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## **Hydrostatical paradoxes**

**Boyle, Robert**

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### Appendix I.

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## APPENDIX I.

*Containing an Answer to seven Objections, propos'd by a late Learned Writer, to evince, that the upper parts of water press not upon the lower.*

**A**fter I had, this Morning, made an end of reviewing the foregoing papers, there came into my hands some questions lately publish'd, among other things, by a very recent Writer of Hydrostaticks. In one of which Questions, the Learned Author strongly defends the contrary to what has there been in some places prov'd, and divers places suppos'd.

The Author of these Erotemata asserts,

asserts, That, in consistent water, the upper parts do not gravitate or press upon the lower.

And therefore, I think it will be neither useleſs, nor improper, briefly to examine here the Arguments he produces. Not uſeleſs; becauſe the Opinion he aſſerts, both is, and has long been, very generally receiv'd; and becauſe too, it is of ſo great importance, that many of the Erroneous Tenets and Concluſions, of thoſe that (whether profeſſedly or incidentally) treat of Hydroſtatical matters, are built upon it. And not *improper*; becauſe our Learned Author ſeems to have done his Reader the favour to ſumme up into one page all the Arguments for his Opinions that are diſperſedly to be found in his own or others mens Books. So that in anſwering theſe, we may hope to do much towards a ſatisfactory Deciſion of ſo important

a Controversie. And, after what we have already deliver'd, our Answers will be so seasonable, that they will not need to be long: The things they are built on having been already made out, in the respective places whereto the Reader is referr'd.

Our Author then maintains, that, in Consistent water, the Superiour do not actually press the Inferiour parts, by the seven following Arguments.

*Object.* 1. Sayes he, *Because else the inferiour parts of the water would be more dense then the Superior, since they would be compress'd and condens'd by the weight of them.*

*Ans.* But if the Corpuscles, whereof water consists, be suppos'd to be perfectly solid & hard; the inferior Corpuscles may be press'd upon by the weight of the superior, without being compress'd or condens'd by them. As it would  
happen

happen, if Diamond dust were lay'd together in a tall heap : For though the upper parts, being heavy and solid Corpuscles, cannot be deny'd to lean and press upon the lower ; yet these, by reason of their Adamantine hardness, would not be thereby compress'd. And 'tis possible too, that the Corpuscles of water, though not so perfectly hard, but that they may a little yield to an extream force, be solid enough not to admit from such a weight, as that of the incumbent water, (at least in such small heights as observations are wont to be made in,) any compression, great enough to be sensible ; As, besides some Tryals I have formerly mention'd in another place, those made in the presence of this Illustrious Company seem sufficiently to argue ; viz. That water is not sensibly compressible by an ordinary force. And I find not, by those that  
make

make the Objection, that they ever took pains to try, whether in deep places of the Sea, the lower parts are not more condens'd then the upper: nor do I see any absurdity, that would follow from admitting them to be so.

*Object. 2.* Our Authors second Argument is, *Because Divers feel not, under water, the weight of the water that lyes upon them.*

*Ans.* But for Answer to this Argument, I shall content my self to make a reference to the ensuing Appendix, where this matter will be considered at large; and where, I hope, it will be made to appear, that the phænomenon may proceed, partly from the firm Texture of the Divers body, and partly from the nature of that pressure which is exercis'd against bodies immers'd in fluids; which, in that case, (as to sense) presses every where equally, against all  
the

the parts of the body, expos'd to their  
Action.

*Object.* 3. The third Argument is,  
That ev'n the slightest Herbs growing at the  
bottom of the water, and shooting up in it  
to a good height, are not oppress'd or lay'd  
by the incumbent water.

*Ans.* But the Answer to that is easie,  
out of the foregoing Doctrine. For the  
Plants, we speak of, sustain not the  
pressure of the water above them by  
their own strength; but by the help  
of the pressure of water that is be-  
neath: which being it self press'd by the  
water that is (though not perpendicular-  
ly over it) superior to it, presses them  
upwards so forcibly, that if they were  
not by their Roots, or otherwise  
fastned to the ground, they, be-  
ing *in specie* lighter then water,  
would be buoy'd up to the top of the  
water, and made to float; as we often  
see that weeds do, which storms, or  
other

other accidents have torn from their native soyle.

*Object.* 4. A fourth Objection is this, That a heavy Body ty'd to a string, and let down under water, is supported, and drawn out with as much ease, as it would be if it had no water incumbent on it; nay, with greater ease, because heavy bodies weigh less in water then out of it.

*Ans.* But an Account of this is easie to be rendred out of our Doctrine; For, though the water incumbent on the heavy body do really endeavour to make it sinck lower, yet that endeavour is rendred ineffectual, to that purpose, by the equal pressure of the water upon all the other parts of the Imaginary surface, that is contiguous to the bottom of the immers'd body. And that pressure upon the other parts of that suppos'd plain, being equal not only to the pressure of the pillar of water,

ter,

ter, but to that pillar, and to the weight of as much water as the immers'd body fills the place of; it must needs follow, That not only the hand that sustains the body, should not feel the weight of the incumbent water, but should be able to lift up the Body more easily in the water, then in the aire. But though the pressure of the water incumbent on the stone can not, for the reason assign'd, be felt in the case propos'd; yet if you remove that water, (as in the Experiment brought for the proof of the last Paradox,) it will quickly appear by the pressure against the lower part of the heavy body, and its inability to descend by its own weight, when it is any thing deep under water; it will (I say) quickly appear, by what will follow upon the absence of the Incumbent water, how great a pressure it exercis'd upon the stone whilst it lean'd on it.

*Object.*

*Object. 5.* The fifth Argument is propos'd in these words, *Because a Bucket full of water, is lighter in the water, then out of it; nor does weigh more when full within the water, then when empty out of it; nay it weighs less, for the reason newly assign'd (in the fourth Objection;)* therefore the water of the Bucket, because it is within water, does not gravitate, nor consequently press downwards, either the Bucket, or the water under the Bucket. This is the grand and obvious Experiment, upon which the Schools, and the generality of Writers, have very confidently built this Axiom: *That the Elements do not gravitate in their proper place; and particularly, that water weighs not (as they speak) in its own Element.*

*Ans.* What they mean by proper or natural place, I shall not stand to examine, nor to enquire whether they can prove, that water or any other sub-  
lunary

lunary body possesses any place, but upon this account, that the cause of gravity, or some other movent, enables it to expel other contiguous Bodies (that are less heaue or less moved,) out of the place they possess'd before; and gives it an incessant tendencie, or endeavour towards the lowermost parts of the Earth.

But as to the Example propos'd, its very easie to give an account of it. For suppose  $A B C D$ , to be a Well; wherein, by the string  $E F$ , the Bucket is suspended under water, and has its Bottom contiguous to the imaginary plain  $I K$ . If now we suppose the Bucket to consist only of wood, lighter then water, it will not only not press upon the hand that holds the Rope at  $E$ , but will be buoyd up, till the upper parts of the Bucket be above the top of the water; because the wood, whereof the Bucket is made, being lighter *in specie* then

then water, the pressure of the water in the Bucket *G*, and the rest of the water incumbent on that, together with the weight of the Bucket it self, must necessarily be unable to press the part *H* so strongly, as the other parts of the imaginary plaine *I K* are press'd by the weight of the meer water incumbent on them. But if, as tis usual, the Bucket consists partly of wood, partly of iron; the Aggregate may often indeed be heavier then an equal bulk of water: But then the hand, that draws up the Bucket by the Rope *FE*, ought not, according to our Doctrine, to feel the weight of all the Bucket, much less that of the water contain'd in it. For though that aggregate of wood and iron, which we here call the Bucket, be heavier then so much water; yet it tends not downwards with its whole weight, but only with that surplufage of weight, where-

by

by it exceeds as much water as is equal to it in Bulk ; which surplufage is not wont to be very considerable.

And as for the water in the Cavity ,  $G$ , of the Bucket, there is no reason why it should at all load the hand at  $E$ , though really the water both in the Bucket and over it do tend downwards with their full weight ; because that the rest of the water,  $LI$ , and  $MK$ , do full as strongly press upon the rest of the imaginary Superficies  $IK$ , as the Bucket and the incumbent water do upon the part  $H$ : and consequently the bottom of the Bucket is every whit as strongly press'd upwards by the weight of the water, upon all the other parts of the plain  $IK$ ; as it tends downwards, by virtue of the weight of the Incumbent water, that is partly in the Bucket, and partly above it ; and so these pressures ballancing one another, the hand that draws the

P

Rope

Rope at *E*, has no more to lift up then the surplufage of weight, whereby the empty Bucket exceeds the weight of as much water as is equall in bulk (I say, not to the Bucket as 'tis a hollow Instrument, but) to the wood and iron whereof the Bucket confifts.

And becaufe this Example of the lightness of fill'd Buckets within the water has for fo many Ages gain'd credit to, if it have not been the only ground of, the assertion, That water weighs not in its own Element, or in its proper place; I shall add (though I can scarce present it to such a *company* as this without smiles) an Experiment that I made to convince those, that were, through unskilfulness or prejudice, indispos'd to admit the Hydrostatical account I have been giving of the phænomenon. I took then a round wooden Box, which I substituted in the room of a Bucket; and (having fill'd it with melted  
Butter,

Butter, into which, when it was congeal'd, some small bitts of lead were put, to make it a little heavier then so much water, ) I caus'd a small string of twin'd silk to pass through two small holes, made in the opposite parts of the upper edge of the box, and to be suspended at one end of the beam of a pair of Gold-smiths Scales; and then putting it into a vessel full of water, till it was let down there, to what depth I pleas'd, it appear'd that not only the least endeavour of my hand would either support it, or transport to and fro in the water, or draw it up to the top of it; and this, whether the box were made use of, or whether the butter and lead alone, without the box, were suspended by the silken string: but (to evince, that it was not the strength of my hand, or the smallness of the immers'd body, that kept me from feeling any considerable resi-

stance, ) I cast some grains into the scale that hung at the other end of the above mention'd Beame, and presently rais'd the Lead and Butter to the surface of the water. So that unless the Schoolmen will say that the butter & lead were in their own Element; we must be allow'd to think, that the easie sustentation, and elevation of the box, did not proceed from hence, That those bodyes weigh'd not because they were in their natural place. And yet in this case, the effect is the same with that which happens when a bucket is drawing out of a well.

And, to manifest that 'twas the pressure of the water against the lower part of the surface of our suspended body, that made it so easie to be supported in the water, or rais'd to the top of it; I shall add, that though a few grains suffic'd to bring the upper surface of the butter to the top of the water:

yet

yet afterwards there was a considerable weight requisite, to raise more & more of its parts above the waters surface ; & a considerabler yet, to lift the whole body quite out of the water. Which is very consonant to our Doctrine. For, suppose the bucket to be at the part *N*, half in and half out of the water : the hand or counterpoise, that supports it in that posture, must have a far greater strength then needed to sustain it, when it was quite under water ; because that now the imaginary plain *PQ*, passing by the bottom of the bucket, has on its other parts but a little depth of water, as from *L* to *P*, or *M* to *Q*, and consequently the bottom of the bucket, *H*, will scarce be press'd upwards above half as strongly as when the bucket was quite under water. And if it be raised to *O*, & consequently quite out of the water ; that liquor reaching no longer to the bottom

of the bucket, can no longer contribute to its supportation; and therefore a weight not only equal, but somewhat superiour to the full weight of the bucket, and all that it contains, (being all suppos'd to be weigh'd in the aire,) will be necessary to lift it clear out of the water.

But to dwell longer on this subject cannot but be tedious to those that have been any thing attentive to the former Discourses. I proceed therefore to our Authors sixth Argument, which is,

*Object. 6. That Horse-hairs, which are held to be of the same gravity with water, keep whatever place is given them in that Liquor; nor are depress'd by the weight of the super-incumbent water.*

*Answ.* Whether the matter of fact be strictly and universally true, is scarce worth the examining, especially since we find the difference in point of specific

cifick gravity, betwixt most Horfe-haires, and most waters, to be inconfiderable enough. But the phenomenon, fupposing the truth of it, is very eafily explicable, according to the Doctrin above deliver'd. For fupposing in the laft Scheme the body,  $R$ , to be bulk for bulk exactly equiponderant to water; 'tis plain there is no reason why that body fhould prefs the part  $S$ , of the imaginary Superficies  $IK$ , either more or lefs then that part  $S$  would be prefs'd, if, the body  $R$  being annihilated or remov'd, it were fucceeded by a parcel of water of juft the fame bulk and weight. And confequently, though all the water directly above the folid  $R$  do really lean upon that body, and endeavour to deprefs it; yet that endeavour being refifted by an equal and contrary endeavour, that proceeds ( as we have been but too often faine to declare ) from the preffure

exercis'd upon the other parts of the Superficies,  $I K$ , by the water incumbent on them; the body,  $R$ , will be neither depress'd nor rais'd. And its case being the same in what part of the water soever it be plac'd, provided it be perfectly environ'd with that Liquor; it must keep in the water (which in this whole Discourse we suppose to be Homogeneous as to gravity) the place you please to give it.

And, (to add That on this occasion) though Mathematicians have hitherto contented themselves to prove, that in case a Body could be found or provided, that were exactly equiponderant to water, it would retaine any assignable place in it; yet the Curiosity we had, to give an Experimental proof of this Truth, at length produc'd some glass Bubbles, which some Gentlemen here present have not perhaps forgot, that were (by a dexterous hand we employ'd

employ'd about it) so exquisitely pois'd, as, to the wonder of the Beholders, to retain the places given them, sometimes in the middle, sometimes near the top, & sometimes near the bottom of the water (though that were Homogeneous) for a great while, till some change of consistence or gravity in the water, or some of its parts, made the bubble rise or fall.

The Application of this, to what has been objected concerning Horse-hairs, being too easie to need to be insisted on, there remains to be dispatched our Authors seventh and last Argument, which is this.

*Object. 7. That, otherwise, all the inferiour parts of the water would be in perpetual motion, and perpetually expell'd by the Superior.*

*Answ.* But if, by the inferior parts, he means, such portions as are of any considerable bulk; the Answer newly made to the last objection (where we shew'd

shew'd that the body, *R*, would retain  
 its place any where in the water, and  
 consequently near the bottome) will  
 shew the invalidity of this Objection.  
 And unless we knew of what bignesse  
 and shape the Corpuscles of water are,  
 it would perhaps be to little purpose  
 to dispute how far it may be granted,  
 or may be true in the particles that  
 water is made up of. Onely this I  
 shall add, That, whereas this Learned  
 Authour mentions it as an absurdity,  
 that the lower parts of water should  
 be in perpetual motion: And *Stevinus*  
 himself, in the beginning of his *Hy-*  
*drostatical Elements*, seems to me to  
 speak somewhat inconsiderately of this  
 matter; and though, as I lately said,  
 I allow such sensible bodies, as those  
 whose gravity in water Writers are  
 wont to dispute of, to be capable of  
 retaining their places in water, if they  
 be *in specie* equiponderant to it: Yet I  
 am

am so far from thinking it absurd, that the inferiour Corpuscles of water should be perpetually in motion; that I see not how otherwise they could constitute a Fluid body, That restless Motion of their parts, being one of the generalest Attributes of Liquors; and being, in water, though not immediately to be *seen*, yet to be easily *discover'd* by its Effects: As, when Salt, being cast into water, the aqueous parts that are contiguous to it, and consequently near to the bottom, do soon carry up many of the saline ones, to the very top of the water; where, after a while, they are wont to disclose themselves in little floating grains of a Cubical shape.

But, of this restless motion of the parts of Liquors having professedly treated elsewhere already; I shall add nothing at present: But rather take

*In the History of fluidity & firmness*

notice

notice of what our Authour subjoyns to the last of his Arguments, (as the Grand thing which they suppose) in these words, *Ratio porro, a priori, hujus sententiae videtur esse, quia res non dicitur gravitare nisi quatenus habet infra se Corpus levius se in specie.* The erroneousness of which conceit, if I should now go about solemnly to evince; I as well fear it would be tedious, as I hope it will be needless to those, that have not forgot what may concern this subject in the former part of the now at length finish'd discourse; and especially where I mention those Experiments, which show, That neither a stone, nor Gold it self, when plac'd deep under water, would sinck in it, if the Superiour water, that gravitates on it, did not contribute to its depression.