. The predicted excess of 3 per cent. in the fall of 1923 became an actual 4 per cent. deficiency, but the predicted excess rainfall for the latter part of 1927 and all of 1928 was even exceeded by the actual figures. Reports received by Dr. Alter for the first three months of 1929 showed even less rainfall than the 22 per cent. he had predicted. The prediction is "practically normal" for the second half of this year.

Dr. Alter leaves for Europe the latter part of August to spend a year under a fellowship granted by the Guggenheim Foundation. He expects to spend the greater part of his time in England and Scotland, examining rainfall records, many of which are only in manuscript form, in a hope to discover further data that will make his predictions more accurate.

He disclaims all hope of being able to predict long in advance the weather probabilities for any particular day, but he does believe there are possibilities in predicting in larger units the possible weather, especially as to rainfall. Such predictions, if reasonably accurate, he believes, would be of great benefit to agriculture.

Science News-Letter, August 17, 1929

Torricelli's Vacuum—*Continued*

Water E F: then the Mouth A was closed, that so onely the *Water* in the space A G H might press upon the *Mercury,* which nevertheless lost none of the height lately gained by the weight of all the Incumbent *Water* E F, above the First Level I; yet in this case the included *Water* A G H, not by vertue of any Springs (which perchance it had not) but because it had been forced by the Charge of the whole height E F into the space left by the *Quick-silver* rising from I to O, and kept there by the same force, and so hindered from Returning. The same may be said to happen to the *Air.*

Lastly, Some desirous to see what Effect a greater, or lesser Rarefaction of the *Air* included in A G H would have, made this Trial.

Joyning to the Vessel A B the Beak C D (into which they fastned a Mouth of Metal with a *female Screw*), they adapted a *Syringe;* Then whenever a *Suction* was made of the *Air* in A G H, and so what remained attenuated and weakened, the Level I, might be seen to *subside,* contrarily when compressed more, by forcing in new *Air;* the same Level I *was raised.*

The same happens from *Fire* or *Ice* approaching it; for the Mouth C being closed, when *Fire* is Externally applyed to the Air in A G H, the *Mercury* rises, and by the application of *Ice subsides;* as if after the same manner, as it happened in the contrary operations of the *Syringe;* the *Air* had been Condensed, and enforced by Heat, and rarefied and weakened by Cold; from all which Matters it seemed probable, that this *sustention* of the *Fluid* does not absolutely depend upon the *weight* of the *Air,* but also upon the *compression* which *lower* parts of the *Air* receive from those above.

Evangelista Torricelli (1608-1647) was born at Faenza, Italy. At the age of 19 he was sent to Rome to study science. His work was chiefly in mathematics and mechanics. His development of the theory of some of Galileo's experiments led his teacher, Castelli, to send him to Galileo, and Torricelli served as amanuensis to the blind Galileo for the last three months of the older man's life. But Torricelli himself lived only six years longer. The famous experiment of creating a vacuum above the column of mercury supported by air pressure was first made in 1643.

The Academie del Cimento was a group of Italian scientists, pupils and followers of Galileo and of Torricelli, who banded together for the purpose of making experiments supplementary to those of their masters. They rigidly excluded philosophical interpretation and explanation, and sought only experimental truth. They published their researches only in the name of their society.

Science News-Letter, August 17, 1929

Breathe Exhaust Fumes

Physiology

The U. S. Bureau of Mines, in cooperation with the bridge and tunnel commissions of New Jersey and New York, has recently conducted an experiment to discover whether persons exposed for long periods of time to the exhaust fumes in the Holland Vehicular Tunnel would become ill.

Six men volunteered to breathe the fumes for from four to seven hours each day over a period of 68 days. The gas mixture used in the experiment contained 2, 3, and 4 parts of carbon monoxide to 10,000 parts of air. Some of the men had frontal headaches after breathing the mildest mixture for 3½ hours and after an exposure of only 1½ hours to the strongest mixture. After four hours of exposure to the 4-part mixture the blood had absorbed the gas to an extent of 30 per cent. No serious effects were noted in the short time that it would take to drive through the tunnel.

Science News-Letter, August 17, 1929

Umbrellas are considered signs of dignity and authority among natives of the Gold Coast in West Africa.

Chinese tung oil, which has many uses, is now the fourth largest chemical import of the United States.