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**Three Notes on the Method of Analysis and Synthesis in its Ancient and (Arabic) Medieval Contexts**

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*Abstract:*
Most historians and philosophers of philosophy and history of mathematics hold one interpretation or the other of the nature of method of analysis and synthesis in itself and in its historical development. In this paper, I am trying to prove – through three points – that, in fact, there were two understandings of that method in Greek mathematics and philosophy, and which were reflected in Arabic mathematical science and philosophy; this reflection is considered as proof also of this double nature of that method. Thus, we have to rethink the nature of Arabic philosophy systems.
*Keywords:* Analysis, synthesis, Arabic philosophy, history and philosophy of mathematics.

## 1. Introduction and the First Note on the Method of Analysis and Synthesis in its Ancient Context

The modern historiography about the method of analysis and synthesis, as a method of discovering (analysis) and proving (synthesis) had been in agreement up to the first quarter of the last century on its nature and structure (For example: [17 I, pp. 137-42] where he cites the historians before him, such as Cantor) according to Pappus' famous passage [29 BK. 7, pp. 1-2] on the one hand, and to the scholium to Euclides' XIII [17 iii, p. 442] on the other hand [13, p. 47, n.1], [32, p. 464], [25, p. 318]. According to both of these passages the modern historiography on the method had been reconstructing its logical structure as follows [16 I, pp. 399-401; 32, p. 464-65; 17 I, pp. 139-41; 27, pp. 198-99]: if we have a mathematical proposition/problem (usually a construction) and we want to discover a proof for it, just to assume that it is proved, then to *deduce* from it a proposition and from this another one up to arriving at a proposition in which it is known that it is true (a theorem or first principle). This is the end of analysis by which we discovered the required proposition(s) for our proof. Consequently, the synthesis starts out from the last true proposition(s); by going back *deductively* following our same steps in analysis until we arrive at the original and the sought proposition/construction to be proved/constructed. In doing so we would have proved the original proposition/construction. This could be depicted logically as follows [25, p. 321], [24, p. 71], [cf. 27, pp. 200-204, 209-22, for a quantified formulation]:

Analysis: p → q → r→ s

Synthesis: s → r→ q→ p

But if the analysis ends up with a false proposition, then the original proposition/construction will be false/impossible [29 BK, 2], [32, p. 465], [17 I, p. 140], [24, p. 73].

This understanding of the method of analysis and synthesis is allegedly supported by its practices in Archimedes' *On the Sphere and the Cylinder II*, Apollonius' *Conics and Cutting-off a Ratio* and the alternatives proofs of Euclide XIII 1-5 [27, pp. 195, 197]. However, this reconstruction rests on two assumptions:

1. That both steps of analysis and synthesis are convertible or reciprocal [32, p. 465], [15, p. 1]. But this is logically imprecise [25, p. 321], [18, pp. 33-34], [24, p. 71]. Anyway, most of the proponents of the modern historiography believed in that; Menn [27, p.199] is an exception. In fact, the order of the steps of analysis and synthesis in the practices of Archimedes' *On the sphere and the Cylinder II* and Apollonius' *Conics and Cutting-off a Ratio* are not the same [1, pp. 138-41].
2. That the steps of analysis are *deductive* from the conclusion to the true/false proposition(s).

But since Cornford's work [13] we have had a new understanding for the method. Cornford rejected the above two assumptions and insisted instead that the steps of analysis are not deductive; what we are doing in the analysis is that we are trying by intuition [*Ibid*., p. 43] to grasp ἅπτειν upwardly a proposition from which the sought proposition/construction implies. He supported his understanding by passages from Aristotle *Met.* 1051a:21-30[1]; *NE, iii, 3* 1112b15-27[2] and Themistius *on Anal. Post. I.*, 12[3]. [*Ibid*., pp. 44-45]. Again, we are trying to reach another proposition, if any, from which this last proposition implies, and so on. When we reach a proposition known to be true the analysis is finished, and then we would be ready to start our synthesis from it deductively downward to our sought proposition/construction [*Ibid*., p. 47, n.1]. So the method of discovery or analysis is intuitive while the method of proof or synthesis is deductive. Thus we don't need also the first defective assumption in the classical understanding of the method. According to Cornford, Pappus' report doesn't imply this, he added in his account of the analysis ἑξῆς (succession) which means that its steps are not logical consequences [*Ibid*.]. Cornford connected this understanding of the method and the method itself with Plato's dialectic in *The Republic* 509c-511d [*ibid*., pp. 48-49] which, from his point of view, associates with the method described in *Phaedrus* 265d-266c, i.e. the method of collection συναγωγή and division [ibid., pp. 184-87, 263-68], [cf. 33, p. xliii], [21, p. 300]. Thus, the mathematical analysis reaches upwardly to a hypothesis while the philosophical dialectic reaches to first principles ἀρχαί [Benson, 11, p. 96]. On the other hand, synthesis proves its conclusion downwardly by division διαίρεσις. Thus, Cornford supported Diogenes Laertius [14, III 24] and Proclus [30, 211, pp. 18-23] who claimed that the method of analysis and synthesis went back to Plato (Although Cornford of course concedes that Plato developed it from the mathematical practice of his day [13, p. 44]).

Ian Mueller, in his [28] tried to follow Cornford's footsteps, having added new evidence from Philodemus' history of Platonic school that Plato developed the analysis [*Ibid*., pp. 171-172] he worked on connecting the method of analysis and synthesis with Plato's method of hypothesis in *Meno* 86e4-87b2 on the one hand, and reconstructed it to fit the method of analysis on the other hand. Thus, he considered analysis as arriving at a sufficient and necessary condition διορισμός for our sought proposition/construction [*Ibid*., p. 175 ff.].

Although Stephen Menn [27] accepted that the method of analysis and synthesis went back to Plato, he tried to reconstruct it according to the understanding of modern historiography for it [*Ibid*., p. 212], rejecting its first assumption [*Ibid*., p. 198] and interpreting Aristotle *Post. Anal. I*, 12 78a7-13[4]; SE 16 175a26-28[5]; in addition to *NE, iii,* 3 1112b15-27 and his commentators (criticizing them in reality) to fit his reconstruction [*Ibid*., pp. 204-08].

How could we reconcile these opposite understandings, especially in regard to ancient analysis? Gulley in his [15], and after him Mahoney [25, p. 324] and Knorr [22, p. 355] noticed that there were two different formulations of analysis in Pappus' passage [15, p. 13] one (F1) defined the analysis "as an upward movement to prior assumptions from which an initial assumption follows" [*Ibid*., p.1] this is [29 BK. 1, pp. 13-14] "ἐν μὲν γὰρ τῇ ἀναλύσει, τὸ ζητούμενον ὡς γεγονός ὑποθέμενοι τὸ ἐξ οὗ [τοῦ] τοῦτο συμβαίνει σκοπούμεθα / That is to say, in analysis we assume what is sought as if it has been achieved, and look for the thing from which it follows." The other formulation (F2) defined the analysis "as a downward movement of deduction from an initial assumption," so it is convertible with the synthesis [15, p. 1], this is [Pappus BK. 2, pp. 27-28] "γένους τὸ ζητούμενον ὡς ὄν ὑποθέμενοι καὶ ὡς ἀληθές, εἶτα διά τῶν ἑξῆς ἀκολούθων / we assume what is sought as a fact and true advancing through its consequences."

Gulley [15, p. 13] tried to show that there were two sources for Pappus. He couldn't define the source for (F2) [*Ibid*.; Knorr in 22, p. 56 defined it as Heron], but he defined the source for (F1) in addition to Plato as Aristotle [*Ibid*., pp. 6-8, Knorr in 22, pp. 356-7 defined it as Pappus' contemplations on the philosophers], while Mahoney [25, pp. 325-26] considered it as an interpolation. Gulley used for supporting his position the same texts which Menn [27, pp. 204-209] considered as an evidence for understanding the analysis as (F2) without reciprocity. And he tried to prove his thesis by evidence from Aristotle's commentators, especially Themistius [15, pp. 9-10], the same Themistius whom Menn considered misunderstood Aristotle's passages, and he instead blaming Themistius blamed Philoponus for his misunderstanding Aristotle [*Ibid*., pp. 11-12].

What Gulley [15], Mahoney [25] and Knorr's [22] suggests is that there were two different formulations of the method of analysis, and let us guess accordingly the following:

1. Both proponents of the modern historiography understanding and their antagonists have had the same historiographical presupposition, i.e. that the ancients had only one and unique understanding of the method of analysis and synthesis. Consequently, both of them tried to grasp this unique meaning. But if we give up that presupposition and instead adopt another one which permits us to claim that there was more than one understanding (two traditions) of the method of analysis and synthesis, the conflict will be resolved, and we shall have a better understanding of the ancient concepts of analysis and synthesis. In fact, this is what the evidence of both camps says. Mahoney [25, p. 319] was inclined to think that there were many techniques of analysis, but this is a strategy for analysis not a theory of it).
2. That the source of both formulations was Aristotle [cf. 2, pp. 99-101], [22, p. 357] concerning Aristotle as a source for Pappus] one of them was adopted by the commentators with its obscurity, and the other by the mathematicians.

What supports the above is that methodology of mathematics of the Arabian mathematicians (which is, in some respect or other, a faithful heir to the Hellenistic tradition) had reflected those two traditions in understanding the methodology of analysis and synthesis.

## 2. The Second Note: Arabian Mathematicians and the Method

The Arabian mathematicians didn't know the formulation of the method of analysis and synthesis from Pappus, 1-2 [2, p. 16], they instead probably knew it from ps. Euclid *xiii*, 1-5, but surely from al-Nayrīzī's (865-922) commentary on Euclid's *book ii*[6] [6, p. 22]. al-Nayrīzī's passage is so obscure that it states that the analysis is demonstrating the sought problem, which means that it accords to (F1) not (F2) as Knorr believed [22, pp. 354-55]. But from the other hand the practices of analysis and synthesis in al-Nayrīzī's commentary are compatible with (F2). Moreover, there is no mention of convertibility. But from a criticism of the method of analysis and synthesis in Ibn Sinān's (908-946) treatise on the method of analysis and synthesis [10, p. 230] that there is no convertibility between analysis and synthesis while there should be, one could infer that the Arabian mathematicians knew a) ps. Euclid *xiii*, 1-5. And b) found discrepancy between the practice of the method in Archimedes, for example, and its formulation in ps. Euclid *xiii*, 1-5. This led the Arabian mathematician Ibn Sinān to reconcile the practice and theory. In his reconciling one should notice that he tried to gather between (F2) and the practices of analysis in Archimedes' *Sphere and Cylinder BK ii*, i.e. analysis as a deduction and (F1), exploiting the obscurity of al-Nayrīzī's definition. Thus, he reached his new and inventive definition for analysis i.e. the analysis as searching for the sufficient and necessary conditions for the sought problem (cf. Ibn Sinān text in [10, pp. 230-32] and his classification of the geometrical problems [12, p. 19]).

It seems that al-Sijzī (951-1024) tried to remedy this position by adopting (F1) once and for all in his definition to analysis: "He [The Geometer] assumes the desired aim as if it were already constructed, if the aim is a construction, or he assumes that it is true, if the aim is the investigation of a special property. Then he unravels (analyses) it by means of a succession of preliminaries, or by means of (mutually) linked preliminaries, until he ends up with correct and true preliminaries, or with false preliminaries. If he ends up with true preliminaries, the desired thing can be found as a consequence. If he ends up with false preliminaries, the impossibility of the desired thing follows. This is called: analysis by inversion" [7, p. 12. Cf. J. Hogendijk and M. Bagheri's introduction to the text, also 12, p.17]. However, both Ibn Sinān and al-Sijzī ended up in determination of new logico-mathematical concepts which were not found in Greek mathematics [10, pp. 227-28], which led, in turn, to change in the concept of 'the given' to be the 'known' [2, pp. 25-28], which influenced Ibn al-Haythem epistemology [31].

Thus, we see that there were differences in the definitions of analysis in Arabic mathematics, and this was a *reflection* of its Greek correspondent.

## 3. The Third Note: Analysis and Synthesis in Arabic Philosophy

The study of method of analysis and synthesis in Arabic and Islamic philosophy didn't attract the attention of the scholars in contrast to its study in the medieval mathematical Arabic corpus by the historians of science. However, this position is nearly the same in relation to the history of the Hellenistic philosophy[7] (with some exceptions) in contrast to Greek mathematics and Plato and Aristotle's philosophy.

However, we could define in principal two traditions in understanding and using the method of analysis and synthesis. The first one goes back to al-Fārābī, and the other to Ibn Sīnā.

In fact, although we could infer that al-Fārābī knew the ps. Euclid *xiii* scholium because he talked about the method of analysis and synthesis in his [3, p. 60] in a way compatible with it, but he influenced the method of analysis and synthesis through Plato's dialectic. Thus, he called it the method of division and synthesis (Tarkīb): "When a universal was taken and joint with opposite matters being predicated non-absolutely on this universal and put between each two [of these predicates] the conjunction 'or', such as our saying that animal is either bipedal or non-bipedal, This action is called division/Qesmah" [5, p. 36]. This understanding of the method stemmed from his reading of the method of collection and division in *Phaedrus*. Thus, he comments on this dialogue by saying: "Then he [Plato] investigated the methods that the man who aims at philosophy should use in his investigation. He mentioned that they are the method of division and the method of bringing together. Then he investigated the method of instruction: how it is conducted by two methods – the method of rhetoric and another method he called dialectic; and how both of these methods can be employed in conversation and in speaking and employed in writing" [4, pp. 26-27]. Therefore, we should ask how did al-Fārābī, as an aspiring philosopher, use this method of analysis and synthesis in its dialectic form in his philosophy? And what was its relationship with his understanding of using this method in mathematics? And in neo-platonic philosophy? Also, was there any difference between this method and dialectics/al-jadal which al-Fārābī put in a second rank to proof/Burhān?

If al-Fārābī had appealed to Plato in his version of Analysis and synthesis, Ibn Sīnā had appealed to his understanding of Aristotle and his commentators, on the one hand, and his experience in geometry, on the other hand. Thus, he understood the method of analysis as (F1), and this is clear in his commentary on *Poster Analytics*, I 12 78a7-13: "if there were a sought thing, and wanted a syllogism for by *analysis by inversion …*"[8] [20, p. 199]. Therefore, "by synthesis they are proceeding step by step from a problem to another without prejudicing of premises which have a middle term, and without leaving these premises unless they have elucidated them by near syllogism from them, also any additions should be limited, and the way should be methodized"[9]

[*Ibid*.]. His understanding of analysis as (F1) ascertained by his explanation of the geometrical problem as follows: “but the geometrical problem, for example, is either from a premise which being true and apparent by the geometrical methods”[10] [*Ibid*., p. 193]. It is clear that Ibn Sīnā, in addition to his being influenced by Aristotle and his commentators, was influenced also by al-Sijzī (note the expression analysis by inversion of both of them). This confirms our suggestion about reflection of the Greek context in the Arabic one.

Here a more important question arises: did Ibn Sīnā program his philosophy on a model of analysis and synthesis as Kant did in his Critique (synthesis) and Prolegomena (analysis)? Ibn Sīnā said in his introduction to al-Šifāʾ: “our aim in this book … is to put in it the gist of elements of the philosophical sciences of the ancients which we verified, and which being structured on the ordered and verified thought”[11] [19, p. 9]. Then he described another book for him: “I have another book other than those two books [al-Šifāʾ & the consequences or al-Lāwāheq], put in it philosophy as it is … It is my book al-Falsafah al-Mashraqyahʾ, but this book [al-Šifāʾ] is more presentable and extremely more helpful with the Peripatetics partners”[12] [*Ibid*., p. 10]. If we could answer this question, we will also solve a long running controversy concerning the book of *'al-Falsafah al-Mashraqya*' since Ibn Ţufayl up to today [cf. Madkour‘s introduction to 19, pp. 19-23]. But the most important thing is that we will also be able to put our hands on the climax of the method of analysis and synthesis in its ancient Greek and Arabic mathematical and philosophical contexts.

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## Notes

1. And the constructions/diagrammata are discovered in actuality; for they discover them by dividing. If they had been divided, they would have been evident; but as it is they are in there potentially. Why does the triangle have two right angles? Because the angles around one point are equal to two right angles. So, if the line parallel to the side had been drawn up, it would have been clear immediately on seeing it. Why is there universally a right angle in the semi-circle? Because if three lines are equal, the two which are the base and the one dropped straight from the center, it is clear on seeing it to the person who knows that. So that it is evident that the things which are potentially are discovered when they are drawn out into actuality; the explanation is that thinking is the actuality Makin's [26] trans. Note that Cornford [13, p. 44] translates νόησις by intuition not thinking).
2. "Rather they establish an end and then go on to think about how and by what means it is to be achieved. If it appears that there are several means available, they consider by which it will be achieved in the easiest and most noble way; while if it can be attained by only one means, they consider how this will bring it about, and by what further means this means is itself to be brought about, until they arrive at the first cause, the last thing to be found. For the person who deliberates seems to inquire and analyse in the way described as though he were dealing with a geometrical figure (it seems that not all inquiry is deliberation – mathematics, for example – but that all deliberation is inquiry), and the last step in the analysis seems to be the first that comes to be" (Crisp's trans. In [9]).
3. "Assume a true conclusion and then discovering the premises by which it is inferred" (Cornford's trans.).
4. "If it were impossible to prove truth from falsehood, it would be easy to make an analysis; for they would convert from necessity. For let *A* be something that is the case; and if this is the case, then *these* are the case (things which I know to be the case, call them *B*). From these, therefore, I shall prove that the former is the case. (In mathematics things

convert more because they assume nothing accidental— and in this too they differ from argumentations—but only definitions.)” [8]

5. “Sometimes too it happens as with diagrams; for there we can sometimes analyse the figure, but not construct it again” [8, Construct= συνθεῖναι=synthesize].

6. “As for analysis, lo, it is when some question or other is posed to us, and we say, “We suppose that what is sought is true.” Then we resolve it to something whose proof is already had. Then, when it has been demonstrated, we say, “That which is sought has been found by analysis.” And as for synthesis, that is when one begins with the known things; then one, combines them until the unknown is found, and with that the unknown. as been proven by synthesis.” (For other translations to this passage, see: [18, p. 93; 22, p. 376, n.83].

7. Donald Morrison is working on a project for studying the method of analysis and synthesis in Hellenistic philosophy since the nineties of the last century, but he has published only one paper. See his website for more information: http://report.rice.edu/sir/faculty.detail?p=A8709E12164110EA.

8. "فإذا كان مطلوب وأريد أن يطلب له قياس من جهة التحليل بالعكس ...".

9. "وبطريق التركيب يتدرجون من مسألة إلى مسألة من غير أن يُخلوا بمقدمات ذات وسط ويتجاوزا عنها إلا بعد إيضاحها بالقياسات القريبة منها، ويكون التزيد فيها تزيداً محدوداً والطريق منهوجاً".

10. "بل المسألة الهندسية مثلاً إنما هى إما عن مقدمة صحت وبانت بالطرق الهندسية".

11. "فإن غرضنا فى هذا الكتاب...أن نودعه لباب ما تحققناه من الأصول فى العلوم الفلسفية المنسوبة إلى الأقدمين، المبنية على النظر المرتب المحقق".

12. "ولى كتاب غير هذين الكتابين، أوردت فيه الفلسفة على ما هى فى الطبع... . وهو كتابى ‘الفلسفة المشرقية’. وأما هذا الكتاب فأكثر بسطاً، وأشد مع الشركاء من المشائين مساعدة".