

An Extract of Letters from Dr. John Wallis to the Publisher, 1672. Sept. 26. &c. concerning the Suspension of Quicksilver well purged of Air, much higher than the ordinary Standard in the Torricellian Experiment.

S I R,

I Am not sorry to find, in your *Transactions* for the last Month, (which I have newly received,) that M. *Hugens*, an Ingenious and Inquisitive person, doth endeavour to give a Reason of that Odd *phænomenon* in the Torricellian Experiment (observ'd by my Lord *Brouncker*, and Mr. *Boyle*, many years since, in pursuance of an Order of the *R. Society* to that purpose,) of which I give an account in my Treatise *De Motu Cap. 14. Schol. prop. 13.* The Phænomenon is this:

Whereas in the Torricellian Experiment, the Quicksilver contain'd in the Inverted Tube, how long soever, whose open orifice C. is immerged in stagnant Quicksilver, does usually fall down to the height of about 29. inches above the surface of the stagnant Quicksilver AB, and there remains suspended, as at I: If the Quicksilver be well cleans'd from Air, it has been found to stand top-full, much higher, even to the height of 75. inches (and how much higher it may stand, we cannot tell;) but upon the admission of the left Air, or a concussion of the Tube, it falls down to the usual standard.

Two Reasons I did there hint (though not perfectly satisfied in either:) The *one*, of my own, concerning the Spring of the Air, necessary to put Heavy bodies in motion, not impell'd by any other force: The *other*, of my L. *Brouncker*, that there might be in the Air yet a greater Weight or Pressure than is necessary for the height of 29 inches, in case there be nothing but the bare weight of Quicksilver to be supported.

I find, Monsieur *Hugens* to fall in with that of my Lord *Brouncker*, save that what we comprehend under the name of *Air*, he calls a *more subtile Matter*: which alters not the Case at all, but only the Name.

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By *Air*, I find, Mr. *Hobbes* would sometimes (as in *Dialogus Physicus* p. 4.) have us understand a pure *Æther*, or (as his words are) *Aerem ab omni Terræ Aquæq; effluviis purum qualis putatur esse Æther*; to which, I suppose, answers the *Materia subtilis* of *Des-Cartes*, and *Monf. Hugen's* his more *subtile Matter* than *Air*. On the other hand, *M. Hugen's* here, by *Air*, seems to understand that *seculent matter* arising from those the *Earths and Waters Effluvia*, which are intermingled with this *subtile Matter*. We mean by *Air*, the *Aggregate of both these*, or whatever else makes up that *Heterogeneous Fluid* wherein we breath, commonly called *Air*; the purer part of which is Mr. *Hobbes's Air*; and the *seculent* of it is *Monfieur Hugen's Air*.

And therefore, where I speak of *Vacuity* caus'd by the *Toricellian Experiment*, or such other ways, I do expressly caution (*De Motu C. 14.* and *Hobb. Heaut. p. 152.* and elsewhere,) not to be understood as affirming *Absolute vacuity* (which whether or no there be, or can be in nature, I list not to dispute;) but at least an *Absence* of that *Heterogeneous mixture which we call Air*, such as that is wherein we breath; without disputing against the *purus Æther* of Mr. *Hobbes*, or the *Materia subtilis* of *Des-Cartes* or *M. Hugen's*; as not necessary to the *Inquiries* in hand.

To the *Pressure* of this *Purer matter* (which they suppose so *subtile*, as to penetrate the *Mercury*, *Marble*, and *Glass* it self,) they adscribe the *Suspension* of the *Quick-silver* to so great an height. And my Lord *Brouncker* in particular, while that *Piece of mine* was under the *Press*, had a design (as He then signified to me) of prosecuting the *Experiment* (as *Monfieur Hugen's* does now advise,) to see if he could bring it to some *Determination* (of which I might there have given an account, if it could have been dispatcht time enough;) what were the utmost height at which it might be thus made to stand; thereby to determine the *pressure* of this *Purer matter*, as that of the *Common Air* is determin'd by the *Toricellian Experiment*. But his leisure not then serving, I only gave that brief account of his
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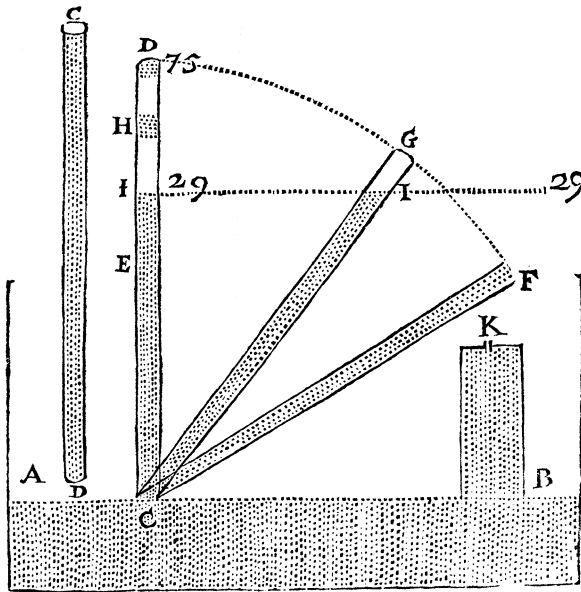
Notion, as it is there inserted : And, whether he have since had leisure, amidst a great press of other business, to pursue it, I am not certain.

Now, though I would not wholly exclude this, if such shall be found to be (but only suspend my Assent till it be evinced ;) yet surely there must be somewhat more in it than that of this Subtile matter, to solve the *Phenomenon*, notwithstanding the two Experiments now alledged by *M. Hugen's* in favour of it. For, if this Matter be so subtile as to pass, through the top of the Glass, upon the Quicksilver (and consequently through the upper upon the neather of the *two-Marbles*,) as is acknowledged ; (and without which it is no more able to precipitate the Quicksilver while impure, and when it is in part subsided, than when it is pure, and the Tube top-full :) I do not see, why it should not balance it self (above and below) in the same manner as Common Air would do, if the Tube were pervious to it at both ends, and the Quicksilver, by the preponderance of its own weight, fall presently.

And the *Answer*, That, though the Glass be penetrated by it, yet not in so copious a manner as where no Glass is ; doth not, to me, solve the difficulty : Because the same obstacle doth just in the same manner remain, when the Tube is in part emptied ; and, when the Quicksilver is un-purged : the pores of the Glass not being, by either of those, made more open or more pervious. And if we suppose the Subtile matter by percolation to be strain'd through, with some difficulty, (as Air or Water would be through a cloth,) this might possibly cause the Quicksilver, when it does sink, to sink *gradually* ; but not (as we see it,) *suddenly* to fall to the height of 29 Inches ; as from D to I.

The Connexion or Cohæsion of the parts of Quicksilver, either each to other, or to the sides of the Glass, which *Mr. Hugen's* supposeth to require for their separation a greater force, than is in these percolated particles till they have room made for them to combine ; seems to me the less considerable, because it is not so necessary to separate them
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from each other, since that they may un-separated slide down by the sides of the Glas; to which, it is well known, and visible to the eye, the Quicksilver is not at all apt to stick, but doth rather decline that contact; in like manner as we find Water not apt to Joyn with Oyle or Grease; though Water to Glas, and Quicksilver to Gold, do very readily apply themselves. So that there needs no such Force to dis-joyn the Quicksilver from the Glas, whatever there may be for dis-joyning its parts one from another.



If therefore we should suppose the pressure of the *Grosser* Air downwards on AB (the surface of the stagnant Quick-silver,) and consequently, by means thereof, upwards at C, sufficient only to bear up that in the Tube to the height of I, but the super-added weight or pressure of the *Purer* Air to hold it up as high as D (75 inches or more,) while it is full, and the Quicksilver well cleans'd; as if so long it could not enter at D; but in case it be not so cleans'd, or be already sunk to H, this *purer* Air would enter at D, and

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thrust it down to I, counterballancing the pressure (at C) of the purer but not of the grosser Air (which I take to be the sum of the Cause assign'd by M. *Hugens* :) I am yet to seek, why it may not as well penetrate D at first to begin the Descent, as afterwards to pursue it; and, why not as well begin the Descent when the Quicksilver is well cleansed of Air, as when it is not so; and why also, if the pure Air do freely enter at D, it does not presently fall; or, if not freely, why, when it does fall, it falls suddenly and not leisurely from D to I; especially since so small a weight as D H of pure Air (for the grosser cannot enter,) is very inconsiderable; if not at all, or not freely, pressed by *that* incumbent on D; and the Adhesion not considerably less, by being separated only at the Top, while it yet continues to touch the sides.

I am apt therefore, as heretofore, to adscribe the *Cause* of this *Phenomenon* to the Spring that is in Air, and the want thereof in Quicksilver. For, that in Air there is a Spring or Elasticity, is now undoubted; but in Water, cleans'd of Air, though many Experiments have been attempted to that purpose, it has not yet been found that there is any: And I am apt to think the like of Quicksilver; though I do not know, that this has been yet so rigorously examin'd. Now supposing, that Matter, being at Rest, will so continue till it be put in motion by some Force; this force may be *either* that of *Percussion* from some Body already in motion (which is the Case, when the Quicksilver falls by shaking or striking the Tube;) or of *Pulsion*, from a contiguous Body beginning to move, as by the Expansion of some adjacent Spring (which is the Case, when the Springy parts of the Air, either left in unpurged, or re-admitted in the Quicksilver, by expanding themselves put the Quicksilver in motion;) Or some *Conatus* or Endeavour of its own; such as is that of a Spring (from whatever cause it be, which I do not here inquire,) but has place only in Springy bodies; and therefore if Water and Quicksilver be not such, they will not on this account put themselves in motion.

Gravity

Gravity or Heaviness is, I know (if we knew what it were,) reputed to be such a *Conatus* or Pronity to move downwards, and so to put it self in motion: And the wonder at present is, why it does not so here. But if this, which we call *Gravity*, should chance to be not a Positive quality or *Conatus* originally of it self, but only the Effect of some Pulsion or Percussion from without, (which possibly may be the Case, and principally from the Spring of the Air about us;) then, while this Pulsion and Percussion is wanting (however obviated,) the Bodies, accounted Heavy, will not of themselves begin to fall: which seems to be the present Case.

And this is the more considerable, because we cannot (at least not yet) find, what is the Utmost height at which the Quicksilver thus accumulated will remain suspended; there having been (for ought I know) no height yet attempted, at which, if cleansed, it will not stand; and that of 75 inches, considering the weightiness of Quicksilver, is a very great one, being more than equivalent to 80 foot of water.

My Lord *Brouncker* doth a little alter the case, from what I take to be the Hypothesis of Monsieur *Hugens*. For he supposeth this purer part of the Air to be of like nature with the grosser part, (which I think M. *Hugens* doth not;) and, though finer than the rest, so as to penetrate Glass, which the grosser will not (there being in all sorts of grains, some greater than others, and which will not pass so fine a Sieve;) yet of a Springy nature, as the grosser parts are: Which therefore acts, not by its *Weight* only, but by its *Spring*; and therefore when once entred, though in a small proportion, acts as effectually, at its first entrance, as if the whole incumbent Air had admission; its Spring being of a like tenseure with that of the outward Air; (as I have heretofore shewed *Cap. 14. De motu prop. 11, 12, 13*;) But M. *Hugens's* more Subtile matter than Air though he must allow it *Weight* (for else its entrance would be nothing to the purpose,) yet whether he allow it a *Spring*, I cannot tell; nor doth he inform us.

matter than Air doth without difficulty penetrate Glas, Water, Quicksilver, and all other bodies, which we find impenetrable to Air; I know not whether he mean, without *any* difficulty (as the words seem to import,) or (as I conjecture by what follows) without *great* difficulty, though with *some*.

But his Lordship (if I mistake not) though he allow his (Springy) Subtile matter to penetrate Glas, yet not without difficulty; and, till it have some room made (as HD) wherein it may recollect it self, cannot exert its Spring, and therefore not while top-full of cleansed Quicksilver; but, so soon as some room is made for it: Whereas, if the Quick-silver be not purged of Air, that little Air remaining doth by its Spring begin the motion.

He thinks it also not improbable (and if it so prove, it will be a good confirmation of this *Hypothesis*,) that a large but low Tube of Glas (shorter than 29 inches) may stand top-full of Quicksilver, though with a small hole in the Top, as at K; at least, if immersed in Water, in case Air be too Subtile for our Mechanicks.

He might also, suitably enough to his own Hypothesis, have so explained himself, as to allow his more Subtile parts of common Air to penetrate Quicksilver, but not Glas; and therefore, in case of room for it at HD, it might through the Stagnant Quicksilver, and that at C, pass upwards to HD, and there exert its Spring.

I shall forbear to dispute against this Hypothesis for the present; because I think it more proper to examine by Experiment (which I think hath not yet been done,) whether well-purged Quicksilver may not be made to stand higher than CI, the ordinary standard, suppose at CH, with a void space about it, as HD. For the issue of this Experiment (amongst others to be after mentioned,) seems very proper for determining of this doubt; which therefore I am not willing to pre-judge. There is yet another way of explicating the same Hypothesis, without allowing this Subtile matter to pierce the Glas; which is this:

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Our common Air being an aggregate of very Heterogeneous parts, we may well suppose some of them to be Springy, and others not to be so. The Springy parts we may conceive to be so many consistent Bodies, like small hairs or springy threads wrapped up in different forms and variously intangled, and so as to form many vacuities capable of admitting (whatsoever other parts of the Air may be supposed to be) some Fluid matter, which may insinuate into those vacuities, (as water in a bundle of Bushes,) without disturbing the Texture of those Springy parts; and which may press as a *Weight*, but not as a *Spring*, (of which distinction see *Cap. 14. De motu, Schol. prop. 11. & Schol. prop. 13. pag. 729, 730, 732, 733.*)

Now if, in the Torricellian Tube, there be a quantity of such Springy matter, the Spring hereof will be of equal strength with that of External Air, (and therefore able to counterballance it, though its weight be much less,) because admitted with such a tenure, (*ibid. prop. 12. 13.*) But if only an Un-springy Fluid (which presseth but as a *Weight* not as a *Spring*,) and this defended by the glass-Tube from any other pressure, save that of its own weight; it will still be too weak to force its own way, till its single weight be equivalent to that with which it is to encounter; which is, not onely the Springy part of the Air, but also that Fluid Un-springy part; which though (because Fluid) it would give way to a Springy body pressing through it; yet not to this Fluid, like it self, and destitute of such a Spring; and is therefore able to keep it up to a much greater height than it could do if un-cleansed of Springy Air: So long at least as till some Springy body be admitted, or some concussion, equivalent to it, put it in motion; but being once in motion, it will so continue (as a Bullet impell'd by Gun-powder, or an Arrow out of a Bow,) till stopped by some Positive force equivalent.

I do not deny, but that this explication may be subject to some Difficulties and Exceptions; but I think, fewer than that of allowing the Glass penetrable by this Subtile matter.

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But the best way to settle this business, being some suitable Experiments; I should recommend (because I am not so well accommodated for this purpose,) these, or some of these, Experiments, to those of the *Royal Society*, who are in that kind better provided than I.

1. (That hinted by my Lord *Brouncker*,) Whether a large low Tube, of less height than the common Standard (of about 29 Inches *English*, or 27 Inches *French*,) might be made to stand top-full of Quicksilver, though a small hole be left open at the Top; at least under Water? I am apt to think, that it will rather sink slowly and with a hissing noise, than fall suddenly and silently.

2. Whether of two polished Marbles or metalline Plates, the lower will be found to stick to the upper, in the exhausted Receiver, longer than is accountable for from the ordinary Counter-balance in the Torricellian Experiment. For though Monsieur *Hugens* now, and Mr. *Boyle* (if my memory do not much fail me) have long since intimated this from his own Experience; yet I judge the Experiment worth repeating. And if it be (as I suppose it may) found to succeed, I should think it may proceed from a want of a Spring or Elastick power between the Plates to force them asunder; and in particular (since with this it hath been tryed) that Spirit of Wine is not a Springy body.

3. Whether a Siphon of unequal Legs will be made to run, in an exhausted Receiver, with Water or Quicksilver, at a greater height than is accountable for; which though Monsieur *Hugens* have tryed it, I think it worth repeating in this *Society*. This when it doth succeed, I take to proceed from the Spring of that little remaining Air in the Receiver not quite emptied.

4. (Which seems of a like nature with the former,) Whether a Tube of greater length than 29 Inches, but so immerg'd as to be less than so much above the level, as CE, may not, if filled with well cleansed Quicksilver, be gently lifted up with the Quicksilver in it, not only to I (as when it is unpurged) but to H or D, higher than the usual Standard.

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5. (Which is equivalent, but more easily administred,) Whether if such a Tube, so filled, be at first so inclined (as CF) that its height above AB be less than 29 Inches, may not be leisurely and gently erected, so as to remain full, not only to the height of I, but of G or D?

6. Whether cleansed Quicksilver will, in the open Air, run in a Siphon higher than 29 Inches?

7. If not in the Air, whether it will so run, if the lower Leg open into well-cleansed Water?

8. (Which I do principally recommend;) In a Tube so filled with cleansed Quicksilver, as to stand top-full at a greater height than the usual Standard, as CD; in case some part be forced out, not by admission of Air but by Jogging the Tube, (I suppose as much as HD,) and a stop then made: Whether the rest CH (at a greater height than I, the usual Standard,) may be made so to stand of it self, notwithstanding the voidance of HD? For by this Experiment alone, if it succeed, it will appear, that it is not onely want of room for the Subtile matter to recollect it self, which hinders the suspended Quicksilver from falling; but rather (unless some probable cause can be found,) the want of a Spring to put it in motion. If it will not succeed, I should rather think, the Springy Air doth make its way through the Quicksilver than through the Glas.

9. Whether cleansed Quicksilver will remain suspended in an inverted Tube (at least a short one, and with a small Orifice,) though its Orifice C be not immerg'd in Quick-silver, but either in the open Air, or at least in Water?

10. If so; then whether it will do the like, if, a little being forced out, there be some void room left at the Top, at HD?

These are nice Experiments, and of some difficulty; but if carefully administred, may be of good use in our search after the true nature of *Gravity*: Which may possibly have a greater connexion with the Spring of the Air, than men are aware of; since on the presence or absence thereof doth mainly depend the falling or not falling of
Bodies

Bodies accounted Heavy. But I am not willing, by interposing my own Conjectures, to pre-judge the Experiments.

An Account of Two Books.

- I. *Observations Topographical, Moral and Physiological made in a Journey through part of the Low-Countries, Germany, Italy and France, by John Ray, Fellow of the R. Society: Whereunto is added a Brief Account of F. Willoughby Esq; his Voyage through a great part of Spain. London. printed for J. Martyn, Printer to the R. Society, at the Bell in St. Pauls Churchyard, 1673. in 8°.*

THis Curious and very Instructive *Itinerary* may well serve as a Pattern for Travelling with that improvement and advantage, as ought to be aimed at by all discreet Travellers; as containing whatever is remarkable both for Persons and Things in those places, which the Ingenious and Inquisitive Author together with his good Company travelled through. Let his Reader be a States-man, an Ecclesiastick, a Philosopher, an Artist, a Trades man, a Father of a Family, an Husband-man, they will all of them find matter in this Book very proper for their respective Genius, Professions and Callings. Here is described the Climat, Government, Revenues, Laws, Customs, Manners, Tempers, Abilities, Studies, Arts, Trades, and Natural Productions of the Countries spoken of; and besides, divers Fabulous relations and ungrounded fancies refuted and rectified.

We shall only hint in this place the principal Heads of such particulars, as belong to the purpose of *these* Tracts; in reference to which is to be noted what the Author observes,

1. Of the several Constitutions of Climats, and the difference, he found, between the Temperature of the *Air* on two opposite sides of some Mountains.

2. Of *Waters*, as the most considerable Rivers and the Fishes bred therein; Of Springs, (the Original of which he discusseth,) ebbing and flowing Wells, *spaw*-waters (particularly