

# PHILOSOPHICAL TRANSACTIONS.

December 27. 1675.

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*Ten New Experiments, made and communicated by the Honourable Robert Boyle Esquire, about the Weaken'd Spring and some Un-observ'd Effects of the Air: Where occur not only several Tryals to discover, whether the Spring of the Air, as it may divers wayes be increased, so may not by other wayes than Cold or Dilatation be weaken'd; but also some odd Experiments to shew the Change of Colors producible in some Solutions and Precipitations by the Operation of the Air. Some Experiments made in the Air-pump upon Plants; directed and tryed by the same persons, mention'd in Numb. 119. An Account of some Books: I. Francisci Willughbeii de Middleton Armigeri, è Reg. Societate, ORNITHOLOGIÆ Libri tres, &c. II. The Comparative Anatomy of the TRUNKS of Plants, together with an Account of their VEGETATION grounded thereupon, by Nehemiah Grew M. D. and Fellow of the R. Society. III. The ROYAL ALMANACK, &c. by N. Stevenson, one of his Majesties Gunners.*

*New Experiments about the weaken'd Spring and some un-observ'd Effects of the Air: Made and communicated by the Honourable Robert Boyle Esq.*

— **A**S for the not yet communicated Tryals that I made in prosecuting my Design of discovering or observing some *latent* Qualities of the *Air*, I will not deny you some of them, as imperfect as they yet are, but will venture to send them you, as my Notes or my Memory suggests them to me; not only, because without being compleated they may be fit enough to countenance

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*suspicions* (for you know, that I do not call them so much as *opinions*,) but for a weightier inducement, to be told you at the end of this Paper.

The two chief things aimed at in the imperfect Attempts I now send you, were to discover; *first*, whether, as some Corrosions of Bodies do in close Vessels *increase* the Spring of the Air (as I long since noted them to do,) so some other Corrosions may not, by a contrary or some other way, *weaken* the Spring of the Air; and *next*, whether in some Solutions and Precipitations the Air on the account of some unobserved Quality may not be found to produce some *Phænomena* not yet taken notice of.

In order to each of these Enquiries, I shall mention a few Tryals, though without curiously sorting them, because sometimes in the same Experiment both those Attempts were jointly prosecuted.

You may remember that in some of my formerly published Tryals I acquainted you with an odd *Phænomenon* of the *Change* of *Color* producible in solutions of *Copper* by the operation of the Air; I shall now add what further *Phænomena* my Memory or Notes supply me with, about the Subject of that and the like Experiments.

*Experiment the First.*

We took filings of crude Copper, and put them into a Crystallin Glass of a Conical shape, into which we poured some strong Spirit of Salt, (that was fitted for our peculiar purpose) to the height of about a fingers breadth above the Filings; and then closing the Vessel with a Glass-stopple exquisitely fitted to it, we suffer'd it to continue unmoved in a Window for some dayes, till the liquor had both obtained a high and darkish brown colour by the solution of some of the Copper, and lost that colour again, growing clear like common water, (which is it self a somewhat odd Phænomenon;) and then taking out the stopple, (without shaking the liquor) and thereby giving access to the outward Air, we perceived, (as we had conjectur'd) that the upper surface of the liquor did in a few minutes re-acquire a darkish brown colour, which penetrating deeper and deeper, at the end of about a quarter of an hour the whole body of the liquor appear'd to be likewise tinged. The Conical Glass being again well stoppt, the *Menstruum* did again in very few daies let fall or otherwise lose its tincture; which, the stopple being taken out, it re-gained as before. Nor were these two the only Tryals I made with the like success for the main; but  
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afterwards being desirous by a further Tryal to resolve a doubt I had, I kept the Glass yet longer in the same place with the same Filings and *Mensstruum* in it for (if I mis-remember not) a moneth or two together; but observed not, that the liquor would any more grow clear.

*Experiment the Second.*

Having taken such a Glass, as is mention'd in *Experiment the first*, wherein the liquor was grown clearer than is usual, and had probably been so a good while before, (for the Vessel, having been hid by others which stood before it, had been for some weeks forgotten;) We took out the stopple and left it open for about half an hour, but did not perceive the liquor to have acquired any colour so much as at the top. Whether this proceeded from the long debarring of commerce with the fresh Air, or from some other cause, being unable to wait the event as long as would perhaps be requisite, I thought fit to try, Whether the Air had already had some operation upon the liquor, though it did not yet appear; and accordingly putting in the stopple, I left the Vessel closed for two or three hours, and at my return to visit it, I perceived, that it had acquired a faint colour tending to a *green*; wherefore taking out the stopple again, I open'd its Commerce with the outward Air, leaving the Glass unstopt for 20 or 24 hours, but found, that in all that time it had not re-gained its wonted dark colour, but was only arrived at a green, deep enough, but not true nor very transparent.

This Observation being made in the same Vessel that had been formerly employed, suggested to us an Enquiry, Whether the advanced time of the year, which was the middle of *October*, might not have an interest in the slow and imperfect success of this Tryal.

*Experiment the Third.*

Some strong Spirit of Salt having been kept upon Filings of Copper till the solution was come to be of a dark brown colour, about three spoonfuls of it by guess was put into a Receiver that might hold eight or ten times as much: Being kept *in vacuo* (if the time be rightly remember'd) about half a year, it retain'd its colour, but the Vessel being open'd and the External Air permitted a free access to it, the solution in about an hour was turn'd into a fine transparent green, though no Precipitation of any muddy substance appeared by any Sediment to be made.

*Experiment the Fourth.*

In one of that sort of Conical Glasses that has been already more than once describ'd, we had put upon some Filings of Copper a convenient quantity of our *Spirit of Salt*; and though we observ'd, that for a great while it would not part with its deep and somewhat muddy tincture; yet we left it in the window for many weeks longer, and at length, towards the latter end of *December*, we found it to have lost its tincture, so much that the liquor appear'd like common water. Upon which observation, though the time of the year were unpromising, I thought fit to try, whether the Air in that season would not have some, though perhaps but a slow, operation on the Saline Spirit, and accordingly taking out the Glass-stopper to give free-access to the outward Air; we observ'd, that in some hours its operation on the liquor was scarce sensible, but within about 24 hours the *Menstruum* had acquired not just its former colour, but a somewhat faint and moderately transparent green: So that this tinted *Menstruum*, as it had been very slow in losing its colour, so it did but slowly and imperfectly re-acquire it.

**I** Have not in the foregoing Experiments made mention of any *Phænomena* of them relating to the Spring of the included Air, because I do not remember, that they were such as invited me to draw any positive Conclusion from them, and my silence on this occasion may be the more allowable, because the way of further making such Observations may be sufficiently deduc'd from the ensuing Tryals; in reciting of which I alter very little, and in some of them not at all, the expressions I find them register'd in, though more than once the *Phænomena* that relate to the Air's Elastic power be mingled in the same Experiment with the mention of its operations upon Colours.

The Spring of the Air and its variations, by the wayes now known to many of the Curious, being things that manifestly appear to have a notable interest in divers *Phænomena* of Nature, whose Causes, if not themselves also, were unknown to former Philosophers; it seem'd an Attempt, though not very promising, yet worth the making, to try whether the Spring of the Air, which may divers wayes, as by Heat, Compression, &c. be increas'd, may not by some other way than Cold and Dilatation be weaken'd: And having often found *Menstruums* that corrode Metals, so as to produce bubbles to invigorate the strengtb

of the Spring of the Air included in the Vessels, wherein the solution was made, I thought fit to try, whether in some metalline Dissolutions, wherein I had observed that few or no visible bubbles at all were produced, the Spring of the neighbouring and included Air would not be debilitated; and in order to this were made the following Tryals.

*Experiment the Fifth.*

[WE took some Filings of Copper, and putting them together with a *Mercurial gage* \* in a Conical Glass fitted with an exactly ground stopple of the same matter, (which was Crystalline) we poured on the Filings as much rectified *Spirit of fermented Urin* made *per se*, as sufficed to swim an inch or better above them; then carefully stopping the Glass, coming to look on it many hours after, we perceived that the Mercury in the seal'd leg was considerably depressed, and gently drawing out the stopple to let in the outward Air, we perceived that access to have a manifest effect upon the Mercury.]

\* About such Glasses see *Experiment the Seventeenth* in the Continuation of our New Physico-Mechanical Experiments.

But this will be better understood by the more Circumstantial Experiment that insues.

*Experiment the Sixth.*

[We took a Crystal Glass of an almost Conical shape, and capable of containing between five and six ounces of water, and furnished with a stopple of the same matter, that by grinding was exactly fitted to it. Into this we put a convenient quantity of clean Filings of good Copper, on which we poured as much strong Spirit of (fermented, or rather) putrifi'd Urin, as served to swim about an inch above the Copper, and having let down a *Mercurial gage*, so that it leaned upon the bottom and side of the Glass, we closed it very well with a stopple, and set it in a quiet and wellenlighten'd place, having taken good notice at what mark the *Quicksilver* rested in the open leg of the Gage. This done, we let the *Menstruum* alone to work upon the Filings; which it did, as we foresaw, somewhat slowly and very calmly *without* producing any noise or sensible bubbles, acquiring by degrees a very pleasant blew colour, and the Glass being kept quiet in the same place for two or three daies longer, the liquor, as I conjectur'd would

See the reference in the foregoing Experiment.

would happen, began to lose of the intensness of its colour, which by degrees grew fainter and fainter, till at the end of three or four daies the liquor was grown very pale, and left me little doubt but that, if I would have staid some daies longer, it would have lost the remaining Eye of blew, and have lookt almost like common water. But being unwilling to tarry so long, I took out the stopple, that the Air *without* the Glafs might have access to that *within*; and leaving the Vial in the same place and posture, my expectation was somewhat answer'd by finding, that within four or five minutes, if not less, the upper part of the liquor, that was contiguous to the Air, had acquired a fine blew colour, which descending deeper and deeper, before the end of the tenth minute had diffused it self, but somewhat weaken'd, through the liquor, whose colour was suffer'd to deepen for a while longer; so that in less than a quarter of an hour from the first unstopping of the Vial, the liquor was grown to be throughout of a rich Ceruleous colour, which grew almost too opacous within a few minutes longer: When carefully closing the Vial again with the same stopple as before, we set it aside in the same place, where, the included Air being denied all Commerce with the External, the liquor began again within two or three daies to lose of its colour; and, to be short, afforded me the opportunity of making a *second* Experiment, much like the former. And the like success I had, for the main, in a Tryal or two made in another Glafs with another portion of the same Spirit of Urin, put upon the Filings of Copper; so that the Experiment was, in all, made divers times, as well when I was not, as when I was alone: And particularly, once to be sure that the *diurnal* Air as such had not any great interest in the *Phenomenon*; I made the Tryal successfully about Nine a clock at night in the presence of so well-known a Witness as the Learned Secretary of the *Royal Society*.

One Circumstance I forgot to take notice of, which was, that in most of these Experiments I forbore to shake the Glafs, lest it should be suspected, that the Agitation of the liquor might have raised some little fine powder that might have been supposed to have been precipitated out of the tincture, and, being thus mingled with the liquor again, restore it to its former colour; but in truth I did not perceive any such powder to be precipitated. And though, to obviate the objection, I forbore to shake the Vial; yet

yet I justly supposed, that if, by the agitation of the liquor, more parts of it should be quickly exposed to the action of the Air, the Coloration would be hasten'd, which upon tryal appear'd to be true.]

*Experiment the Seventh.*

[Experience having made me think it likely, that strong Spirit of *Sal Armoniac*, made without Quick-lime, would operate more nimbly and more powerfully on that metal than our Spirit of Urin had done; we took such a Conical Glass, as has been lately described, and covering the bottom of it with a convenient quantity of Filings of good Copper, we poured on them as much strong Spirit of *Sal Armoniac* as served to swim about a fingers breadth above them; and, having let down such a Mercurial Gage as is formerly mention'd, so that it leaned upon the bottom and side of the Glass, we closed it very well with a stopple and set it in a quiet and well enlighten'd place, having taken good notice at what mark the Quicksilver rested in the open leg of the Gage: This done, we let the *Menstruum* alone to work upon the Filings, which it did, as we foresaw, somewhat slowly and very calmly, without producing any noise or sensible bubbles, acquiring by degrees a very pleasant blew colour, and afforded us also the Phænomenon we chiefly lookt after; which was, that repairing from time to time to the window to see what past, we perceived, that for two or three daies together the Mercury in the seal'd leg of the Gage did, though very slowly, descend till it appear'd to be near a quarter of an inch lower than at first; and probably the depression might have been greater, if some indiscreet body or other had not, by tampering with the Glass, disturbed the Experiment; whose event yet seem'd sufficiently to argue, that the Spring of the Air, contained in the cavity of the Glass, and communicating with that in the open leg of the Gage or Syphon, was weaken'd in comparifon of that in the closed leg, which by the Hermetic Seal on one side, and the Quicksilver on the other side, was kept from such Communication.

And because I thought, it might be suspected, that the Phænomenon might be referrable to some Inequality in the preffure of the Air, occasioned by the greater operation of the heat of the day on the more imprison'd Air of the Gage, than on that more immediately included in the cavity of the Vial; I was careful to observe

observe, whether the Depression did not continue at differing times of the day, and found it to do so, as well at night as at noon, though at this last named time the Sun shined hot upon the place and Vessels too.

This Experiment was made, in all, four or five times, though not alwaies with equal, yet still with some, success, the Mercury in the seal'd leg of the Gage being sometimes more and sometimes less, but alwaies manifestly deprest; which Phænomenon was confirmed by the Observation we more than once made of the sudden return of the Quicksilver to it former station, upon the unstopping of the Glass, to give free admission to the outward Air.

*Experiment the Eighth.*

Considering, whilst I was about these Tryals, that *Spirit of Vinegar*, though in working upon Coral and some other Bodies it not only produces store of bubbles, but also, as I have elsewhere

\* To the better understanding of this, the ensuing Tryal may much conduce; and therefore is transcribed out of another paper, to which it properly belongs.

A Mercurial Gage having been put into a Conical Glass whose bottom was covered with beaten Coral, some Spirit of Vinegar was poured in, and then the Glass stopple, which was very well ground, closing the neck exactly, we observed, that upon the working of the Menstruum on the Coral, store of bubbles were for a good while produced, which successively broke in the cavity of the Vessel, and their accession so constipated the Air, that they compress'd the Air imprison'd in the closed leg of the Gage three marks or Divisions, which I guessed to amount to about the third part of the extent it had before: But some hours after the Corrosion had ceased, the Compression made by this newly generated Air grew manifestly fainter, and the imprison'd Gage-Air drove down the Mercury again 'till 'twas deprest within one division of its first station; and thereabouts, or little lower, continued five or six dayes; so that in this operation there seem'd to have been a double Compressive Power exercised; the one transient, by the brisk agitation of Vapours or Exhalations, and the other durable, from the Aerial and Springy Particles, either produced or extricated by the action of the Spirit of Vinegar upon the Coral.

deliver'd \*, a somewhat odd kind of Elastic Substance, yet being put upon *Minium* it was wont, in my Observation, to work calmly and without producing froath; I thought fit to make tryal, whether this calm and silent solution of *Minium* would be accompanied with a permanent change of the Airs Spring: The Event I find thus set down:

[ A pretty quantity of *Spirit of Vinegar* being put upon *Minium* in a Conical Glass, furnished with a Glass stopple and a Mercurial Gage, continued divers dayes without any sensible Depression of the Mercury in either leg, nor did any change appear in the



the *Gage*, upon the removal of the stopple, though 'twas evident by the great sweetness acquired, that it had made a Solution of a great portion of the *Minium*.]

*But to return to our Tryals upon Copper ;*

*Experiment the Ninth.*

[We took some Filings of Copper, and in a Vial capable of holding some two or three Ounces of Water, we poured on them strong Spirit of *Sal Armoniac* made without Quicklime, till the liquor reached near an Inch above them. This was done about the twentieth of *August* on the *Friday* before Noon, and the following *Munday* presently after Dinner it had acquired a deep Blew tincture, and lost again so much of it, that 'twas pale almost like common water: Then to satisfy a *Virtuoso*, I unstopt the Vial, desiring him to place his eye level with the surface of the liquor, which in a minute of an hour or less appeared, to his surprize and wonder, to have acquired a deep Blew tincture, that reached downwards to the thickness of the back of a knife, the whole liquor becoming of the like Colour in four or five minutes more, and the Glass being presently stopt again, and left where 'twas before, appeared not at the end of nine daies to have lost its tincture; though now and then within that time it seemed manifestly paler than when the Vial was stopt.]

**N**One of the former Tryals with Spirit of *Sal Armoniac* having been made in an *Hermetically sealed Glass*, it will not be amiss both to diversifie and to confirm our Experiments, by setting down the success of one made in such a Vessel:

*Experiment the Tenth.*

[We took a round Vial holding about eight Ounces of water, and having put into it Filings of Copper and a Mercurial *Gage*, we poured on the Metal strong Spirit of *Sal Armoniac*, till it reached to a good height in the Vial, which then being *Hermetically sealed up*, was set by in a South-window, where it quickly ac-

quired a deep Blew tincture: There it stood about twelve daies, before that tincture, which decayed but slowly, did little by little grow so diluted that the liquor was pale and almost like water: During this stay of the Glass in the window, the Mercury in the open leg appeared to be impell'd up, and when after nine a clock at night, (which time I chose to try whether the Nocturnal Air, as Nocturnal, would have any thing to do with the Phænomenon,) the Hermetic Seal was broken off; immediately upon which there was produced a noise, and the Mercury in the shorter and closed leg was briskly impell'd up, by our gueſs, near three eights of an Inch, and though the Orifice at which the Air had access was scarce wide enough to admit a middle seized pea, yet within a minute and half the surface of the liquor being held between the Eye and the Candle, appeared to have acquired a very lovely and fair Colour, which reached downwards a quarter of an Inch; so that the Vial seemed to contain two very differing liquors swimming on one another, and the Coloration piercing deeper and deeper within five Minutes in all, the whole liquor had attained a rich Blew colour.]

*With this Experiment I shall conclude this Paper: For, though I made several other Tryals, with the same design that I made the foregoing ones, as with Spirit of Niter, and Minium, Spirit of Vinegar and Copper; yet a present want of time hinders me from troubling you with them, which I the rather forbear to do, because I fear, they would prove less satisfactory than those I have set down; which themselves must, to a less discerning eye than yours, appear very imperfect, notwithstanding that prolixity in reciting some of them; which I was obliged to by my not yet knowing, in such odd attempts, what Circumstances might safely be omitted. But such as they are I send them you, who by your diffused Correspondency have great opportunity to get them made, if you think them worth it, by Curious persons in several Countries, various manners, and differing seasons of the Year: And, however the things I send you be but trifles, yet their Novelty may perhaps excite the Industry of others, and give rise to further Inquiries.*