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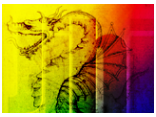

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Vacui ratione
Observability and Causal Powers of a Nonentity

by
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Vacui ratione
Observability and Causal Powers of a Nonentity *

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The notion of the vacuum is transmitted to early modern natural philosophy mainly in two versions: macroscopic void space, as a component of standard atomist theories; and microscopic void spaces interspersed within matter, that according to the pneumatic literature can be forcefully collected into artificial vacua of the first sort. Both kinds of natural vacua are directly or indirectly connected to causal effects, that may be attributed to different causal powers, directly or indirectly pertaining to the vacuum itself. The question also arises whether the purported physical vacuum ought to be observable, either directly or through the presence versus the testable absence of the same causal powers. In contrast to natural philosophy, within the medical discourse—more open to different interpretations of phenomena connected with the vacuum—even the question of observability might present unexpected facets.

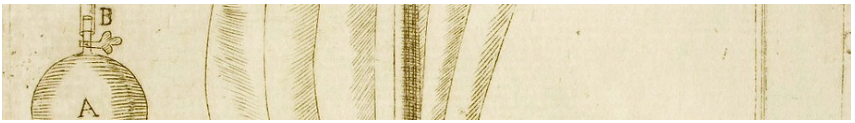
Ancora non lo sai
... non lo sospetti ancora
che di tutti i colori il più forte
il più indelebile
è il colore del vuoto?[1]

'Vacui ratione' means 'by reason of vacuum' or 'because of vacuum'. It appears sporadically in the writings of early modern philosophers,

* This text was first presented in a seminar on "Natureza e causalidade" held in January 2013 in Lisbon in the framework of the project "A natureza no pensamento médico-filosófico na transição do século XVII ao XVIII" of the Fundação para a Ciência e a Tecnologia. I thank Adelino Cardoso for permission to publish it here and the FCT for support.

[1] "Do you not still realize | ... do you still not suspect | that of all the colors the strongest | the most unerasable | is the color of the void?" (Vittorio Sereni, "Autostrada della Cisa", *Stella variabile*, 1981).

scientists, or physicians. They used it, somewhat contraditorily, in connection with the hypothetical causal powers that might be attributed to the vacuum, *i.e.*, to void space, or to the simple possibility of a vacuum being brought into existence. But since void space was not considered to exist positively, and according to many could not and did not exist at all, it neither had any positive nature nor would be capable of action—that is, as a mere 'privation', it could not possess causal powers.



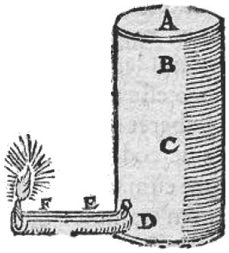
As an example of both the expression and the translation, I would instance Giovanni Battista Della Porta's *Magia naturalis*, translated into English as *Natural Magick*. Let a vessel, turned with the mouth downwards, be filled with water, and the mouth of it be put into a broader vessel full of "the same liquor, or with another that is heavier": the water, says Della Porta, will not descend out of the first vessel, "by reason of Vacuum" (Della Porta 1658, l. XVIII, c. I; 1957, 382–383). In the Latin edition, we read precisely: "ratione igitur vacui" (1619, p. 577)[1].

His explanation is characteristically ambiguous: "Vacuum is so abhorred by nature", says Della Porta in a very traditional discussion of the effects of the *horror vacui*, "that the world would sooner be pulled asunder than any Vacuity can be admitted". Nevertheless, some mighty power is concealed in this impossibility: "from this repugnancy of Vacuum proceeds almost the cause of all wonderful things, which it may be I shall show in a book on this subject. It is the force of Vacuum that makes heavy things ascend, and light things descend contrary to the rule of nature" (Della Porta 1957, 382).

An analogous, but more complex reference, comes from Girolamo Cardano's *De subtilitate* (1550). In this encyclopedic work we find the expressions *vacui*

[1] In the Italian version: "per ragione del vacuo" (Della Porta 1677, p. 514). The upturned vessel is the most classic of examples already since Hero of Alexandria's *Pneumatica* (Hero 1899, 4; 1851, 2); see also Philo of Byzantium 1974, 80.

necessitate (Cardano 2004, 62), *vacui fuga* (63), and also *vacui ratione* (62, 92, 211). The occasion is given, in particular, by the description of a famous lamp that had been devised by Cardano himself: it is known in fact as Cardano's lamp, and it was a fountain-feeding device that used 'vacuum' to regulate the flow of oil.



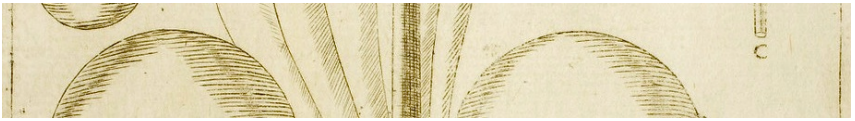
This lamp is of cylindrical form, is completely inclosed, and has only one opening D through which the oil may be poured in until it is entirely filled. It is made wholly of tin. When it is inverted in the position here shown, the oil cannot come out through the opening D. For, if it did come out, the part of the oil at C, because of its weight and the nature of a vacuum, would descend to D, that at B to C, and that at A to B; therefore, a vacuum would be left at A. (Cardano 1934, 86).

The 'nature' of the vacuum corresponds in the translation to what in the Latin text sounds repeatedly *vacui ratione*:

Hac ratione lucerna mirabilis excogitata est, turris forma undequaque conclusa, soloque foramine D, contenta, per quem oleum ipsum infunditur, donec tota impleatur. Solida est ex stanno, cumque convertitur, ut nunc iacet, oleum effundi per D, non potest. Nam si effunderetur, quem est in C, descenderet gravis et vacui ratione ab D: et quem esset in B, ab C: et quem esset in A: ab B: igitur vacuum in A, relinqueretur. Ne igitur vacuum in A, relinquatur, manet: quare etiam in B, oleum, et in C et in D: nihil erit effunditur. Sed quonam pacto igitur dum accenso ellychnio in F, oleum consumitur, per E, canalem ex ipso D, exire potest, itaque ad vacui rationem rursus pervenire videtur necessarium? sive enim trahatur caloris vi, seu sponte descendat oleum, quantum ad vacui rationem attinet, nihil interesse videtur. (Cardano 2004, 62).

The fuel will come out slowly, in the right amount, through the small hole D, and keep the flame for a long time. Why does not the oil come out all together? *Vacui ratione*, because of the vacuum: "Now, that a vacuum may not be left at A, the oil remains there, and also at B, C, and D and, therefore, nothing flows out" (Cardano 1934, 86). A vacuum cannot be allowed to form at the top of the reservoir: void space, which is just an absence, must be kept absent from the place

labeled with A inside the tower-like lamp. So the oil regulates its movements in view of the persistent absence of an absence: the possible existence of a void seemingly has some sort of power and exerts it in limiting the movements of the oil[1].



1 Apropos of these causal powers that operate by reason of the vacuum, it would seem that we have to do with at least two kinds of causation, final and efficient, that in the functioning of the lamp appear to coexist and cooperate. But can an absence have causal properties, either final, or efficient, or both?[2]. It is a very ancient problem, just as that of the vacuum in general.

A few theoretical entities of medieval and early modern thought shared with the vacuum a condition of uncertain existence, but might enjoy causal powers nonetheless. The distance between two points, even in a vacuum, was hold by some (for instance, Roger Bacon) to cause the motion between them to last for some time; whereas Aristotle thought that in a void space, due to the absence of a medium, motion would be instantaneous. It is what the best study on the

[1] And when the lamp is lighted, in fact, no vacuum needs to be created at the top of the reservoir: instead, the space is filled by the vapors of the heated oil: "ignis calefaciendo rarius et tenuius efficit oleum: id rarius factum intumescit, et per D, foramen exuberat, levissimaque eius pars interim ascendit ab summum lucernae, ubi A, scripsimus: quae cum multo aëre referta sit, locum aëre complet, et sic sensim augetur, dum oleum effunditur" (Cardano 2004, 62). But in reality the oil came down unevenly: nearly a century later, Robert Boyle was still busy perfecting Cardano's design (Boyle 1681).

[2] In early modern Aristotelism, it is a commonplace that causes of different kinds can be cause of each other conversely: f.i., an efficient cause can produce the final cause and the final cause can operate on, or bring into being an efficient cause. Quoting from a handbook of metaphysics well known to scholars in the history of 17th century German philosophy: "Causae sunt sibi invicem causae" (Stahl 1651, III, 18: 108). Of course, "Causa causae est etiam causa causati" (III, 12: 84).

history of vacuum, void space, and cognate concepts calls "the causal nature of the *distantia terminorum*" (Grant 1981, 27-28)[1].

But the very same people that attribute causal powers to the distance, will deny to the vacuum those same powers, because, differently from other similar entities, vacuum is really *nothing*. It is only a *terminus privativus*, that is, as we said before, a term denotating an absence; so that cautions normally applied to nothingness are applied to it as well. In the definition of vacuum, 'is' equates to 'means', and 'vacuum' means, but *is* not, 'a place devoid of bodies'. No inference of the form 'if *a is b* then *a is*' can be drawn from 'vacuum is a place that is not filled by a body' to 'vacuum is'[2]. Roger Bacon writes that a negation cannot be the cause of an affirmation; and *ne fiat vacuum*, 'in order to avoid the production of a vacuum', is a negation[3]. Thereby, the abhorrence of the void cannot be said to be the cause of any effect due to the actions of nature against it.

That does not mean that no one would write about the vacuum and its nature, as it were something connected with possible actions. We shall leave Grant here, since my preferred example comes from Ramón Lull, that he does not consider. Among other abstract terms that Lull introduces in his *Kabbala*, we meet 'vacuity' (*vacueitas*), the act of the void (i.e., the character of being void). It is not a purely logical denomination: it denotes the reason why vacuum acts essentially as a vacuum. Vacuum is meant here as a being, the essence of which is being a space without bodies. So it is implied that it is the nature of the vacuum that explains the way the vacuum acts[4].

There are different ways to explain the physical movements connected with the principle of the vacuum without resorting to a causal role of the vacuum itself. A most typical explanation was put forward, within early modern Aris-

[1] Grant's book concentrates more on ancient and medieval theories, and but a chapter is devoted to the 16th and 17th centuries; it can be complemented with Garber et al. 1998.

[2] "Sciendum quod hoc nomen 'vacuum' est terminus privativus et valet in significando tantum quantum hec oratio: locus non repletus corpore et igitur quando dicitur vacuum est locus non repletus corpore, ly est ponitur pro significat. Et ideo non sequitur: vacuum est locus non repletus corpore, ergo vacuum est" (Albert of Saxony, *Phys.*, l. IV, q. 8, quot. in Grant 1981, 269).

[3] "Set negacio non est causa affirmationis: 'ne fiat vacuum' est negatio" (R. Bacon, *Opera*, III, 219, quot. in Grant 1981, 304.)

[4] "Vacuieitas est actus vacui, ratione cuius vacuum non agit nisi vacuum. Est autem vacuum ens, cuius esse est spacium corpore privatum, et habet sua correlativa[:] vacuativum videlicet, vacuabile, et vacuare" (*Kabala Lulliana*, tr. III, c. I; Lull 1609, 84).

totelism, by the slightly unorthodox Giulio Cesare Scaligero, in his *Exoteric exercitations* written against Cardano. Scaligero discusses the *metus vacui*, also *horror* or fear of a vacuum, which is the well-known label for the explanation of the inexistence of vacua in nature by a tendency of natural phenomena to impede their existence. According to him, the idea that nature fears the vacuum is correct in the intention, but the formula itself implies an error. It is right to say that nature brings about the motion, and not the vacuum, since the latter is but nothing. Nevertheless, the correct explanation is that this happens out of fear, not of the vacuum, but of rarefaction:

> Quod bene sentiebant, male sunt eloquuti quidam. Aiunt enim: a vacuo motum fieri. Alii melius: a Natura motum cieri metu vacui. Illos merito reprehendis. Nam quibus rationibus, aut potius machinis, vel moliri motum, vel rebus afferre possit ipsum vacuum, si nihil est? Posteriores vero minus consulto a te castigantur. Quippe sic scribis: Non metu vacui, sed raritatis, agitari motu corpora eam in partem, ubi sine corpore vacuum fuisset- (Scaligero 1557, *Ex.* VIII, c. 18*v*)

Then again, that does not explain rarefaction. But vacuum theories had always appealed to natural philosophers exactly because they helped explain those phenomena that implied some sort of 'non-being', like rarefaction and condensation. Along with the outer space surrounding the cosmos, and the intramundane universal void space where atoms would move, a third kind of vacuum had been devised to that purpose by the Greeks: invisible void spaces between particles of matter.

Such theories—in all bodies hard, soft, and fluid, very small solid particles are divided by very small regions of vacuum—were attributed to Erasistratus, a renowned physician and an atomist; and specially to Strato of Lampsacus. According to Simplicius, Strato had tried to show that the void exists interspersed in every body, so that bodies are not continuous. Be the latter a correct attribution or not, it will be one of the main sources for the post-Greek tradition of interspersed vacuum[1].

2.

Interspersed vacuum is also known, from Hero of Alexandria, as 'Hero-

[1] See Simplicius, *In Phys.*, 639, 10 ff. (Wehrli 65a). On Strato's theory of micro-voids see Algra 1995, 60-69; Sanders 2011.

nian void'. Hero had written in his *Pneumatica*: "The particles of the air are in contact with each other, yet they do not fit closely in every part, but void spaces are left between them, as in the sand on the sea shore: the grains of sand must be imagined to correspond to the particles of air, and the air between the grain of sand to the void spaces between the particles of air". That explains how the air can be compressed, and the working of cupping-glasses, those egg-shaped cups used by physicians, in which by heat a partial vacuum is created to produce a local suction (Hero 1851, 2-3; 1899, 6-8).

Precisely the same concept reappears during the Renaissance in the works of Francesco Patrizi: "Sicut inter arenae particulas, aer minutim est interspersus, ita cogitandum est inter aeris particulas, spacii inanis portiunculas esse interspersas" (1591, c. 63*r*)[1].

Let us consider some passages of the introduction to an Italian translation of Hero's *Pneumatica*, which shows a perfect awareness, even in an early modern humanist scholar imbued with Aristotelian physics, of the peculiarity represented by Hero's theory: the translator, Alessandro Giorgi, observes that "there is only one operation that can be attributed to the vacuum: when you have a vacuum no local motion is possible"; which in turn proves the inexistence of the vacuum, "since Nature does not allow it to exist, because it would be idle". Hero was not ignorant of this, he knew Aristotle for sure, but to explain pneumatic phenomena he resorted to the opposite theory: "With all this, our Hero is of a different opinion; and he tries to prove with reasons and arguments from experience that the vacuum is fragmented into many small particles, which are dispersed among the mass of the other natural bodies; and that those particles of disaggregated vacuum could be united together by some violence"[2].

[1] "Just as air is interspersed minutely between the particles of sand, so must it be thought that tiny bits of empty space are interspersed between the particles of air" (Brickman 1943, 232). Patrizi thinks, as many others did at the time, that water contracts when it freezes, and he accounts for it by the particles of water withdrawing into the interspersed void spaces. On Patrizi, see Grant 1981, 97-98; Henry 2001. He was not the first after Antiquity to defend the existence of interspersed vacua; it had been done f.i. by Nicolas d'Autrecourt (see Grant 1981, 74 ff.).

[2] "[D]ato il vacuo, non si può altrimente fare movimento locale. Oltra di questo non si può attribuire al vacuo operatione alcuna; adunque non è, che se fusse, non permetteria la natura, che stesse otioso, come non lo permette a l'altre cose, che hanno l'essere. Con tutto questo, tiene diversa opinione il nostro Heroe, e sforzasi di provare con ragioni, e prove sensibili, che il vacuo si trovi disgregato in varie particelle minute, sparse per la massa de gl'altri corpi naturali, e che quelle

Giorgi clearly understood that this interspersed vacuum can be operated on—the passive power to be united will be used in pneumatic operations by engineers; certain operations will become possible, some further powers will be activated—and that this is the most important disagreement between the two theories.

3

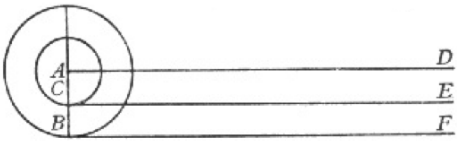
A FINE example of a scientific application of the theory of interspersed vacua is found in Galileo Galilei's *Discorsi e dimostrazioni su due nuove scienze* (1638). Galilei tried to solve some of the most traditional problems of atomism—density, rarity, and cohesion—while also revisiting the relation of the curved to the straight in geometry (a class of problems that had inspired among others Cusanus' *De mathematica perfectione* and were being treated at that time by his scholar Bonaventura Cavalieri by means of 'indivisible elements'). Galilei's solution was both geometric and physical, as it was customary for him: he introduced the "indivisibili vacui", which can mean 'indivisible vacua', but also 'void indivisibles'.

The late Scholastic had discussed at length the possibility of unextended atoms (in Latin *indivisibilia*) as the ultimate components of the continuum: they attributed this doctrine to Zeno of Elea and considered it an alternative to Aristotle's continuum theory. In the 17th and 18th century, this became a widespread flavor of atomism[1].

particelle di vacui disgregati, si possino con qualche violenza riunire insieme. Il che non credo, che faccia per non havere veduto quanto ne scrisse Aristotile, che già era stato prima di lui al mondo, e conveniva, che li suoi scritti fussero pubblicati; ma più tosto, perché si trovasse obligato a qualche altra setta, o vero forse, perché con questi principii parve a lui, di potere più facilmente salvare, e rendere la ragione, di quanto si vedeva succedere intorno alli suoi Spiritali" (Giorgi 1592, c. 6 *v*).

[1] See Pasini 1994.

Both kind of problems are connected in a famous paradox known as the *Rota Aristotelis* ('Aristotle's Wheel'), since it was described in the *Mechanical Problems* that were traditionally included in the Philosopher's corpus: "A difficulty arises as to how it is that a greater circle when it revolves traces out a path of the same length as a smaller circle, if the two are concentric"[1].



In any finite portion of a geometric or physical continuum, according to Galilei, there are infinite many indivisible elements, or 'indivisibles'. They are not considered as infinitely small (a denomination that comes about some forty years later), but, in his own words, *non quanti*, 'devoid of magnitude'. In the *rota Aristotelis*, two circumferences of different length ought to touch each and every point of the same length of line: apparently the inner one must slide. According to Galilei, all lines, both curve and right, are made of unextended indivisible elements that are alternately 'void' and 'full'; in his mind this allows for the required stretching. By the way, he has already shown that two infinites can paradoxically correspond element to element, just as natural numbers and their squares do (Galilei 1890-1909, VIII, 93).

E qui voglio che notiate, come risolvendo e dividendo una linea in parti quante, e per consequenza numerate, non è possibile disporle in una estensione maggiore di quella che occupavan mentre stavano continuate e congiunte senza l'interposizione d'altrettanti spazii vacui; ma imaginandola risoluta in parti non quante, cioè ne' suoi infiniti indivisibili, la possiamo concepire distratta in immenso senza l'interposizione di spazii quanti vacui, ma sì bene d'infiniti indivisibili vacui. E questo, che si dice delle semplici linee, s'intenderà detto delle superficie e de' corpi solidi, considerandogli composti di infiniti atomi non quanti: che (…) se intenderemo l'altissima ed ultima resoluzione fatta ne i primi componenti non quanti ed infiniti potremo concepire tali componenti distratti in spazio immenso senza l'interposizione di spazii quanti vacui, ma solamente di vacui infiniti non quanti. (Galilei 1890-1909, VIII, 621).

[1] Aristotle, *Quaest. mech.*, XXIV; 1963, 387.

The division of the line into a number of quantifiable parts would not have solved the problem; but imagining the line resolved into parts that have no quantity, "that is, into its infinitely many indivisibles", it can be expanded by the interposition of "infinitely many indivisible voids". In natural bodies, unextended indivisible vacua would alternate with unextended matterly indivisible elements, or atoms. In Stillman Drake's translation:

> What is thus said of simple lines is to be understood also of surfaces and of solid bodies, considering those as composed of infinitely many unquantifiable atoms; for when we wish to divide them into extended parts, doubtless we cannot arrange those in larger space than that originally occupied by the solid unless extended voids are interposed. (…) But if we take the highest and ultimate resolution into the prime components, non-extended and infinitely many, then we can conceive such components as being expanded into immense space without the interposition of any extended void spaces, but only of infinitely many non-extended voids. (Galilei 1989, 33).

This theory did not die with Galilei. Among his followers, for instance, Borelli maintained that at any moment "innumerable tiny void spaces" are brought into being by the motions and bendings of fluid bodies between the hard particles that compose the latter; and since the vacua can't be filled absolutely instantly, of necessity they must have some duration[1].

4

Can such things be experienced, or tested by experiments? In principle, one would say that it is not possible: either something is there, or we have a vacuum; but how could a privation be tested? A possible answer is that exactly this absence could be put to test by looking for causal connection that it could not originate.

There had been hefty debates in Italy concerning the possibility to directly observe the presence of void space in Torricelli's experiments. Vacuum of ordi-

[1] "[C]ertum est, quod textura, ordo, et dispositio constipata particularum fluidi perturbatur dissolviturque, ut innumera spatiola vacua in instanti creentur. (…) est impossibile, ut aliud corpus fluidum accurrere possit ad replenda praedicta spatia vacua, quae creantur in instanti, dum motus aut disgregatio fluidi, quod conatur spatia illa replere, fieri debeat, in tempore; igitur est impossibile, ut subito spatia praedicta repleantur (…) necessario vacuitates aliquae, saltem per aliquod breve tempus, admitti debent" (Borelli 1686, 345). He further remarked that also for Cartesian subtle matter, ether, and porosity of unmoving bodies, void spaces are needed (346).

nary dimensions had been brought to the attention of Galilei and his school by the height limitation of water pumps. Torricelli substituted a column of mercury for the water column and demonstrated that there was a proportion between the height of the column and the weight of the liquid. But was there a real vacuum in the upper part of the glass pipe? A harsh attack against the supporters of the vacuum came from the Jesuit father Daniello Bartoli, who wrote a small book in which he suggested that only the inner tension and the external atmospheric pressure could be causes of the barometric phenomena, while at the same time denying any existence to genuine vacua[1].

Epicurean atomists, according to him, insinuated the existence of interspersed vacua to make perceivable, plain to see ("quasi agli occhi"), their explanation of rarefaction and condensation, making a fraudulent use of the equivalence of vacuum and nothingness: "Hor il Vacuo non è egli una specie del nulla? Adunque, se Vacuo s'interpone fra atomo e atomo, nulla s'aggiugne, e nondimeno s'accresce: se si lieva, nulla si toglie, e nondimeno si scema. Così eglino" (Bartoli 1677, LVII: 263). Nothing needs to be added, since 'nothing' is added: and *voilà*, the air in the vacuum tube becomes limitlessly stretchable. But if that nothing must have observable effects, objected Bartoli, it ought to be something: "Ma se quel nulla è possente a far qualcosa, come sarà egli nulla?" (XXVII: 121).

The most important instance of a *bona fide* experiment based on the theoretic principle that no causal powers can be attributed to the vacuum is offered by Isaac Newton, as the core of his experimental demonstration of the existence of the ether, in the 18th *Query* of the third part of the *Opticks*:

> If in two large tall cylindrical Vessels of Glass inverted, two little Thermometers be suspended so as not to touch the Vessels, and the Air be drawn out of one of these Vessels, and these Vessels thus prepared be carried out of a cold place into a warm one; the Thermometer *in vacuo* will grow warm as much, and almost as soon as the Thermometer which is not *in vacuo*. And when the Vessels are carried back into a cold place, the Thermometer *in vacuo* will grow cold almost as soon as the other Thermometer. (…) Is not the Heat of the warm Room convey'd through the *Vacuum* by the Vibrations of a much subtiler Medium than Air, which after the Air was drawn out remained in the *Vacuum*?

[1] Bartoli 1677. On the attitude of Jesuit scientists towards the vacuum, see Gorman 1994.

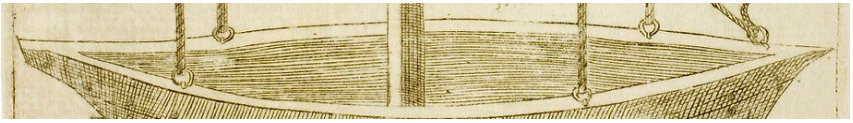
And is not this Medium the same with that Medium by which light is reflected and refracted, and by whose Vibrations Light communicates Heat to Bodies, and is put into Fits of easy Reflexion and easy Transmission? (Newton 1730, 348-49; 1952, 323).

The conclusion is interrogative just because these are 'Queries', that is, hypotheses. Plainly, Newton does not consider the possibility that the light communicates heat *and* can travel in a vacuum.

Interestingly, this is not the final word of the Newtonian school on the causal powers of the vacuum. For instance John Desaguliers, although he was a mad admirer of Newton's physics, not only affirmed the existence of vacua in bodies, but he insisted that there are experimental proofs of it: "The bending in of the *Strata* of elastick Bodies, would be a sufficient Proof of a *Vacuum*, if there was no other. For without void Spaces within the Body for the Particles displaced by the Blow to retire to, and return from, there could be no elasticity". This, he adds, "may be further illustrated by the following Experiment" (Desaguliers 1744, 7). Rub a piece of money with quicksilver so that it imbibes it: the coin will have a dull sound. "This seems to arise from filling some of the Pores into which the elastick Strata used to retire by the Blow, and hereby hindering their more perfect Vibrations" (8). Let the Mercury evaporate, and the piece will recover its tingling sound.

Giorgio Valla, the author of a very well known 16th century humanist encyclopedia, had written in it a chapter on the vacuum, that ended with this pronouncement: "Multae de inani multorum sunt philosophorum sententiae, argumentationes quoque" (Valla 1501, l. XXIII, c. viii, c. PP VI*r*)—so many philosophers have stated so many opinion on the vacuum, and with so many arguments!

In the end, a major problem is that all later 'arguments' concerning the presence or absence of causal powers in connection to the vacuum, would be deemed experimental, although in fact they were based only on indirect experiences. But was there any chance to directly observe what we are talking about?



5 Parallel to natural philosophy since antiquity, and also to the early modern natural sciences, there is another tradition in which it was common to put to use certain causal powers related to the vacuum: it is medicine. Physicians have always had a more relaxed attitude towards vacua than their philosophical counterparts would have, and the theory of interspersed vacua—we have already mentioned Erasistratus—made an early appearance in the medical sciences.

Galen polemizes repeatedly against Erasistratus in his work *On the Natural Faculties*. With regard to the dispersal of nutriment (*anadosis*), the secretion of urine, etc., Galen discusses whether, in order to explain percolation processes, we should resort to the theory concerning the natural tendency of a vacuum to become refilled, when we can ascribe it to some attractive faculty naturally belonging to the organs involved: "in the case of anadosis [Erasistratus] was not satisfied with saying that this took place through the veins, but he also considered fully the method", i.e. the manner and causes, "which he held to be from the tendency of a vacuum to become refilled" (*De nat. fac.* I, 16; Galenus 1916, 99).

Object of Galenus' hostile remarks was the ascription of an autonomous attractive power to the vacuum. In fact there are three main sources of attraction in the medical tradition, that are pain (a punched lip swells up because pain attracts humours), heat, and vacuum. We shall turn to the celebrated physician and medical theorist Daniel Sennert's chapter on revulsion (that is, the drawing of humors, or of diseases, from one part of the body to another) in his *Institutiones*:

> Retrahuntur autem humores vel vacui, vel caloris, vel doloris ratione. Vacui ratione humores retrahunt, quae illos per alias partes e corpore effundunt et evacuant, ut venae sectio, scarificationes, hirudines, mensium fluxus, haemorrhoides, purgatio per alvum, vomitus, urinae, sudores. Calore et dolore retrahunt, quae vim calorem et dolorem ciendi, aut etiam utrumque praestandi habent, ut sunt frictiones, ligaturae, lotiones, fomenta, vesicatoria, caustica et similia. (Sennert 1620, V, II, I, 18: 1057).

Again it happens *vacui ratione*. Some vacuity is produced in some part of the body and by reason of this vacuum humors are brought to that part of the body. Vacuum attracts to be refilled.

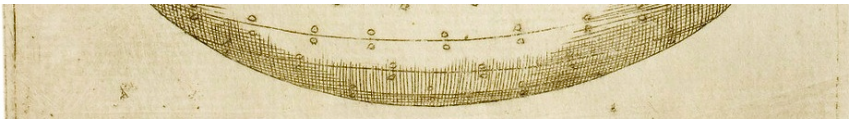
Interestingly, when Galen's *Natural Faculties* were first put into humanist

Latin, the cautious translator, Thomas Linacre, used the horrible expression 'consecutione ad id quod vacuatur'[1] and not 'vacui ratione' or similar phrases, as if he deemed inappropriate to mention the vacuum, or the tendency of the vacuum to be refilled. It is also interesting that Sennert, in the following edition (1628, 1175), after 'vacui ratione' added "vel potius vacuando". But he left untouched many other passages, like e.g. in the tractation of *alexipharmaca* that "vel caloris vel vacui ratione venenum extrahunt" (1628, 968).

Moreover, an empty stomach is not a properly void space, a *real* vacuum. But physicians have always been accustomed to make use of cups. And cups and cupping add indeed a realistic touch to the way physicians will allow for the existence of void space. Even Sennert, in the same edition that saw that retractive appendage, also added some lines on the theme of "Cucurbitularum applicatio". All the powers of cups and their force of action, he says there, come 'by reason of the vacuum': "Est autem cucurbita vel etiam cucurbitula vas ventricosum, a forma cucurbitae ita dictum, quod corpori attrahendum affigitur; (…) Vis autem omnis earum et agendi ratio a vacui ratione provenit" (1628, V, I, II, 9: 1030).

In fact, you will often meet in early modern medical handbook and treatises a side note, or an *obiter dictum*, that states the obvious inexistence of the vacuum, as it is proven by Aristotle in his *Physics* (and taught in the faculty of Arts), and then you mostly see the authors happily ignoring all cautions when discussing the attracting virtues of vacuity, or the operations of cups.

The most symptomatic proof of this peculiar openness is the existence of a learned and not altogether obscure physician who, mid-17th century, will testify to the actuality of the vacuum by direct acquaintance—in other words, who could see the void.



[1] "Non enim id modo dicere satis habuit, quod ea per venas fiat: sed etiam qua ratione fiat, narravit. Nempe consecutione ad id quod vacuatur" (Galenus 1528, c. 23 *r*).

6 In his intellectual and professional life, Pierre Borel ascended from small-town academician to royal physician[1]. He even counts among the first biographers of Descartes, since he authored one of the short sketches that appeared before Baillet's *Vie de Descartes*.

It is well known that Cartesians identified matter and extended space ('extension') and had no conceptual tolerance for the vacuum of the atomists. But Pierre Borel was by no means an orthodox Cartesian, and perhaps none at all. Instead, in his *Vitae Cartesii compendium* he shows a remarkable tendency to assimilate his protagonist's life and doctrines to those of the founder of the atomist school: "Cum nil dignum apud homines scientiae suae invenisset eremum ut Democritus aliique veri Philosophi elegit sibi iuxta Egmundum in Hollandia ibique solitarius in villula per 25 annos remansit" (Borel 1656, 7); "Atomos etiam Democriteos agnovit pro rerum principiis ut optime comprobavit" (8).

In 1657, together with a reprint of his *Compendium*, Borel published four hundred medical observations and case histories. The theme of the 12th observation of the 4th *centuria* is titled *Vacuum visu perceptum*, that is, 'The vacuum observed with the view'.

It sports an inspired opening: "We can but scratch the surface of things and we know very little of their nature: so we often abandon true knowledge for false beliefs". A short history of vacuum theories follows: Democritus was able to give a theoretic proof of the existence of the vacuum, but Aristotle's authority averted everybody from it; recently some new experiences with glass pipes and mercury have shown that the vacuum exists in nature. Borel adds that he was still worried that a subtle air might be found inside the pipe—so he looked for some surer experience. It should be remarked at this point that in the same year he published this observation, the jesuit Kaspar Schott announced to the world a series of historic experiences on the vacuum as an appendix to his *Mechanica hydraulico-pneumatica* (Schott 1657): that is, Guericke's experiments with evacuated spheres. Thus Borel, it can be said, was somewhat *à la page* in his preoccupations. But he looked for a source of *direct* experience, and this is the conclusion he reached: "I considered the matter more deeply and now I can declare that the vacuum can be perceived not only by the use of reason, but with one's own eyes as well".

[1] On his life and works see the corresponding entry in Michaud 1843–1865, V, 76.

Cum Cortices rerum tantum possideamus, paucaque vera sciamus de rerum natura, fit plurimum ut veras cognitiones pro falsis reiiciamus, sic olim Democritus vacuum in rerum natura necessario extare probaverat, nihil enim aliter in orbe moveri posset, Aristoteles vero qui nimiam apud scholas famam et imperium comparavit, homines ab eius cognitione removit contrarium statuens. Annis praeteritis equidem experientiis comprobatum variis fuit per tubos et argentum vivum, vacuum extare in rerum natura, tamen ego adhuc existimans aërem subtilissimum adytus invenisse, rem altius speculatus illud percepi non solum ratione sed etiam oculis propriis quod visu percipi posse assero. (Borel 1657, IV, 12).

How did it happen? Vacuum, states Borel, comes in two different sizes: small and big. The latter is Nature's enemy and cannot be produced. The small vacuum that corresponds, according to him, to Democritus's and Epicurus's idea of the vacuum, is dispersed in minuscule parts in the air and allows for the movements of atoms and other things.

Dupliciter autem vacuum intelligi debet, vel parvum vel magnum, magnum est naturae inimicum nec illud ferre ullo modo potest ut multis probatur experientiis et de illo vera dixerunt peripathetici, parvum vero seu Democriticum et Epicureum in minimas partes per aëra dispersum ut atomis et aliis rebus detur locus penetrandi et movendi se, sic enim aër instar spongiae coarctari et dilatari potest ob porosam eius ut in spongia contractionem. (Borel 1657, IV, 12).

"Sed ad nostram veniamus experientiam", he adds: let us get to our experience. When we gaze fixedly, with the eyes wide open, sometimes we see certain small spheres that move around. The same will happen when we stare at a candlelight.

Si ergo oculis fixis aërem intuearis per aliquot tempus, videbis tandem illum tanquam parvis spherulis refertum nigris quae semper moventur et aëris vacuum sunt, ad candelam sub Elychnio fixe etiam aspiciens idem vidi, imo clarius et quasi olei guttulas in aqua respersas. Hae spherulae nigrae apparent cum colores suscipere nequeant, cum accidens substantiae tantum adhaerere possit, hae vero cum sint privationes colorari nequeunt. (Borel 1657, IV, 12).

The spheres appear to be black, but in fact they lack any colour, since they are, according to Borel, small vacua interspersed in the air. It seems that the

vacuum, just like Henry Ford's Model T, could be "any colour, so long as it is black" (Ford 1922, 72): more precisely, since it is nothing but privation, it cannot be coloured—colour being, as a scholasticizing Borel explains to the reader, an accident that needs a substance to adhere to.

Medice cura te ipsum… Borel is quite evidently speaking of floaters, those entoptic phenomena that may be a first signal of a degeneration of his vitreous humour. In contemporary medical texts it was called *suffusio*, and the famous Lazare Rivière, a former royal physician himself, in his *Praxis medica* had defined it as a "levis quaedam visus obtenebratio" (Rivière 1645, 20); he had also written: "Verae autem suffusionis differentiae, sequentibus signis erunt distinguendae. In suffusione incipiente corpuscula quaedam ut pili, culices, muscae volitantes, lanarum aut aranearum fragmenta, oculis observantur" (30). The denomination *muscae volitantes* began some time later to be used as a sort of official denomination for such phenomena, but already the Latin translation of a 9th century text like Serapion's *Breviarium medicinae* (or *Practica Serapionis*) contained the recipe of a remedy "iuvativum (…) ad illum qui videt sicut muscas inter oculos suos" (Serapion 1497, c. 84 *r*).

Anyway, we know thus that at least one representative early modern physician was so convinced of the existence of the vacuum that he seriously tried to see it—which he also believed to have been able to.

We began with an exergual poetic quotation that evoked the 'colour of the void', as an expression of 20th century anguish before the nonsensical patterns of traffic and emptiness on a modern highway; we end with a historiographic specimen concerning again that very colour and expressing a quirk, self-styled experimental attitude towards it. This specimen was the ultimate target of our interrogation and, confessedly, the *causa occasionalis* of this note.

True, this is an utmost rare if not unique occurrence: as such it is nothing more than a symptom. But a symptom is the visible sign of a more extensive condition. And it seems to me that in the framework of what I shall call a 'symptomatic' approach to the history of ideas, the seeming faux-pas committed by Borel can be recognized as the surer sign of a more general attitude, that can be said to be peculiar to the practitioners of the medical science, in favor of a more positive conception of the vacuum, and of its properties and powers, than the natural scientists or the philosophers of nature of the time would ever allow.

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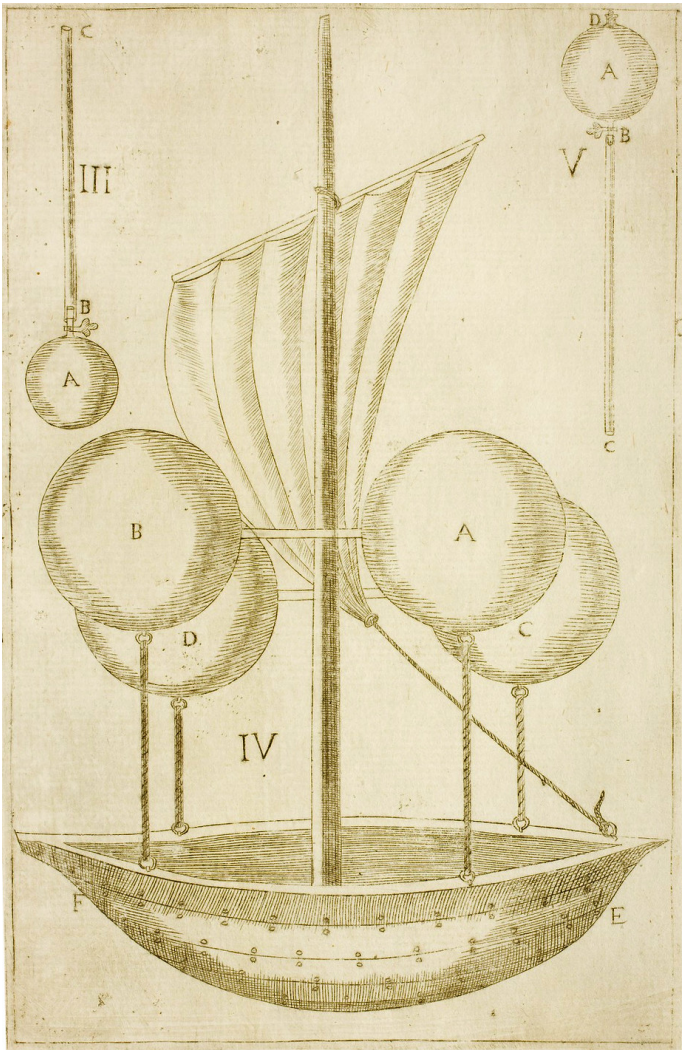

F. Lana's project of an aerostatic vessel sustained by evacuated copper spheres (Lana Terzi

1670, 267; http://echo.mpiwg-berlin.mpg.de/MPIWG:F5DN1FGA).