Scientific Communication During a Major Change in the Approach to Empirical Research: *Annales de chimie* vs *Observations sur la physique/Journal de physique* (1789-1803)*

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The founding of several scientific journals during the second half of the 18th century spawned interesting controversies on chemical issues. In the *Observations sur la physique*, in particular, it is possible to scrutinize in detail the evolution of important discussions concerning crucial questions: "Inflammation or Combustion?", "Pure Air or Oxygen Gas?", "Fire or Caloric?". In the *Annales de chimie*, the discussions were inspired by other questions such as "Simple or Compound substances?".

Some of the specific comments and questions raised by the participants involved were as follows: "In order to stop all these philosophical debates dividing chemists, how is it possible to define combustion?";[1] "Should we consider the word *combustion* according to the meaning proposed by M. Arejula in his well done Memoir published in the issue of October of the present year? And, consequently, for example, considering *combustion* the combination of pure air with nitrous air, or, as we have already said, the combination of pure air during respiration, etc. I don't think so".[2] "Unfortunately gentlemen, in order to support a system, you wanted to change the overall language. [...]. Let's take, for instance, the pure air, first of all, Priestley has called it dephlogisticated air; Scheele, fire air; Bergman, pure air; Turgot, vital air, the new nomenclature called it oxygen gas".[3] "Is the combined or isolated caloric distinct from the matter of fire and of light?".[4] "Besides, this distinction among *un-decomposed substances* and *simple* or *elementary substances* should have been explained. Maybe is it another distinction of convenience?".[5]

* This paper was presented at the 6th International Conference on the History of Chemistry (Leuven 28 August-1 September 2007) and it is forthcoming in *Ambix*.
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The evolution of all these debates helps us understand how the panorama within the scientific community gradually changed. Thanks to the reconstruction of the ongoing disputes between the two journals, we can understand how a growing number of chemists, physicists and naturalists, followed the developments in experimental chemistry, decided to adopt the principles of the Lavoisierian analysis.

Furthermore, the availability of new data on the constitution of bodies, both organic and inorganic, had significant effects on the more general domain of the life sciences. At the beginning of the 19^{th} century, Jean Baptiste de Lamarck, one of the most active naturalists in the Parisian scientific community, ruled out his own original ideas concerning the applicability of "chemistry" to the study of living beings and accepted the new chemical image of "organized bodies" as natural systems of predictable operations.

The Problems of interpreting Laboratory Results

In 1788, a pro-Lavoisierian memoir by Louis Lefèvre Gineau was published in the Parisian journal *Observations sur la physique*. In his memoir, Gineau's analysis regarding the experiment of water dripped into an incandescent iron tube differed from the traditional interpretation.[6] Contrary to the opinion of the editor of the journal, Jean-Claude Delamétherie, according to which this experience confirmed the existence of the phlogiston/principle of inflammability in iron,[7] Gineau maintained that it was a further proof that metals were simple bodies.

Although diametrically opposed, both interpretations perfectly justified the iron's increase in weight: according to the traditional hypothesis, it was caused by water entering the body, thus triggering the expulsion of phlogiston (perfectly in line with the Priestleian perspective presented in the same volume).[8] According to the new theory, the increase in weight of the iron was due to the blending of the metal and the oxygen base produced by the decomposition of water.

Furthermore, according to Gineau it was possible to prove quantitatively that water decomposed into two gaseous constituents.[9] Thus the oxygen component was responsible for oxidizing the metal while the hydrogen component was released in a vapour state. The logical consequence was that the hydrogen came from the water and not, as wrongly believed, from the iron.

This controversy was not, as may appear at first sight, limited to a mere discussion of the cause/effect of the processes at stake. If that were the case, Gineau's memoir, though perhaps more detailed and sophisticated, could be considered one more study among others within a substantially equivalent course of investigation. Actually, the comparison emphasized two contemporary and incompatible notions of the chemical art, i.e. two different approaches to laboratory research in relation to the information provided by the senses, as became explicit in later years:[10] "It will be said, how is it possible to reconcile the result of this experiment with that of M. Lavoisier and his friends?".[11]

Divergences and subsequent reconciliations within the European chemical community in the period 1789 to 1803

In his treatise of 1789 Antoine-Laurent Lavoisier explained his position regarding the phlogiston/hydrogen equivalence theory formulated by the traditional chemists. He sustained that it did not provide any information on the processes really occurring during combustion. Consequently, while Lavoisierian chemists were emphasising the distinction between *presuming* an idea and *proving* it;[12] the traditional chemists were certain that phlogiston existed because its reality was proved by means of the sensory experience (i.e., smell, taste and colour).[13]

In the same year, Lavoisier published a memorable paper on the *Observations* of Delamétherie in which he presented a new theory of "vegetation" that was in dispute with the traditional ones. While Ingen-Housz, Priestley and Cavallo assumed a mere mechanical function of water in contact with the plants, Lavoisierian theory was based on two "facts": water is a compound of 15 parts hydrogen and 85 parts oxygen; carbon dioxide is a compound of 72 parts of oxygen and 28 parts of carbon.[14]

The inability at the time to determine the real mechanisms of combustion fuelled disagreement within the chemical community. The divergences of opinion grew to the point that, in his preliminary speech for the year 1789, Delamétherie declared a state of "scientific crisis". In the same year, as the anti-Phlogistonists felt that the editorial policy of the *Observations sur la physique* misrepresented them, the Lavoisierian school founded its own scientific journal: the *Annales de Chimie*, an explicitly anti-Phlogiston journal. This new scientific publication aimed at updating the chemists on the discoveries made in the applied chemistry without omitting the philosophical or general considerations underlying each specialised branch of knowledge, as emphasised in the introduction for the new course in 1797.[15]

The Lavoisierian memoir on combustion of iron stood out among the large number of interesting papers discussed in the first volume of the *Annales*. In his account Lavoisier sustained that in nature, combustion without flames did occur[16]. Thus, he clarified the distinction between ordinary burning and combustion: an issue on which the majority of traditional chemists were confused. The need for accuracy and precision in laboratory practice was emphasised in his study, as it was a means to determine quantities rather than assuming them.

This division gave rise to two different series of debates concerning the combustion of bodies. European scientists involved in these discussions expressed their views in their journal: articles in the *Observations* debated the "presumed" theory of the decomposition of water as well as that of fixed air,[17] whereas accounts in the *Annales* reflected the belief that those same theories were not merely probable but certain, and therefore could lead to further scientific research. Consequently the concerns of the arguments in the *Annales* were entirely different from those in the *Observations*; in addition, other issues were discussed: such as the simple nature of carbon[18] and of nitrogen.[19] Furthermore, the approach to solving the above-mentioned debates differed profoundly: on one hand, the Phlogistonists continued to base their reasoning on old Aristotelian assumptions rather than to accept the new definition of "combustion".[20] On the other hand, the anti-Phlogistonists refused to consider matters that were impossible to verify and focused on experimental procedures. The Dutch group, for example, devoted itself to the reproduction of several combustion experiments by means of sophisticated apparatus and claimed that many distinguished scientists, including Priestley, Wiegleb and Wurzer, lacked professionalism as they had confused results with accidental products.[21]

Even the anti-phlogiston Christoph Girtanner received harsh criticism from Claude-Louis Berthollet for deriving his conclusions from poorly implemented experiments.[22] On the other hand, the abbot Spallanzani was presented to the European scientific community as "one of the most brilliant Italian naturalists". It was due to his precise eudiometric experiences that professor Goettling's thesis against the new system was disproved.[23] In particular, Lazzaro Spallanzani had undertaken specific quantifications that refuted the German thesis that nitrogen gas is an oxygen compound. Spallanzani placed pure gases (nitrogen, hydrogen and carbonic acid) in contact with phosphorus inside a eudiometer of Giobert. The Italian researcher verified that no light was produced thus indicating that phosphorus could not be ignited in the presence of substances other than oxygen. Spallanzani's investigations also included an analysis of organic substances containing phosphorus, such as those found in fireflies.[24] He concluded that luminescent bodies showed the same characteristics of common phosphorus, with additional interesting peculiarities: the chemical reaction is the same for a live or dead firefly. In particular, when alive the firefly's light shines brighter owing to its respiration. Spallanzani argued that this was the result of a slow combustion of hydrogen gas and "carbonic hydrogen gas", the components of animal and vegetable substances occurring in all luminescent bodies.

Although the discoveries of pneumatic chemistry (that organic matter was composed of carbon, hydrogen, oxygen and nitrogen) enabled further investigation of vital phenomena (a matter that brought to a halt other naturalistic traditions), it was necessary to avoid any chemical reductionism that the growing number of applications of the new system seemed to instigate. This was reflected in a dispute between Antoine-François de Fourcroy and Friedrich Alexander von Humboldt. While the German naturalist thought it was possible to explain vitality as the chemical equilibrium of the organic constituents,[25] Fourcroy considered that "Mr. Humboldt proceeded too quickly in his explanations".[26] Humboldt's reply to Fourcroy came promptly: "We are going on two different roads: while you analyse matter in which the vital principle is extinct, […] I confine myself to describing phenomena observed in organized matter".[27] The Frenchman's blunt response followed shortly: "In this series of premature conclusions and forced applications, I have understood neither your experiments nor your useful results".[28] In a memoir published the following year on the application of chemistry to medicine, Fourcroy confirmed his position by refusing to accept "the inappropriate explanation of the phenomenon of animal life by means of a chemical force".[29] In fact, immediately following this clash, Humboldt went to Vauquelin and Fourcroy's laboratories in Paris where he sought to gain experience on the new French methodology. Thanks to this training, Humboldt wrote a memoir on the earth's absorption of oxygen that was soon to become famous. This memoir is also the evidence that Humboldt had joined the new way of reasoning in chemistry.[30]

However, the majority of the European naturalists were not as keen to abandon the long-standing philosophy used to set apart living beings from the rest of the physical world. For them, living beings were such by virtue of an unknown organisation of matter, the result of an extra-natural vital principle. In 1794 Jean Baptiste de Lamarck published a work, written eighteen years before, that described natural phenomena, both organic and inorganic, without relying on the recent chemical discoveries.[31] Incidentally, this was the year of Lavoisier's death. The Lamarckian researches, praised by Delamétherie,[32] sustained the illegitimacy of the chemical analysis applied to vital phenomena as these were elusive by nature. In 1796 Lamarck joined actively the debates in progress by publishing his refusal to accept the pneumatic theory.[33] Lamarck thus confirmed that his researches of 1794 were not an isolated event, but actually the beginning of a coherent project meant to provoke a naturalist reaction against chemistry. Later, in 1799 (when Spallanzani died), Lamarck published a memoir in Delamétherie's journal on the subject of fire, in which he reaffirmed his absolute distrust of chemical analysis.[34]

Once the new century started, Lamarck surprisingly ended his opposition to the Lavoisierian system and, in his researches of 1802 (when the chemical debates were nearly defined in favour of the new doctrine), he silently borrowed the information about organic transformations from chemical analysis thus exhibiting his own obscure conversion.[35]

Unlike Lamarck, the Italian naturalist Spallanzani never attacked the new French methodology. On the contrary, perfectly aware of the limits of traditional technology, he had readily adopted the new method of reasoning/experimenting and applied it to living beings in their diversity. He was thus able to prove that living organisms were regulated by identifiable processes of decomposition/recomposition of material. Spallanzani's scientific manuscripts, currently at the Municipal Library of Reggio Emilia, are of great interest, as they describe his experimental procedures. Parts of the manuscripts were later used by the scientist/librarian Jean Senebier[36] in his edition of Spallanzani's memoirs on respiration. In these laboratory books, the organism is analysed as a natural system open to exchanges of matter with the environment rather than a body endowed with extraordinary qualities that do not exist in inorganic matter.[37] Spallanzani's readiness and courage in following the new methods resulted in valuable contributions of new data to the life sciences and in an innovative approach well ahead of Lamarck's establishment of the "science of living bodies", or *Biologie*.[38]

In the literary news for the year 1803, Delamétherie introduced Spallanzani's memoirs as work full of "well done experiments", praised the new chemical-physiological researches, and underlined that "everything written by Spallanzani's pen is made to interest the scientists".[39] This leads to the conclusion that the Italian scientist had succeeded in the outstanding accomplishment of resolving the conflict of twenty years in favour of the new system. Spallanzani confirmed the Lavoisierian model of organic matter characterized by the oxidative regularities by presenting experimental results that began to be accepted as scientific data. His results appeared in Delamétherie's journal and inaugurated a new way to investigate the living world beyond the hypothesis of an absolute hiatus from the inorganic world.

Reflections on the late eighteenth-century chemical debates

What is the historical-scientific meaning of the above account of the years between 1789 and 1803? First of all, the examination of the debates recorded in the two journals unquestionably shows a disparity in the process of scientific production in consequence of which every attempt to equate those who produced *accurate data* and those who considered them *probable* is historically inappropriate.

The new doctrine built up knowledge thanks to a modern definition of the concept of scientific "fact", *i.e. a definite relationship among different terms*, which made it possible to avoid confusing oneself with opinions which were often in contradiction. It also redefined by the end-of-the-century scientific communication by ensuring a previously unimaginable collective understanding.

Following this line of research it became possible to distinguish facts from testimonies, combustions from inflammations, aggregates from compounds. *Theory* and chemical *practice* were reconnected thanks to the adoption of a new analytical method (or procedural method from "known to *un*known"). The traditional domain of combined physical-chemical knowledge redefined itself as a unique thermochemical relationship.[40] The scientific debates became independent of literary discussions.[41]

This *ensemble* (complex network) of redefinitions cannot be reduced to an innovative interpretation of the cause/effect relationships at stake during chemical reactions and marks the beginning of a way of reasoning and experimenting in chemistry which leaves out of consideration unquantifiable entities.[42] In this regard, in Lavoisier and Laplace's memoir on heat (1783) we read:

"Here we will limit ourselves to comparing the amounts of heat that are evolved in combustion and respiration with the corresponding changes in the oxygen, without considering whether that heat comes from the air or from the combustible bodies and the animals that breathe. In order to determine these changes we performed the following experiments".[43]

Notes

[1] "Pour terminer tous les débats philosophiques dont la chimie est partagée; comment définir la combustion?" Henry Reboul, "Lettre à M. De La Métherie sur la combustion, le 8 Décembre 1788", *Observations sur la physique, sur l'histoire naturelle et sur les arts* (Paris: Le Jai, 1773-1793), 34 (1789): 124-126, 124.

[2] "Doit-on donner à ce mot *combustion* toute l'étendue que propose M.Arejula dans son beau Mémoire inséré dans le mois d'octobre de cette année? Et appeler, par exemple, *combustion* la

combinaison de l'air pur et de l'air nitreux, ou comme on avoit déjà dit, la combinaison de l'air pur dans l'acte de la respiration, etc. Je ne le crois pas." Jean-Claude Delamétherie, "Discours préliminaire", *Observations sur la physique* 34 (1789): 3-55, 31.

[3] "Mais malheureusement Messieurs, pour soutenir un systême, vous avez voulu changer toute la langue [...]. Prenons par exemple l'air pur: M.Priestley l'appela d'abord air déphlogistiqué, Schéele air du feu, Bergman air pur, Turgot air vital, la Nouvelle nomenclature gaz oxygène." Delamétherie, "Réponse à M.Hassenfratz", *Observations sur la physique* 33 (1788): 385-388, 386.

[4] "Le calorique combiné ou isolé, diffère-t-il de la matière du feu et de la lumière?" Michel Dizé, "Mémoire sur la matière de la chaleur", *Journal de Physique, de chimie, d'histoire naturelle et des arts* (Paris: Cuchet, 1794-1823), 6 (1799):177-202, 178.

[5] "Au reste, cette distinction de *substances non-décomposées* d'avec les *substances simples* ou *élémentaires*, auroit mérité d'être expliqué. Ne seroit-ce pas encore une distinction de convenance?" Delamétherie, "Réponse à MM. Adet et Hassenfratz sur la Chimie des Pneumatistes, le 21 Février 1787", *Observations sur la physique* 30 (1787): 218-226, 219.

[6] Louis Lefèvre Gineau, "Mémoire lu à la Séance publique du Collège Royal le 10 novembre 1788: Dans lequel on rend compte des expériences faites publiquement dans ce même collège aux mois de Mai, Juin et Juillet de la même année, sur la composition et la décomposition de l'eau", *Observations de physique* 33 (1788): 457-466. In 1794 Delamétherie changed the name of his journal to *Journal de Physique, de chimie, d'histoire naturelle et des arts* and its publication was interrupted from 1795 to 1797.

[7] Delamétherie, *Essai analitique sur l'Air pur et les différentes espèces d'air* (1785), 2° édition, 2 vols., (Paris: chez Cuchet libraire, 1788).

[8] Joseph Priestley, "Expériences et Observations relatives aux principes d'Acidité, la Composition de l'Eau et le Phlogistique", *Observations de physique* 33 (1788): 103-110.

[9] By calculating the increase in weight of iron and adding the hydrogen released, the result is more or less equal to the weight of the vanished water.

[10] A few years later Priestley admitted that in chemistry there was divergence in the way of interpreting and doing the same research: "La doctrine du phlogistique et celle de la décomposition de l'eau a depuis long-temps attiré l'attention des chimistes philosophes; et l'expérience a semblé favoriser tantôt l'une, tantôt l'autre." Priestley, "Dernières expériences relatives à la décomposition de l'Air déphlogistiqué et de l'Air inflammable", *Observations sur la physique* 40 (1792): 91-97, on 91. In this regard, see Ferdinando Abbri, "J. Priestley e A.L. Lavoisier: il diverso significato di uno stesso esperimento", in *Scienza e storia: analisi critica e problemi attuali,* eds. Silvano Tagliagambe, Antonio Di Meo (Roma: Editori Riuniti, 1980): 147-167; Maurice P. Crosland, *Scientific institutions and practice in France and Britain, c. 1700-c.1870* (Aldershot: Ashgate, Variorum, 2007). See also, Abbri, "Alchemy and Chemistry: Chemical Discourses in the Seventeenth Century", *Early Science and Medicine* 5 (2000): 214-226.

[11] Priestley, "Farther Experiments relating to the Decomposition of Dephlogisticated and Inflammable Air, read April 7, 1791", *Philosophical Transactions: Giving some account of the present understandings, studies and labours of the ingenious, in many considerable parts of the world* (London, 1665-1862) LXXXI (1791):213-222, on 217.

[12] "Quelques chimistes d'un ordre très-distingué se persuadent que l'hydrogène est le phlogistique de Stahl, et, comme ce célèbre chimiste admettait du phlogistique dans les métaux, dans le soufre, dans le charbon etc. ils sont obligés de supposer qu'il existe également de l'hydrogène fixé et combiné dans toutes ces substances; ils le supposent; mais ils ne le prouvent pas, et, quand ils

le prouveraient, ils ne seraient pas beaucoup plus avancés, puisque ce dégagement du gaz hydrogène n'explique en aucune manière les phénomènes de la calcination et de la combustion. Il faudrait toujours en revenir à l'examen de cette question: le calorique et la lumière qui se dégagent pendant les différentes espèces de combustion sont-ils fournis par le corps qui brûle ou par le gaz oxigène qui se fixe dans toutes ces opérations? et certainement la supposition de l'hydrogène dans les différents corps combustibles ne jette aucune lumière sur cette question." Antoine-Laurent Lavoisier, *Traité élémentaire de chimie,* in *Œuvres de Lavoisier publiées par les soins de S.E. le ministre de l'Instruction publique et des cultes*, 6 vols. (Paris: Imprimerie Impériale et Nationale, 1862-1893), vol. 1 (1789), 154.

[13] "Il est impossible de méconnoître l'existence d'un principe inflammable dans beaucoup de corps, à moins que l'esprit soit absolument égaré par des préjugés. [...] Mais serait-il raisonnable de mettre l'existence de ce principe en doute, parce qu'on ne peut le recueillir immédiatement? Je réponds par la negative car l'expérience prouve que pendant la calcination des métaux, ou pendant que d'autres corps brûlent avec une flamme, il se répand dans l'air une matière particulière sensible à l'odorat, et qui doit être la même dont dépend l'inflammabilité de ces corps; car ces derniers ayant été dépouillés de ce principe, sont ou entièrement consumés, ou cessent d'être inflammables. " Johann Christian Wiegleb, "Doctrine de Stahl sur le Phlogistique, rectifiée et appuyée par des preuves, en opposition au nouveau Systême chimique des François, dont on cherche en même tems à démontrer le peu de solidité, Extrait des Annales de Chimie de Crell", *Observations sur la physique* 41 (1792):81-85, on 84-85.

[14] Lavoisier, "Réflexions sur la décomposition de l'Eau par les substances végétales et animales", *Observations sur la physique* 34 (1789): 460-471, on 460.

[15] "Avant-Propos", in *Annales de Chimie, ou recueil de mémoires concernant la chimie et les arts qui en dépendent par MM. de Morveau, Lavoisier, Monge, Berthollet, Fourcroy, Dietrich, Hassenfratz et Adet* (Paris: chez Cuchet, 1789-1815), 19 (1797, An V): iii-xi, on ix. Crosland has claimed that for a clear understanding of the Chemical Revolution the new journal of the *Annales de chimie* can be rightly considered as fundamental as the *Traité élementaire de chimie*. Crosland, "Lavoisier, the two French Revolutions and 'The Imperial despotism of oxygen'", *Ambix* 42 (1995), 101-118. See also, Crosland, *In the Shadow of Lavoisier: The* Annales de Chimie *and the establishment of a new science* (Oxford: British Society for the History of Science, 1994).

[16] Lavoisier, "Mémoire sur la combustion du fer", *Annales de chimie* 1 (1789): 19-30.

[17] Concerning this, it is interesting to note that in his preliminary speech for the year 1799 Delamétherie admitted that water was decomposable and falsely declared to have always supported that theory: "J'ai toujours supposé la décomposition de l'eau; néanmoins, j'avoue que, quoiqu'il y ait un grand nombre de faits en sa faveur, elle ne me paroît pas encore démontrée. [...] C'est moi, néanmoins, qui a fait la première expérience sur la combustion de l'air pur et de l'air inflammable." Delamétherie, "Discours préliminaire", *Journal de physique* 5 (1799): 3-99, on 97.

[18] The dispute arose from the observations of the Italian Landriani, subsequently confirmed by the Dutch van Marum, about the presence of flammable gas in carbon. Consequently carbon could not be classified as simple. Berthollet solved the misunderstanding stressing that the term "*carbone*" could not be confused with the term "*charbon ordinaire*": the first one indicated a simple element, the second one indicated a substance combined with extraneous earth, hydrogen and nitrogen. See Martinus Van Marum, "Extrait d'une lettre écrite par Van-Marum à M.Berthollet, Harlem, le 5 Décembre 1788", *Annales de Chimie* 2 (1789): 270-277.

[19] The dispute involved the Germans Girtanner, Wiegleb, Goettling and Wurzer who sustained the compound nature of nitrogen and some new chemists who experimentally confuted these

hypotheses. In particular, See Christoph Girtanner, "Extrait d'une lettre de M. le conseiller Girtanner au citoyen Van-Mons sur l'analyse de l'azote, Gottingue, le 26 Décembre 1799", *Annales de chimie* 33 (An VIII): 229-231; idem, "Mémoire dans lequel on examine si l'azote est un corps simple ou composé; par l'auteur à Van Mons", *Annales de chimie* 34 (An VIII): 3-40.

[20]According to Reboul, combustion had been redefined as a pure process of "mutual combination" between the combustible body and the vital air yielding a new body whose weight equals that of the constituents. Reboul, "Lettre de M.Reboul de l'Académie de Toulouse à M.De La Métherie sur la Combustion", *Observations sur la physique* 34 (1789): 124-126, on 125. Concerning this, it is useful to remember the dispute initiated on Delamétherie's journal by the Lavoisierian chemists about the new meaning of "combustion" (or, the combination of bodies producing loss of their original qualities) different from the pre-Lavoisierian one. In the case of water, for example, they claimed that "l'eau n'est point un simple mêlange de gaz inflammable et d'air vital; elle est le produit de la combinaison de deux bases de ces deux fluides élastiques; or, la base du gaz inflammable étant saturée d'air vital, doit former un composé qui ne doit plus avoir d'affinité avec ce dernier corps, comme nous voyons le soufre constituant l'acide vitriolique par son union avec l'oxygène, ne plus avoir de tendance à se combiner avec lui une fois qu'il en est saturé". Pierre-Auguste Adet, Jean-Henri Hassenfratz, "Lettre de MM. Adet et Hassenfratz à M. De La Métherie sur la Chimie des Pneumatistes, le 21 Février 1787", *Observations sur la physique* 30 (1787): 215-218, on 217-218. According to the historiographical hypothesis of Holmes, instead, the Lavoisierian redefinition of combustion did not constitute a moment of discontinuity within the eighteenth-century chemistry as the meaning of the term itself changed "gradually" during the century: "Like other terms in eighteenth-century chemistry, "combustion" was gradually acquiring a broader meaning abstracted from its original applications." Frederic L.Holmes, *Lavoisier and the Chemistry of Life. An Exploration of Scientific Creativity* (Madison: University of Wisconsin Press, 1985), 126.

[21] The Dutch anti-phlogiston group constituted itself on the reproduction of the experiments of analysis/synthesis of water by electricity; see Adriaan Paets Van Troostwyck, Johann Rudolph Deiman, "Lettre de MM.Paets van Troostwyck et Deiman à M.De La Métherie sur une manière de décomposer l'Eau en Air inflammable et en Air vital", *Observations sur la physique* 35 (1789): 369-378. The Dutch group of experimenters then disproved the Priestleian conclusions on the newly defined gas "*oxide gazeux d'azote*"; see Deiman, Paets Van Troostwyck, P.Nieuwland, Nicolas Bondt, Anthoni Lauwerenburgh, "Mémoire sur la nature de l'oxide gazeux d'Azote, nommé par Priestley gaz nitreux déphlogistiqué", *Observations sur la physique* 43 (1793): 321-333. Then, followed the refutation of Wiegleb and Wurzer's hypothesis that nitrogen was obtainable from water in Deiman, Paets Van Troostwyck, Lauwerenburgh, "Recherches sur l'origine du gaz qui est produit par le passage de la vapeur aqueuse à travers des tubes rougis", *Annales de chimie* 26 (1798): 310-334; Deiman, Paets van Troostwyck, Lauwerenburgh, Vrolik, "Expériences nouvelles sur la prétendue conversion de l'eau en gaz azote", *Annales de chimie* 29 (An VII): 225-236. See Roberts's recent studies on the Dutch Enlightenment. In particular, Lissa Roberts, "Science Becomes Electric. Dutch Interaction with the Electrical Machine during the Eighteenth Century", *Isis* 90 (1999): 680-714.

[22] Claude-Louis Berthollet, "Remarques sur le Mémoire dans lequel M.Girtanner examine si l'azote est un corps simple ou composé", *Annales de chimie* 35 (An VIII): 23-31.

[23] Lazzaro Spallanzani, "Extrait de l'Examen chimique des expériences de M.Goettling sur la lumière du phosphore dans les différens gaz (Modena, 1796) par le citoyen Venturi", *Annales de chimie* 22 (1797): 246-257.

[24] In regard with the phenomena of phosphorescence during the previous seventeenth-century, see in particular Jan Golinski, "A Noble Spectacle. Phosphorus and the Public Cultures of Science in the Early Royal Society", *Isis* 80 (1989): 11-39.

[25] Friedrich Alexander von Humboldt, "Lettre au citoyen Van-Mons sur le procédé chimique de la vitalité", *Annales de chimie* 22 (An V): 64-71.

[26] Antoine-François de Fourcroy, "Extrait d'une lettre au citoyen Van-Mons au sujet de celle de M.Humboldt", *Annales de chimie* 22 (An V): 77-80, on 77.

[27] Humboldt, "Lettre au citoyen Fourcroy sur l'application prématurée de quelques découvertes chimiques à la médecine", *Annales de chimie* 27 (An VI): 62-66, on 65. We must remember that in the French literature of the 18th century the term *organisation* was considered synonymous with *life*.

[28] Fourcroy, "Réponse", *Annales de chimie* 27 (An VI): 67-71, on 67.

[29] "Mais, si j'annonce avec sécurité l'espoir d'une heureuse et prochaine révolution dans l'art de guérir [...] Je repousse également et la prétendue suffisance de la doctrine Brownienne pour toute théorie de l'art de guérir, et l'indiscrète explication du mécanisme entier de la vie animale par une puissance chimique." Fourcroy, "Mémoire sur l'application de la chimie pneumatique à l'art de guérir, et sur les propriétés médicamenteuses des substances oxigénées", *Annales de chimie* 28 (An VII): 225-281, on 232.

[30] Humboldt, "Mémoire sur l'absorption de l'oxigène par les terres", *Annales de chimie* 29 (An VII): 125-160.

[31] Jean Baptiste Pierre Antoine de Monet de Lamarck, *Recherches sur les causes des principaux faits physiques* (Paris: Maradan, 2 vols., 1794).

[32] Delamétherie, "Nouvelles littéraires", *Journal de Physique* 1 (1794): 400-403.

[33] Lamarck, *Réfutation de la théorie pneumatique, ou de la nouvelle doctrine des chimistes modernes* (Paris: chez l'Auteur, Agasse, 1796).

[34] Lamarck, "Mémoire sur la matière du feu, considéré comme un instrument chimique dans les analyses", *Journal de Physique* 5 (1799): 345-361.

[35] "Cela étant ainsi, il me sera facile de faire voir dans un instant que la *chaleur*, cette mère des générations, cette âme matérielle des corps vivans, […] a pu être le principal des moyens qu'emploie directement la nature pour opérer sur des matières appropriées, un acte de disposition des parties, d'ébauche d'organisation, et par suite, de vitalisation analogue à celui de la fécondation sexuelle." Lamarck, *Recherches sur l'organisation des corps vivans* (Paris: chez Maradan Libraire, An X, 1802), 102.

[36] Spallanzani, *Mémoires sur la respiration par Lazare Spallanzani traduits en français d'après son manuscrit inédit par Jean Senebier* (Genève: J.J. Paschoud, 1803).

[37] In his manuscripts the Italian naturalist Spallanzani claimed that he always adopted the surest method for his original chemical-physiological researches: "Mi son dunque appigliato al metodo più esatto, e sicuro." Spallanzani, *Mss Regg B* 49, 153 (306], Biblioteca Municipale "Panizzi", Reggio Emilia.

[38] Lamarck, *Hydrogéologie* (Paris: chez l'Auteur, Agasse, An X ,1801-1802), 8.

[39] Delamétherie, "Nouvelles littéraires", *Journal de Physique* 13 (1803), 476.

[40] According to Partington, in their *Mémoire sur la chaleur* of 1783 Lavoisier and Laplace established a fundamental law of thermochemistry according to which *all changes in heat, whether real or apparent, suffered by a system of bodies during a change of state recur in the opposite sense when the system returns to its original state*. See James Riddick Partington, *A History of Chemistry*, 4 vols. (London: MacMillan, 1962), vol. 3, 428. See also Virginia M. Schelar,

"Thermochemistry and the Third Law of Themodynamics", *Chymia* 11 (1966), 99-124; Angela Bandinelli, "The Isolated System of Quantifiable Experiences in the 1783 *Mémoire sur la chaleur* of Lavoisier and Laplace", *Ambix* 54 (2007): 274-284.

[41] These redefinitions occurred during the late eighteenth-century, thereby confirming the classical interpretation of Herbert Butterfield regarding the tardy development of the scientific revolution in chemistry. See Herbert Butterfield, *The origins of modern science* (London: G. Bell, 1958).

[42] According to the tradition inaugurated by Holmes, instead, the Lavoisierian principle of heat would come from the Stahlian phlogiston: "this elusive matter [of fire], so simply defined in the abstract, became in practice as malleable as ever its predecessor, phlogiston, has been reputed to be." Holmes, *Lavoisier and the Chemistry of Life,* 37.

[43] Lavoisier, Laplace, *Memoir on Heat, Translated with an Introduction and Notes by Henry Guerlac* (New York: Neale Watson Academic Publications Inc., 1982), 30.