AL FÂRÂBÎ'S ARTICLE ON VACUUM

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This article of Al Fârâbî, the Arabic text of which has recently been edited together with its English and Turkish translations,[1] is not mentioned by our biographic and bibliographic sources prior to the thirteenth century. In addition, although Ibn abî Uṣaybi'a, one of our thirteenth century sources, mentions it,[2] there is no reference to it in Ibn al Ḳifṭî, another important thirteenth century source. Moreover, among later bibliographic sources, Ṣafadî seems to be the only one speaking of it.[3] Haji Khalîfa, e. g., does not seem to have seen it.

In this connection we should bear in mind, however, that we do not possess the full text of Ibn al Ḳifṭî's book, but only a somewhat abbreviated version of it.[4] It is clear, moreover, that our pre-thirteenth century sources do not, in general, intend or claim to give a full list of Al Fârâbî's works. Ibn al Nadîm, e. g., enumerates certain works of Al Fârâbî and adds that he is also the author of other works on logic, but he does not name them.[5] Bayhaḳî, likewise, gives a short list of Al Fârâbî's works and ends with the remark that Al Fârâbî wrote many other short works, but he does not specify them by name.[6]

[1] Necati Lugal and Aydın Sayılı, *Al Fârâbî's Article on Vacuum*, Ankara 1951, A publication of the Turkish Historical Society, Series 15, No. 1. It may be pointed out here that in the facsimile reproduction the damaged sections of the pages appear in a more hopeless state than they really are. The arrangement of the pages in the MS. are also different from that of the photographic copy. In the MS., the pages facing one another are 2 and 3, 4 and 5, and so on.

[2] Ibn abi Uṣâybi'a, *'Uyûn al anbâ' fî ṭabâḳât al aṭibbâ*, Bulak 1299 H., vol. 2, p. 138.

[3] Ṣafadî, *Al wâfî bî'l wâfayât*, vol. 1, Istanbul 1931, p. 109.

[4] Ibn al Ḳıfṭi, *Târîkh al ḥukamâ*, J. Lippert edition, 1903, Einleitung, p. 11.

[5] Ibn al Nadîm, *Kitâb al fihrist*, Flügel edition, p. 263, Cairo edition, p. 368.

[6] Bayhaḳî, *Tatimma ṣiwân al ḥikma*, Muḥammad Shâfî edition, Arabic text, p. 17, Persian text, p. 20-21.

It seems that our earlier sources have not tried to compile exhaustive lists of Al Fârâbî's works, and the later ones were probably not in a position to do so. Al Fârâbî's intellectual achievements were eclipsed by those of Ibn Sînâ. This situation must undoubtedly have hastened the disappearance of many of the Farabian works, or their becoming rare.

Some of the writings of Al Fârâbî contain brief references to the question of vacuum and show that Al Fârâbî rejected the idea of absolute space, at least in so far as this question refers to the space beyond the celestial spheres, and very likely believed in the non-existence and impossibility of vacuum; [7] and in view of his Aristotelian inclinations he would be expected to hold such convictions. The present article is seen to be in general agreement with the Aristotelian ideas on vacuum and with other extant works attributed to Al Fârâbî.

The author has high claims to being a competent logician. He also asserts that thorough acquaintance with logic is an indispensable prerequisite for becoming an accomplished scientist. These convictions are found reiterated in other Farabian works, especially those touching science. Moreover, part of this article is of a polemical nature, and the scheme followed here by the author is to represent himself as confronted by imaginary opponents. He proceeds with a marked self-confidence and finality to lead his opponents into what he considers to be impasses. Possible objections are thus partly taken into consideration and answered. Here he is seen to be quite severe and harsh in his criticisms and denunciations, and from this point of view too the work may be said to bear resemblance to certain other works of Al Fârâbî.

The manuscript is of quite an old date (the beginning of the thirteenth century)[8] and was copied from an older manuscript. This fact too should, at least to some extent, decrease the probability of its being apocryphal, i. e., corroborate the impression gained through the preceding considerations.

The article deals with a clearly defined problem, and within this limited scope we find it to possess comprehensiveness of exposition.

[7] See below, p. 157 and notes 20-22.

[8] N. Lugal and A. Sayılı, op. cit., English preface, p. 20.

The language and mode of expression should be described as relatively clear and simple. Yet, this article may not, on the whole, be characterized as pithy and concise. At times it is rather circuitous and repetitious. It also contains doxographic phrases. Both these features may constitute mutually corroborating items of evidence to the effect that this article is not among the latest works of Al Fârâbî.[9]

On the whole, the subject matter is clearly conceived and well-organized. This article divides itself naturally into four parts, and the wording of the text may be said to indicate that the author himself had such a subdivision in mind, although the different parts are not clearly separated with the help of subtitles.

The article begins with a clear introductory part wherein the problem dealt with is posed briefly and neatly.[10] Here Al Fârâbî describes two experiments, closely related with each other and together forming a single experimental demonstration, explains how the observed facts connected with these experiments were interpreted by his opponents, and how they arrived thereby at the conviction that it is possible to create vacuum artificially.

The second and third parts constitute the main body of the article though they are not the most important parts of the article from the view point of their contents. In the first one of these,[11] the author refutes the beliefs of his opponents in a dialectical manner; he is a bit repetitious here. Then follows the section, i. e., the third part,[12] which could be characterized as preparatory to his final conclusions.

Here, certain properties of various bodies which are relevant to the subject in hand are discussed. This section may be conceived as a second introduction. It impresses the reader as a digression, and it is not till the very end of this section that the author comes to the point. It is rather awkwardly and circuitously expressed. This was perhaps unavoidable due to the vagueness and scantiness of the knowledge available at that time on the particular subjects discussed,

[9] See above, p. 62.
[10] Arabic text, p. 2-4, English tr., p. 21-22.
[11] Arabic text, p. 4-10, Engl. tr., p. 22-27.
[12] Arabic text, p. 10-14, Engl. tr., p. 27-33.

the variation of hotness or coldness of bodies. On the whole, however, when reading this section after the article is thoroughly understood, one feels that it is conceived well and that it smoothly paves the way to the conclusions which are to be derived later.

The conclusion is clearly the most important part of the article. It is set forth briefly and with great lucidity.

In the first one of the two experiments discussed in this article an upside down vessel is lowered down upon the surface of a body of water, then it is pressed down in the water. Then this vessel is lifted out of the water, and it is observed that no water entered the cavity of the vessel in spite of its having been pressed down quite deep into the water.

The second experiment is the repetition of the first one with certain alterations. This time some air is sucked out of the vessel before it is lowered down upon the surface of the water. The mouth of the vessel is obstructed with the fingers after the extraction of air from it, and the obstruction is removed only after the mouth of the vessel is in the water. In this experiment it is observed that water rises into the vessel although the vessel is not pressed down.

Al Fârâbî goes on to explain that the people against whom he is about to direct his criticisms have inferred from these observed facts that in the first case the vessel was full with air, but that in the second case vacuum was produced inside the vessel when part of its air was extracted and that this vacuum attracted the water into the vessel; the rise of the water into the vessel was also attributed to the action of a force of repulsion.

It is seen that this article of Al Fârâbî exhibits at the very start a highly interesting feature. It deals with experimentation at a period when experiments were quite rare. It is true that these particular experiments belong to a class and type of experiments which were far from being unknown at the time. In addition, the experiments performed in the Middle Ages and earlier times generally constituted examples of experimental demonstration rather than experimental research. Nevertheless, even in this restricted sense, experiments were rare, and a question that naturally comes to the mind is whether Al Fârâbî himself resorted to such experimentation.

Al Fârâbî's statements do not imply such a claim. It may be

of interest, however, to note that he seems to be fully familiar with the small details of operation and fine points of technique. He divides, e. g., the downward movement of the vessel into two stages. First, it has to be lowered down to the surface of the water, taking care that its mouth comes squarely against the surface of the water. Then it is to be pressed down. He says that the vessel should have an even and symmetrical mouth, and that when pressing the vessel down in the water it should not be deviated from its vertical position.

This account of Al Fârâbî's prescriptions is a bit distorted. For his statements have been taken out of their contents and brought too much into relief by making them assume the character of precautionary measures. But an element of overemphasis or exaggeration seems to exist in Al Fârâbî's own statements too.

On the other hand, in one point of detail the result of the first experiment is not described altogether accurately. Stating that no water enters the vessel is not entirely in accord with the facts, in that, by pressing the upside down vessel deep into the water, some water would enter the vessel and the amount of this water would increase together with the depth of the mouth of the vessel below the surface of the water. We do not know, however, how deep the vessel was pressed down, and it should also be noted in this connection that according to the exact wording of the text water does not enter "the cavity,, (jawf) of the vessel,[13] and it is probable that Al Fârâbî refers to the belly part of the vessel when he uses the word "cavity,,. This item makes it quite clear, however, that Al Fârâbî had not repeated these experiments under altered circumstances.

In trying to refute the claims of his opponents, Al Fârâbî starts with ideas which seem, at the first approach at least, to be based on the idea of the impossibility of absolute space. For the sake of argument, he first supposes that, in conformity with the claims of his opponents, a partial vacuum is formed inside the vessel when it is sucked from its mouth. That is, he supposes vacuum to have formed within a fraction of the total volume and the rest to be full with air. He then proceeds to show that the section assumed to be empty of all matter must necessarily possess dimensions, i. e., volume. Then he adds an additional evidence, probably involving the assump-

[13] Arabic text, p. 1, Engl. tr., p. 21.

tion that light cannot propagate except through a material body,[14] and reiterates his previous conclusion in a more detailed form. He repeats, namely, that the section in question which is inside the vessel possesses dimensions, and adds that it is occupied by a body possessing volume, transparent sides, "and other properties characteristic to material bodies.,,[15]

The last phrase is somewhat of a surprise. For it reminds us of properties such as softness, hardness, heaviness, and lightness, and nowhere do we find Al Fârâbî adduce any evidence that the body occupying that section of the vessel possesses properties peculiar to material bodies other than volume and transparency.

The Aristotelian idea that the mere existence of dimensions constitutes a proof to the effect that a space is occupied by a body and that the conception of space without body is self-contradictory seems to be implicit in the statements of Al Fârâbî, but this is not very clear. Syntactical considerations have necessitated two corrections in the part of the text dealing with these subjects[16] and two sections were abandoned as illegible.[17] There may be a lacuna here, and in this missing section Al Fârâbî may have adduced evidence showing the existance of such properties as degree of hardness and weight, although it is difficult to imagine how he could have done this. The discovery of a second manuscript only could clarify these points.

Whether a lacuna of this nature exists or not, the result seems to be that Al Fârâbî may have been aware of the shortcomings of the peripatetic argument in question which was accepted during many centuries by a great number of scholars. For even if there should be no lacuna here, the present text gives one the impression that Al Fârâbî is probably trying to avoid the weak link in this Aristotelian argument.

It is interesting in this connection to observe that this passage is expressed in plain and simple language; it is quite uncouched in high sounding philosophical terminology, so that the very plainness

[14] This part of the text is partly illegible. See Engl. tr. p. 25, note 5.
[15] Engl. tr. p., 26.
[16] See Arabic text, notes 28, 39. See also note 32.
[17] See Arabic text, notes 32, 35.

with which these assertions are made may be said to reveal the weakness of the related Aristotelian argument.

Furthermore, toward the end of this section, Al Fârâbî says that these arguments are in accordance with the limited understanding of his interlocutor and not in accordance with the nature of the problem in itself.[18] This may be considered an additional evidence to the effect that Al Fârâbî is not willing to subscribe wholeheartedly to the argument he has put forth. He may be referring by these words, however, to the imaginary particles and the assumptions involving the division of the space inside the vessel into two sections, one full of air under normal pressure and the other absolutely empty, and to the fact that this is very artificial and not at all in conformity with the real state of things as explained by him later.

It is to be noted in this connection that some other works of Al Fârâbî contain brief indications of his general ideas concerning the subject of vacuum, but apparently none of these are of a nature to shed a sufficiently clear light on our present problem.

In *Ithbât al mufâraḳât*, a work attributed to Al Fârâbî,[19] it is claimed that vacuum being impossible of realization (muḥâl), its non-existence cannot have a cause.[20] This bears some resemblance to his following statement occurring in the present article : "It is impossible to imagine that what is absolutely nothing attracts water to itself, or for that matter, to imagine such a thing at all.,,[21] But there is a double uncertainty here : the authorship of *Ithbât al mufâraḳât* is uncertain, and the last phrase in the above quoted sentence is not very clearly expressed.

In certain other writings of his the formula "lâ khalâ' wa lâ malâ',, (no vacuum and no plenitude) occurs.[22] It is thus seen that he rejects the idea that any empty or full space exists beyond the celestial spheres — a doctrine usually implying the rejection of the idea of the plurality of worlds. This means that Al Fârâbî was antagonistic to the idea of absolute space in so far as its existence beyond

[18] See Engl. tr., p. 27.

[19] See above, p. 61, note 3.

[20] Haydarabad edition, 1345 H. p. 5.

[21] Engl. tr., p. 29.

[22] *'Uyûn al masâil*, Cairo edition, p. 27 ; *Fî jawâb masâil suila 'anhâ*, Answer No. 36 ; *Al da'âwî al ḳalbîya*, Haydarabad 1349 H. p. 7.

the celestial spheres is concerned, but does not necessarily mean that he considered the conception of space within our world as something independent of material bodies to be nonsensical.

In support of such a claim, it may be of interest that although Al Fârâbî speaks, in the present article, of the impossibility of the interpenetration of two material bodies without an increase of volume beyond that of one of the bodies involved,[23] he does not extend this argument, as Aristotle and many of his followers did,[24] to the interpenetration of material bodies and space considered as independent of bodies.

It is true that in this article Al Fârâbî does not deal with the question of vacuum in a general manner and does not even touch many of the well-known arguments, but here he comes very close to this question and approaches it from more than one direction. It is likely, therefore, that he was in favor of making a distinction between the interpenetration of two bodies and that of a body and space. In fact, certain Islamic followers of Aristotle made this distinction and claimed that Aristotle himself had done the same thing.[25]

After defeating his opponents with the above mentioned discussions, Al Fârâbî changes the subject and introduces the question of the increase and decrease of heat. Here he states that the loss or gain of the heat or coldness of a body takes place either by the addition or subtraction of material bodies of greater or smaller heat contents (or tepmerature), or the warmness may change while the bulk of the body remains unchanged. These details are apparently borrowed partly or wholly from Aristotle's *De generatione et corruptione*.[26] Al Fârâbî is speaking here of what may be called "foreign heat,, in the Aristotelian terminology.[27] Some of his statements bring to the mind the possibility of an approach to the distinction between heat and temperature, but the passage taken as a whole does not warrant such a claim.

[23] Engl. tr., p. 28.

[24] Aristotle, *Physics*, book 4, chapter 8, p. 216b.

[25] Salamon Pines, "Etudes sur Awḥad al Zamân al Baghdâdî", *Revue des Etudes Juives*, Nouvelle série, vol. 4, 1938, p. 7, note 32.

[26] W. D. Ross, *Aristotle*, French translation, Paris 1930, p. 127.

[27] See Aristotle's *Meteorology*, p. 389a 26, 389b 3 and 19.

After this rather clumsily expressed section on heat, Al Fârâbî makes an analogy between change of degree, or amount, of heat or coldness and change of volume. He says that change of volume too need not necessarily be accompanied with change in mass. He then states that air is an example of bodies whose behavior is of this kind, i. e., which may undergo a change of volume without any change of mass.

He then observes that, due to its excessive humidity, air takes the shape of its container, that the expansion of air takes place radially in all directions, and that, as a result, it fills all the space made available to it by the bodies neighboring on it. Al Fârâbî probably also makes a comparison here between water and air, and draws our attention to the fact that although water too takes the shape of its container, with water this process takes place without any change of volume, whereas air is elastic and expands in all directions, radially, and with perfect ease.[28] As we shall presently see, Al Fârâbî considers any expansion in a given body of air to represent a state imposed upon it by force.

It is observed that what Al Fârâbî does here is simply to make a rather good formulation or to give a statement of observed facts. It is also seen that his statements involve an implicit or explicit comparison of liquids and gases.

These remarks seem to involve a certain divergence from or an elaboration of the Aristotelian explanation of compressibility. According to Aristotle, the compressibility of bodies is not due to the existence of empty spaces between the particles of bodies as declared by the atomists. Compressible bodies have pores, but these interstitial spaces are not empty. They are filled with materials which do not possess as high a degree of hardness as the body itself, and during compression these softer bodies contract, or escape from the pores.[29]

[28] The text would need a slight alteration at this point in order to assume such a meaning (see Arabic text, note 77); such an alteration may not be considered permissible, but even then, it may be said that if this comparison is not explicit in Al Fârâbî's text it is there implicitly.

[29] S. Pines, op. cit., p. 9. See also, Aristotle's *Meteorology*, p. 386b. In these matters the general views held by Al Fârâbî were apparently identical in other

This Aristotelian explanation, which was offered as a substitute for that of the atomists, was considered by Abû'l Barakât al Baghdâdî (d. 1152—64) to explain the compressibility of everything except air.[30] For the compressibility of many substances was explained by claiming the existence of air within their pores. It may be that Abû'l Barakât's criticism was directed against the Farabian explanation mentioned above, but it is likely too, on the other hand, that such a criticism had already been made before Al Fârâbî's time and that Al Fârâbî is trying to circumvent this troubling aspect of the Aristotelian explanation of compressibility.

If so, however, his attempt is clearly an uncuscessful one, and had Al Fârâbî claimed to have proved the impossibility of vacuum in this article, this claim would have implied his having fallen into a vicious circle. For in case he had such a claim, his proof of the non-existence and impossibility of vacuum would have ultimately rested on his explanation of the compressibility of air, although the latter contains the tacit assumption that vacuum does not exist or at least it sidetracks the issue.

In fact, what Al Fârâbî does here consists of little more than a statement of observed facts. He does not elaborate and could not have elaborated his statements to the point of giving convincing evidence that it renders an assumption of the existence of vacuum unnecessary.

Al Fârâbî is apparently aware of this himself. For nowhere in this paper, with the possible exception of one phrase,[31] does he make a clear and general claim that vacuum does not exist or is impossible. In this paper, Al Fârâbî's position is in reality a defensive one. A new argument had been developed in favor of the possibility of producing vacuum artificially, and Al Fârâbî undertakes the task of showing that the evidence offered in favor of this claim consists of a misinterpretation of facts; there is air where vacuum is claimed to have been produced.

details with the views of Aristotle. See, e. g., *Fî jawâb masâil suila 'anhâ*, Answers No. 5, 6, 7.

[30] Pines, p. 9-10.

[31] See above, p. 157 and note 21.

Was Al Fârâbî undecided concerning the general question of vacuum? Did he believe that the question of the possibility or impossibility of vacuum remained uncertain? It is true that the present article gives one the impression that Al Fârâbî was against the claim of the possibility or existence of vacuum, but this can only be read between the lines and may not correspond to the factual situation.

It is possible that Al Fârâbî shares the views of the Aristotelians or is favorably inclined toward them and that his non-committal attitude and his almost studied reserve in this respect are due to his awareness of the fact that the argument he presents in this paper is of a strictly defensive character.

Al Fârâbî tries to determine the laws underlying and governing this type of change of volume, i. e., change of voulme without change of mass. The scheme he puts forward is clearly based on the Aristotelian laws of motion. He claims that to each body of air corresponds a natural volume, and any departure from this volume represents a forced state imposed upon that body of air. Compressed or expanded air will, therefore, remain at its new volume only as long as it is under constraint, and as soon as the constraining force departs, the air will return to its natural volume. This, Al Fârâbî asserts, is like the motion of a stone. For as long as the latter is in its natural place, it will not move by itself, and conversely, if the stone is not in its natural place, it is held there by a force. Such bodies will remain at their forced position or state only as long as a constraining force adheres to them, and they will start moving to their natural place or volume as soon as the force leaves them free to do so.

Some additional details are given concerning the behavior of a body of air when an unnatural volume is imposed upon it and when it gets free from the force holding it at its forced volume. Al Fârâbî claims that the greater the constraint the greater the increase or decrease of volume, and the greater the constraint the quicker and the more forceful its return to its normal volume.

These details, in turn, are vaguely reminiscent of the Archimedian law of hydrostatics determining the force governing the upward motion of an immersed body which is lighter than the liquid into which it is immersed. It is probable that this law served as a source of inspiration for Al Fârâbî.

The above mentioned ideas concerning the compressibility of air are most likely original with Al Fârâbî. The scientific literature prior to Al Fârâbî's time contains certain items concerning expansion without increase of matter, but apparently all these examples refer to expansion taking place under the influence of heat. The Alexandrians knew, e. g., of the expansion of air through heat and had devised an apparatus which may be considered the forerunner of the modern thermoscope. A more interesting case, reminiscent of Al Fârâbî's above mentioned statements, is a peripatetic argument, however, and it may have inspired or influenced Al Fârâbî. This peripatetic argument, which was adduced in support of the claim that vacuum does not exist, is the following.

In view of the fact that growth takes place by the intussusception of food, the phenomenon of growth was invoked by the atomists as an evidence in favor of the existence of interstitial particles of vacuum within the bodies of living organisms. The peripatetics answered this by stating that growth is not merely the result of the intussusception of foreign material into the organism, but is also the result of a transformation analogous to the expansion of water when heated. In support of this view, they drew attention to the fact that when water grows hot it will increase in volume without the incorporation of any additional material body, and its expansion will even cause its container to break.[32]

Continuing to read the text, we find Al Fârâbî speak of a property peculiar to water and air. The idea involved, which is apparently entirely original with Al Fârâbî pertains to the spatial interrelationship of these two elements. According to Al Fârâbî, the behavior of these bodies is such that they adhere to each other and continue remaining in contact all the time. If one of them moves, or the surface forming the boundary between them is displaced as a result, e. g., of a change of volume of air, a corresponding motion takes place in the other body, the result being that the two bodies remain in contact as previously.

Moreover, this movement takes place even if the resulting motion has to occur in a sense contrary to the sense of the natural movement of the body concerned, i. e., even if this movement violates the Aris-

[32] Pines, p. 10.

totelian doctrine that each body tends to move to its natural place.

On the basis of the preceding preparatory items, Al Fârâbî now comes to the main problem in hand, i. e., to the explanation and interpretation of the facts observed in the experiments made with the upside down vessels. He pieces together the preceding items in the following manner.

When the vessel was sucked from its mouth and part of the air contained in it extracted, the remaining air was forced to fill the whole vessel, and as long as the mouth of the vessel was obstructed with the fingers, this air was impelled to occupy a volume in excess of its normal volume. No vacuum was produced; the air was simply made to remain at an expanded state. When, on the other hand, the obstruction was removed from the mouth of the vessel after having dipped it into the water, the constraining force disappeared. The air returned, therefore, to its natural volume, and because of the property of air and water of maintaining their contact and adhering to each other, the water followed this air in its upward motion and filled the space inside the vessel as the air receded from it as a result of its return to its normal volume.

In the first case, the formation of vacuum was avoided because of the elasticity of air; no vacuum was formed in the vessel although part of its air had been extracted by force. In the second case, i. e., when the obstruction was removed from the orifice, the vessel having been lowered to the water, the formation of vacuum was prevented again, this time by the entry of water into the vessel. The entry of water into the vessel is due to the adhesion of water and air, and no such thing as the force of attraction of vacuum exists.

It is to be stated that, leaving certain details out of account, Al Fârâbî gives a good interpretation of the observed facts, but this would not preclude his being wrong had he jumped to the more general conclusion that vacuum cannot be created artificially. The position of his opponents is just the opposite. Their alleged interpretation and explanation of the observed facts of the particular experiments in question are wrong, but the general conclusion, namely that vacuum can be created artificially, which they drew from these experiments, is correct.

After this worm's-eye-view study of the contents of the article,

we may try to place it within its historical setting. For this article seems to have clear earmarks of a work occupying an important place in the historical development of the ideas on the subject. It seems to contain, in addition to the contributions of a more specific nature already mentioned, ideas of a wider scope as well as new methods of approach, which have had far reaching repercussions in physics in the late medieval times. The question arises, however, whether these novelties belong to Al Fârâbî himself. How are we to sort out those items which are his personal contributions to the subject ?

In this connection it is well to keep in mind that this article does not deal with the question of vacuum in general. Its scope is very limited and clearly defined. In this article Al Fârâbî does not put the question of vacuum in its philosophical and theological setting. He does not take up the numerous arguments of the Aristotelians,[33] and neither does he deal with the theoretical and empirical views of their opponents. He merely attempts to refute an experimental demonstration of the possibility of creating vacuum artificially, and shows that the arguments of his opponents serve to strengthen the point of view they are trying to refute.

It is clear that this paper is not an exposition and discussion of ideas concerning vacuum. It is a monograph, and it should be very likely, therefore, that the main ideas contained in it are Al Fârâbî's personal contributions to the subject. In fact, our present state of knowledge leads us to a similar verdict.

The subject of vacuum is of great importance in the history of science and one which was pregnant with new developments in medieval times. The atomists had maintained the universal existence of empty space. Trying to refute their ideas, Aristotle put forth a number of arguments as proofs of the impossibility of vacuum, and his arguments dominated to a large extent throughout the Middle Ages.

The Aristotelian arguments which were conceived as proofs of the non-existence and impossibility of vacuum were philosophical arguments. As in Aristotelian physics in general, so in the subject

[33] These are exposed especially in his *Physics*. See book 4, chapters 1-9, especially 6-9.

of vacuum, the peripetatic approach was of a deductive nature. It had occurred neither to Aristotle nor to his Greek and Byzantine followers and commentators to invoke experimentation to support their thesis on the subject of vacuum. Sometime during the Islamic Middle Ages, however, arguments based on experimental demonstration of the non-existence and impossibility of vacuum are seen to make their appearance.[34] New proofs or demonstrations involving a basically new method are thus seen to be added to the peripatetic list of arguments, and it was apparently the present article of Al Fârâbî that ushered in the new tradition. Such men as Al Ghazâlî, Ibn Rushd, and Maimonides continue and amplify the tradition,[35] while Abû'l Barakât al Baghdâdî is seen to take up this new argument in order to refute it together with other peripatetic arguments touching the question of vacuum.[36]

A statement of Maimonides makes it seem likely that the above mentioned innovation was made by the Banû Mûsâ Brothers, but this statement of Maimonides merely contains the assertion that the *Book of artifices* of the Banû Mûsâ Brothers contains over one hundred artifices which constitute demonstrations of the impossibility of vacuum. There is no direct claim or allusion in it to the effect that the authors of that book themselves presented these atrifices as arguments in favor of the Aristotelian thesis on the question of vacuum.[37] The statement of Maimonides, therefore, in no wise constitutes a conclusive evidence of the priority of the Banû Mûsâ Brothers in this question.

Partial or complete translations of Aristotelian works such as his *Physics* and its different commentaries were being made during the life-time of these brothers by such men as Ḥunayn ibn Isḥaḳ, 'Abdulmasîḥ 'Abdullâh al Ḥumsî, and Ḳusṭâ ibn Lûḳâ al Ba'labakî.[38] On the whole, however, in contrast to that of scientific works, the translation of Greek philosophical works was only beginning to be

[34] Pierre Duhem, "Roger Bacon et l'Horreur du Vide", *Roger Bacon, Essays contributed by various writers on the occasion of the commemoration of the seventh century of birth*, Oxford 1914, p. 241.

[35] Duhem, p. 242-45.

[36] Pines, p. 19-20.

[37] Duhem, p. 242.

[38] T. J. de Boer, *The History of Philosophy in Islam*, London 1933, p. 18.

taken up systematically and in large numbers. Moreover, the Banû Mûsâ Brothers were scientists rather than philosophers. It is very likely, therefore, that they were not thoroughly acquainted with peripatetic views on vacuum. They may not even have been interested in Aristotelian physics. The title of their above mentioned book suggests that in these matters they were followers of such men as Philo of Byzantium and Hero, whereas Al Fârâbî was the first philosopher of Islam in the strict sense of the word, and the first Islamic philosopher who was thoroughly familiar with Aristotelian views;[39] and he was also an eminent scientist.

As we have seen, it is likely that Al Fârâbî did not fully agree with the peripatetic views on the subject of vacuum and with the objections of the Aristotelians to the idea of absolute space. Nevertheless, this would not necessarily prevent him from contributing to the Aristotelian thesis on vacuum and from supplying the Aristotelians with a new argument.

The reason why Aristotelianism comes to the foreground with respect to the taking root of the new tradition is that Aristotelian physics was dominant in the Middle Ages and that the peripatetic philosophers were armchair scientists strongly inclined toward deductive and speculative thinking. A decision on their part to resort to experimental demonstration was, therefore, of great significance for the future course of scientific work. Consequently, it matters little whether Al Fârâbî, as the originator of the new argument, did not strictly adhere to the Aristotelian views. What matters more is that Al Fârâbî conceived his new argument as a contribution to the peripatetic cause, or that, at any rate, he formulated it in a manner acceptable to them. In fact, we see that this demonstration was accepted by the peripatetics and incorporated into their list of arguments. This is clearly seen from the writings of Abû'l Barakât al Baghdâdî.[40]

As Duhem has pointed out, this peripatetic innovation consisted of little more than the mere adoption of an idea already set forth by the Mechanicians of Alexandria.[41] Strato and the Alexandrian

[39] See above, p. 48.
[40] Pines, p. 19-20.
[41] Duhem, p. 243.

Mechanicians combined the belief in the existence of small particles of vacuum in the bodies with the claim that an empty space of appreciable dimensions cannot be produced artificially. This latter claim was based on the impressions gained from the observed facts connected with their hydrolic and pneumatic contraptions.

The peripatetics could have taken advantage of these experimental data at a much earlier date. They might have utilized them to construct a defensive argument for themselves and thus reinforce the peripatetic position by incorporating experimental proof and demonstration into their system of arguments long before the time of Al Fârâbî. It is difficult to explain why such an attempt was not made before Al Fârâbî. It is perhaps well to remember that usually a question of this kind does not have much meaning. For, while a logical sequence may roughly be assigned to the evolution of scientific work, generally the time intervals between the various items of discovery and innovation are unpredictable. It is seen, however, that this article of Al Fârâbî does throw some light on this question.

Apparently the Aristotelians did not think of benefiting from the experiences of the Mechanicians so long as they did not feel compelled to do so; the pneumatic and hydrolic devices of the Mechanicians did not appeal to them. These experimental demonstrations did not affect the speculative philosophers so long as the deductions based on them were harmless. The situation changed, however, when an attempt was made to utilize these demonstrations for the refutation of the Aristotelian point of view. It was then only that the possibilities inherent in these demonstrations was brought home to them clearly. It is at this juncture, in fact, that Al Fârâbî's article makes its appearance.

Without being in possession of sufficient documentary evidence, Duhem had made a correct guess in this connection. Namely, on the basis of a statement in a late medieval European work, he surmised that some Alexandrian experiments had been considered by certain scholars to demonstrate the possibility of producing vacuum artificially.[42]

[42] Duhem, p. 269-70.

It should be noted that at this stage it was a more difficult task to harness these experiments and the ideas inherent in them to the Aristotelian chariot. Another point which is of interest is that in adopting this mode of demonstration, Al Fârâbî does not act as a mere copyist. He rejects, or at least modifies, the explanation and interpretation of the observed facts offered by the Mechanicians. This step, which we shall presently consider in some detail, was of great historical importance. We shall speak of it after a brief reference to two other items of interest.

It has been considered probable that Al Fârâbî wrote this article as a refutation of the views of Al Râzî,[43] but the text of the article does not shed a clear light on this question. Alledgedly, Al Fârâbî's adversaries lacked an adequate knowledge of logic and should, therefore, be scientists of a non-philosophical turn of mind. They perhaps were men who worked on mechanical contraptions and automatic machines. In fact, as we have seen, Al Fârâbî describes them as lacking the background and formation necessary to see a problem in its broad philosophical perspective and accuses them of inability to interpret their observations and reach their conclusions in the light of a thorough knowledge of logic so indispensable for an accomplished scientist according to Al Fârâbî.

This description would undoubtedly not fit Al Râzî who was a great thinker and philosopher as well as an accomplished scientist. It may be relevant in this connection, however, that Al Râzî, perhaps because of his strong antireligious ideas, was very severely criticised by certain scholars of Islam, e. g., by Ibn Sînâ, who claimed in no uncertain terms that Al Râzî's proficiency was strictly limited to the field of medicine.[44] It is difficult to say whether Al Fârâbî too, at a certain period of his life at least, had such strong feelings against Al Râzî. Al Fârâbî himself does not seem to have been very religious in the ordinary sense of the word, in his later life at any rate,[45] and he was a freind and teacher of Yaḥyâ ibn 'Adî, who is said to have been a desciple of Al Râzî.[46]

[43] S. Pines, *Beiträge zur islamischen Atomenlehre*, Berlin 1936, p. 81-82.
[44] S. Pines, "Etudes sur Awḥad al Zamân ..", p. 5, note 20.
[45] See above, p. 29-41.
[46] *Encyclopaedia of Islam*, art. "Râzî", Fr. ed., vol. 3, p. 1213.

It is also of interest in this connection that Al Râzî is said to have been a representative of the idea that vacuum exerts an attractive force.[47] For the proponents of this idea, which is among those refuted by Al Fârâbî in this paper, do not seem to have been very numerous. It seems quite certain, however, that Al Fârâbî's criticisms in this paper are not directed against a single person or against the representatives of a single point of view. He refutes, e. g., the idea that the flow of water into the vessel is due to the repulsion of the external air as well as the claim that it is due to the attraction of vacuum. It is quite probable, however, that Al Râzî too is among those criticised by Al Fârâbî in this paper.

This article of Al Fârâbî seems to contain an extremely interesting bit of information, but unfortunately it is not very clearly set forth. From a statement of Al Fârâbî it would seem that already before his time a very remarkable approach had taken place toward a correct undurstanding of the phenomenon of atmospheric pressure. For Al Fârâbî speaks of a claim that water enters into the vessel because of a force of "attraction or repulsion,, exerted by the outside air.[48]

Very likely a mistake has slipped into this part of the text, but it is possible to interpret it in such a manner that it will sound reasonable, and this can be done without changing the wording of the manuscript (See its English tsanslation). It is possible too that there is either a lacuna here, or the word "attraction,, is wrong. As we have seen, elsewhere in the same article Al Fârâbî speaks indirectly but in a clear manner of a claim that the entry of water into the vessel is due to the attractive force of vacuum.[49] Therefore, the above mentioned phrase should probably be changed into some such form as "the attractive force of vacuum inside the vessel or the repulsion of the air outside.,,

This interpretation seems quite reasonable. For Al Fârâbî speaks of forces of attraction and repulsion on three other occasions in this article, but without specifying the agents exerting these forces.[50]

[47] Pines, *Beiträge*, p. 47, note 1 ; Pines, "Etudes", p. 20, note 83.
[48] Arabic text, p. 15, Engl. tr., p. 35.
[49] Arabic text, p. 9, Engl. tr., p. 29.
[50] Arabic text, p. 3, 10, 14, Engl. tr., p. 22, 29, 35.

By reading the article it becomes clear that the attracting agent is vacuum. Therefore, the agent exerting the force of repulsion, mentioned more than once, turns out to be the outside air, in the light of the above mentioned passage.

Al Fârâbî rejects the idea of the repulsion of the outside air, as well as the attraction of vacuum, and substitutes for it the hypothesis that water and air preserve their contact with each other and follow each other in their movements. Both this hypothesis and his previously mentioned assertion that air possesses the quality of pervading all the space made available to it by bodies neighboring on it involve the tacit assumption that the behavior of both air and water are such that they prevent a solution of continuity in nature, i. e., they forestall the formation of vacuum in nature. The action of air is to fill all spaces which are being emptied by other bodies, but such an air is in an unnatural state, and if there is water neighboring upon it, the air will return to its normal volume and water will occupy the space emptied by the contracting air.

The idea of spatial continuity of air and water had wide repercussions in medieval physics, and it was ultimately responsible for the emergence of the idea of atmospheric pressure, the growth of which it may have checked at first, as we have just seen. Although the doctrine of nature's abhorrence of vacuum, i. e., the later and more generalized version of the Farabian hypothesis just mentioned, was much ridiculed in later times, like every fallen theory or hypothesis, it facilitated research and collection of facts, especially by drawing attention to the facts it was incapable to explain and thus paved the way for a new and better understanding and explanation of observed facts. In this case, the doctrine of nature's abhorrence of vacuum gave significance to the fact that in suction pumps water does not rise beyond a height of about thirty feet, and that there must, therefore, be a limit to and a measure of nature's abhorrence of vacuum. The celebrated experiments of Toricelli followed, and nature's horror for vacuum was replaced by the idea of atmospheric pressure.[51]

Duhem who investigated the writings of thirteenth and fourteenth century European scholars bearing on the question of

[51] Duhem, p. 268.

nature's horror for vacuum had come to the conclusion that this hypothesis was a personal contribution of Roger Bacon, that it was cenceived and originated by him exclusively. Duhem believes to have detected all the phases of development of this idea in the works of Roger Bacon, and claims that only a most rudimentary germ of it, namely the idea of an attractive force exerted by vacuum, is to be found among the precursors and sources of Roger Bacon.[52]

The distinctive features of this hypothesis, claimed for Roger Bacon by Duhem, are the following. In accounting, in accordance with the hypothesis, for the facts observed in a number of experiments, Roger Bacon takes precaution lest his statements be interpreted so as to make an efficient cause out of vacuum. According to him, it is wrong to say that vacuum exerts an attractive force. Nature, rather, tends to preserve the continuity and contiguity of its parts. It is claimed, in addition, that this behavior of bodies has a priority over the Aristotelian laws concerning the movements of bodies. That is, a body would remain in a place which is not natural for it or would even move away from its natural place rather than allow the formation of vacuum.[53]

All these ideas exist in Al Fârâbî. Only the idea of spatial continuity occurs in a more generalized form in Roger Bacon. By a generalization of a purely theoretical nature, he considers it valid for all the regions of the universe,[54] and he does not limit it to a mutual property of water and air. He cites, e. g., the adhesion of solid to solid and liquid to solid, clepsidras, and cupping. Roger Bacon thus presents the hypothesis with somewhat greater detail and extends its field of exemplification by citing a variety of experiments demonstrating its validity, whereas Al Fârâbî mentions only one (i. e., a set consisting of two experiments). The experiment mentioned by Al Fârâbî does not occur in Roger Bacon, however, and this explains and constitutes a symbol of their main points of divergence.

In fact, the most significant difference between Al Fârâbî and Roger Bacon is that Al Fârâbî assigns a specially important part to the properties of air, whereas in Roger Bacon's more generalized

[52] Duhem, p. 266-67, 241, 253-54, 284.
[53] Duhem, p. 256-57, 265.
[54] Duhem, p. 265.

version of the hypothesis this emphasis is seen o have disappeared. Roger Bacon does not speak of the compressibility and elasticity of air. In view of the fact that the historical and scientific importance of the hypothesis lies mainly in its having served as a jumping board to the discovery of atmospheric pressure, it is clear that this development constitutes a retrograde step.

All in all, it is certain that Roger Bacon was not the originator of the hypothesis; to him may only belong the elaboration and generalization of the hypothesis put forth by Al Fârâbî.

Philo of Byzantium[55] and Ioannes Philoponos[56] believed vaguely in the existence of a force preventing the formation of vacuum. Al Râzî, on the other hand, is said to have claimed that vacuum exerts an attractive force.[57] Al Fârâbî's idea that the formation of vacuum is prevented because of the elasticity of air and the property of air and water to preserve their spatial continuity seems, therefore, to have been a development and elaboration of the ideas of the Mechanicians of Alexandria and of Philoponos. And on the other hand, it was a reaction to the ideas of the people he calls his opponents, who claimed to demonstrate through experiment the possibility of producing vacuum artificially, and perhaps also to Al Râzî's idea that vacuum exerts an attractive force.

Coming back to Al Fârâbî's recourse to experimentation, as we have seen, it is, from one point of view, the continuation of a tradition started by the Alexandrian school. The Mechanicians of Alexandria were far from being peripatetics, however, and, as Duhem has pointed out, the tradition of having recourse to experimental demonstration in order to support the peripatetic arguments for the non-existence of vacuum and the impossibility of creating it atrificially within a limited space was originated in Islam. And this tradition too, as has been discussed previously, seems to have been a personal contribution of Al Fârâbî.

The procedure of resorting to experimentation, as it came to exist among the partisans of the Aristotelian views on vacuum, is seen to continue and develop in Islam after the time of Al Fârâbî. It is

[55] Duhem, p. 266-67.

[56] Pines, "Etudes", p. 20, note 83.

[57] Pines, *Beiträge*, p. 47, note 1, "Etudes", p. 20, note 83.

seen, e. g., in Al Ghazâlî,[58] with whom we find the number of experimental demostrations to have increased. He also makes a brief reference to the property of bodies concerning their tendency to preserve their spatial continuity and contiguity, and does not specify it as a property of air and water only.[59] The extension of the validity of the hypothesis so as to make it encompass a larger group of phenomena and its demonstration by the help of a variety of examples seem both, therefore, to have been developments which were not brought about by Roger Bacon for the first time; they had taken place already in the time of Al Ghazâlî in Islam.

Although Duhem considers Roger Bacon to have been the originator of the new hypothesis, he believes in the existence of a work which set Roger Bacon in this direction of thought, but he is convinced that this work was a simple translation or an adaptation from the works of Philo and Hero, or a Latin translation of such an Arabic book.[60] As we have seen, he admits, in addition, that the tradition of supporting the Aristotelian view of the impossibility of vacuum with experimental demonstration originated in Islam. Furthermore, on the basis of some statements occurring in a work attributed to Robert Grosseteste, as we have seen, he ventures the guess that in Islam some of the Alexandrian experiments were misinterpreted and, as a result, were considered to prove the possibility of producing vacuum artificially.[61]

It is thus seen that Duhem too had realized the existence of an Islamic influence in this matter but had minimized its importance very much. In the light of this newly discovered article of Al Fârâbî it now becomes necessary to modify Duhem's claim and to conclude that the part played by Roger Bacon was very small indeed, if any. Al Fârâbî was the originator of the new hypothesis, and later research may alter this verdict only if it turns out that these views existed already before the time of Al Fârâbî.

It should be added here that the new hypothesis was of great importance also because it constituted a modification of Aristotelian

[58] Duhem, p. 241-42.
[59] Ghazâlî, *Maḳâṣid al falâsifa*, Cairo edition, p. 241-47, 246.
[60] Duhem, p. 247-48, 263.
[61] Duhem, p. 269-270.

views on dynamics. It was meant to account for certain facts which could not be explained by the Aristotelian laws of motion. Consequently, it was a contribution to the development of physics, regardless of its individual merits. The part it played was similar to that of the theory of impetus; it was intended to modify and complete the Aristotelian laws of motion, but because of this modification it was in reality among the factors that undermined the Aristotelian views which otherwise seemed to be strongly entrenched in the medieval mind, dominating or influencing also such other fields as astronomy and philosophy in general. It may consequently be considered to occupy a place of honor among the factors which paved the way for the emergence of the new physics in the sixteenth and seventeenth centuries.

It should also be noted that lack of recourse to experimentation or systematic observation was one of the main and basic shortcomings of Aristotelian physics and also of medieval science in general. The importance of this innovation brought about by Al Fârâbî which involves a new step in methodology and affects the physics that reigned supreme in medieval times can, therefore, hardly be exaggerated. In fact, when we follow up the later historical developments of this branch of science, i. e., when we consider the investigation and research made in this particular field during the late Middle Ages, we find it to be exceptionally rich in examples approaching the experimental method.