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**Scientific Knowledge in
Aristotle's Biology**

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Scientific Knowledge in Aristotle's Biology

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Abstract

Aristotle was the first thinker to articulate a taxonomy of scientific knowledge, which he set out in *Posterior Analytics*. Furthermore, the “special sciences”, i.e., biology, zoology and the natural sciences in general, originated with Aristotle. A classical question is whether the mathematical axiomatic method proposed by Aristotle in the *Analytics* is independent of the special sciences. If so, Aristotle would have been unable to match the natural sciences with the scientific patterns he established in the *Analytics*. In this paper, I reject this pessimistic approach towards the scientific value of natural sciences. I believe that there are traces of biology in the *Analytics* as well as traces of the *Analytics*' theory in zoological treatises. Moreover, for a lack of chronological clarity, I think it's better to unify Aristotle's model of scientific research, which includes *Analytics* and the natural sciences together.

Keywords: Aristotle, Scientific Knowledge, Zoology, Demonstration.

Introduction

Aristotle was one of the greatest philosophers of biology. He devoted part of his life to the systematic investigation of animals. Before him, many of his predecessors wrote reflections about nature, but nobody developed a science of living beings.

This fact, together with the fact that Aristotle was the first to articulate a model of scientific investigation, raises the question about the relationship between science of biology and the model of science established in the *Analytics*.

This uncertainty remains, regardless of the chronology assigned to the Aristotelian canon for three reasons. First, though it is likely that the *Analytics* is among Aristotle's early writings, it is difficult to believe that he could have produced the *Analytics* after having finished his biological studies. Second, evidence from Aristotle's discussions of animals and places indicates that at least a portion of his biological studies may have been written soon after the death of Plato, but it is unlikely that all of them were written at that time. It is more reasonable to assume that his biological works were written over a long period of time, part of which coincided with his composition of the *Analytics*. Finally, if the *Analytics* were drafted after the biological writings, why did Aristotle propose a mathematical axiomatic method after conducting a different type of scientific inquiry? Do the *Analytics* represent a rejection of the work he did in his biological studies? The crux of the question is not why there are no traces of the *Analytics* in Aristotle's biology, but why there are no traces of biology in the *Analytics*. Though the problem is inverted, the terms are the same.

I want to soften this picture. I believe that there are elements of biology in the *Analytics* and elements of *Analytics* in natural treatises. In natural treatises Aristotle states that he aims at generating demonstrations and shows the differences with the type required in theoretical sciences¹. On the other hand, in the *Posterior Analytics* Aristotle uses examples drawn from meteorology², botanic³ and zoology⁴ together with mathematical examples. Moreover, in *Posterior Analytics* II 12, the philosopher explicitly introduces the demonstration of events that come to be usually rather than universally⁵.

¹Aristotle, *Parts of Animals* I 1, *Physics* II 9, *Generation of Animals* II 6 and *Generation and Corruption* II 11.

²See Aristotle, *Posterior Analytics* II 89b27-31; 90a1-5; 90a14-25; 93a22-25; 93a30-35; 93b8-15; 94a3-4; 94b31-37; 95a15-22; 98a30-35.

³See Aristotle, *Posterior Analytics* II 98a37-98b16; 98b34-99a1; 99a24-30.

⁴See Aristotle, *Posterior Analytics* II 89b43-35; 91a25-30; 91a37; 91b5-8; 91b18-20; 92a1-3; 92a30-35; 94b10-25; 96b33-97a5; 97a35; 98a3-23. 98a37-98b25; 99b5-7.

⁵Cf. Aristotle, *Posterior Analytics* II 12, 96a12-19: "If A is predicated universally of B, and B universally of C, A must also be predicated of C, and of all C [...]. But ex hypothesi A is predicated for the most part of C, then the middle term B must also be for the most part. Thus, the immediate premises of for the most part events must also describe states or processes which are for the most part".

My study consists in three parts: in the first section, I present the reasons that support doubts about the scientific character of natural treatises; in the second section, I focus on the model of science and on the place of natural science within this model; in the final section, I discuss the demonstration of processes in natural treatises.

Status Quaestionis

There are strong arguments that support doubts about the natural treatises' scientific character¹. The position defended by the scholars is that a) in natural treatises there isn't demonstration of the type Aristotle has exemplified from geometry in the *Analytics*²; b) Aristotle's natural works do not include definitions capable of becoming premises in a syllogistic structure of demonstration.

The arguments for the natural treatises' limited scientific value have acquired many proponents since the early twentieth century and have been the subject of lively debate, particularly in the 1980s and 1990s with the works of David Balme, Robert Bolton, David Charles, Wolfgang Detel, Allan Gotthelf, Wolfgang Kullmann, Pierre Pellegrin and James G. Lennox. These scholars think that Aristotle's zoological treatises reflect scientific ideas and explanations expressed in the *Analytics*, but they introduce also a variety of concepts that the *Analytics* ignore.

The differences between the canonical model of demonstration proposed by the *Analytics* and the inquiries in the natural sciences are evident. In the *Analytics*, Aristotle demands that the behaviour of the scientific object be without variation (ANGIONI 2002, 2)³; and he never mentions "conditional necessity", even in his short discussion of natural processes⁴. Additionally, in *Generation and Corruption* II 11, 338b6-11, Aristotle explains that contingent relations pertain to the natural processes that are rectilinear and concern perishable substances. In this case, the inference necessitates the effect only in a conditional way and the nature of the causal inference is modal⁵.

Because natural entities are composed by matter, which is, by definition, a principle of movement and accidental change, natural entities do not exhibit absolutely an unchanging behaviour⁶. Therefore, it is impossible to understand them scientifically because only in that "which cannot be otherwise", which is

¹LLOYD 1990 provides an overview of experts' positions on this problem. Important contributions have also been made by LENNOX 2001 and BOLTON 1987.

²See LLOYD 1996, 7-37.

³See Aristotle, *Posterior Analytics* I 4, 73a21; I 6, 74b5; I 8, 75b24.

⁴Aristotle, *Posterior Analytics* II 11, 94b27-95a9.

⁵The expression "modal notion of necessity" concerns with the nature of causal inference, when the cause necessitates the effect only in the general run and contingently. Cfr. Aristotle, *Partibus of Animals* I 1, 639b29-640a9; *Physics* II 9, 200a15-30; *Generation and Corruption* II 11, 337b14-25; II 11, 338b10-11. For the modal nature of causal inference, see LEUNISSEN 2010, p. 46-48.

⁶Aristotle, *Metaphysics* VII 5, 1032a20-21; VII 14, 1039b27-1040a2.

eternal and necessary, does science exist. Other entities are beyond science's purview: "Though there are things which are true and real and yet can be otherwise, scientific knowledge clearly does not concern them"¹.

Other important argument supporting the incompatibility of scientific theory and natural science addresses the part that causality plays within demonstration. For Aristotle, scientific knowledge is knowledge of causes achieved through demonstration². Such demonstrations rely on premises that are undeniable, true, universal and necessary³. Thus, "science" is, for Aristotle, equivalent to apodictic or causal syllogism⁴. However, as Angioni (ANGIONI 2002, 9-10) observes, the theory of the four causes established in *Physics* II 3 and present also in *Metaphysics* I, *On the Soul* and in the biological works is unsatisfactorily discussed in the *Posterior Analytics*⁵. Moreover, according to Barnes, the two examples in *Posterior Analytics* II 11 94a36-b8 involving change hardly look like scientific demonstrations at all (BARNES 1993, 228-229)⁶. Finally, the philosopher does not clarify how final causes fit into a rigid structure in which the cause is the middle term of a syllogism⁷.

The Method of the Scientific Knowledge

In this paper, I try to show that the theory of science outlined by Aristotle in the *Posterior Analytics* is compatible with the investigative and definitional method that the philosopher prescribes in his writings on the natural sciences, particularly zoology, and that behind certain biological inquiries lie principles enunciated in the *Analytiks*.

Two points should be emphasized to prevent the biological works from being considered a form of weak knowledge inferior to the strength of mathematic axiomatic method.

The first point is that the theory of deduction offered in the *Analytiks* should not be reduced to an abstract method for the ideal systematisation of science but should be thought as the form of scientific knowledge itself. The Aristotelian idea that the science is a type of demonstrative knowledge implies

¹Aristotle, *Posterior Analytics* I 33, 88b32-34.

²Aristotle, *Posterior Analytics* I 2, 71b 9; b16-19; cf. *Prior Analytics* I 4, 25b26-31 and *Posterior Analytics* I 2, 71b9-19; I 6, 74b26-32; I 13, 78a22-79a16; I 14, 79a17-24; 85b23-27; I 31, 87b33-88a11; II 2, 89b36-90a11; II 7, 92a34-37;

³For a discussion of true premises, see *Posterior Analytics* I 2, 71b 19-33; I 2, 72a6-7; I 3, 72b18-25; I 4, 73a21-74a2; I 6, 74b5-75a32. About primitive and immediate premises, see *Posterior Analytics* I 2, 71b26-27; 72a6-7; 72a7-8; I 15, 79a33-36; 79a38; I 23, 84b31-85a1. About universal premises see *Posterior Analytics* I 4, 73a21-74a2. About necessary premises see *Posterior Analytics* I 6, 74b5-75a32.

⁴Aristotle, *Posterior Analytics* I 2, 71b16-19; cf. *Prior Analytics* I 4, 25b26-31; *Posterior Analytics* II 7, 92a34-37. Aristotle illustrates causal syllogism in *Posterior Analytics* I 2, 71b9-19; I 6, 74b26-32; I 13, 78a22-79a16; I 14, 79a17-24; 85b23-27; I 31, 87b33-88a11; II 2, 89b36-90a11.

⁵Aristotle, *Posterior Analytics* II 11, 94a36-b8.

⁶See LEUNISSEN 2010, 36-37.

⁷See BARNES 2005, 92.

that it should be presented in the form of a systematic exposition of chains of syllogisms. However, it is clear that this is not the case in either the sciences upon which Aristotle modelled his arguments, such as mathematics, or in Aristotle's scientific practice. Greek geometry is demonstrative, but its demonstrations cannot be reduced to chains of syllogisms. In the *Corpus Aristotelicum* undisputed examples of syllogistic demonstrations are even rarer both in the more abstract sciences and in the special sciences. The classic solution suggested by Jonathan Barnes (BARNES 1993, XII) is that Aristotle conceived the *Analytiks* as a *paradeigma*, i.e., an ideal and abstract model of a complete and finished science, and that the zoological writings record the philosopher's research efforts.

I believe that this solution is unnecessary and even impossible. In the opening passage of the *Posterior Analytics*, the philosopher says: "knowledge comes through demonstration. By "demonstration" I mean a scientific syllogism, and by "scientific syllogism" I mean a syllogism by virtue of which, by having it, we know scientifically"¹. The syllogism is the specific form of scientific knowledge. Through demonstration, the entities, the form and the order of nature can be scientifically known. The syllogism is more than an ideal form, although abstract, of scientific knowledge, it is its cause. Believing that syllogistic demonstration is only a paradigmatic example of scientific discovery is like stating that no knowledge of this type yet exists or, if scientific knowledge does exist, there is little of it. However, such pessimism is not expressed in Aristotle's writings; the opposite is true². The philosopher offers more scientific contributions (as opposed to philosophical contributions) when the discussion turns to zoology (ANGIONI 2002, 1), and in the biological works, *History of Animals*, *Parts of Animals* and *Generation of Animals*, "states explicitly that he aims at generating demonstrations of same sort" (LEUNISSEN 2010, 32)³. It thus seems more reasonable to inquiry the extent of the relationship between the demonstrative science and the natural inquiries than to question this relationship.

Two Misunderstandings

I think that the pessimistic approach to the natural treatises' scientific value is based on two misunderstandings. The first is about the epistemological statute of zoological treatises; the second relates to the biological treatises' position within the unified edifice of science.

¹Aristotle *Posterior Analytics* I 1, 71b16-19.

²See CRUBELLIER & PELLEGRIN 2002, 51-52.

³See Aristotle, *History of Animals* I 6, 491a7-13; *Parts of Animals* IV 10, 689a9-13; *Generation of Animals* II 6, 742b23-36; II 8 and IV 9, 769a14-25.

The First Misunderstanding

As Berti (BERTI 1998, 48) noted, the distance between the *Analytiks* and the biological and zoological works is created by the more “relaxed”¹ form of rationality of natural sciences, although this does not indicate an inferior degree of scientific knowledge. In Book VI of *Metaphysics*, Aristotle identifies the object of natural science as “that substance that is *for the most part*² according to form, but is not separated”³. Natural substance is, therefore, determined by form; however, because its form is deep-rooted in matter and involved with change and movement, a natural substance is not “always” determined by the form, as in the case of mathematical entities, but only in the general run and not universally. To use a contemporary expression, we can attribute to natural science a “weak rationality” and to the science described in the *Analytiks* a “strong rationality” (BERTI 1998, 49 and 54), but the intent of this terminology is not to deny the scientific value of zoology. This weakness is justified by the object of the natural sciences and allows to natural substance to be more closely and deeply known.

The Second Misunderstanding

The second misunderstanding concerns the biological treatises’ position into the scientific knowledge. It is unreasonable to expect the zoological treatises to present first and definitive definitions of *phenomena* capable of acting as premises in a chain of scientific inferences. The philosopher was inaugurating a new science: zoology. A substantial amount of information was to be collected, selected, recorded and systematised (BARNES 2005, 27; see also 22). All of these elements constitute preliminary data for developing the science that justify *why* what is known is true. Angioni (ANGIONI 2002, 8) observes that Aristotle’s zoological writings are located in the ascending phase of the research, rather than the descending one, where conclusions are progressively demonstrated from their own principles and, ultimately, from first definitions⁴. In Book II of the *Posterior Analytiks*, Aristotle recognises that there are different types of definitions that reflect the distinction between different levels of knowledge⁵. Preliminary definitions correspond to the results of preliminary inquiries, and real definitions determine what something is and explain why it must be so. Both types of definitions have scientific value and are part of scientific development.

In the next part I briefly talk about demonstration in biological treatises.

¹The Greek word is *malakoteron*. See Aristotle, *Metaphysics* V 1, 1025b13. At the lines 1025b6-13, Aristotle distinguishes the rationality of physics from mathematics’ rationality.

²The Greek expression is *hos epi to poly*, that means ‘in the general run’ and not universally.

³Aristotle, *Metaphysics* VI 1, 1025b26-28.

⁴See BALME 1987 and LENNOX 2001.

⁵Aristotle, *Posterior Analytiks* II 8-10.

Demonstration in Zoology¹

In *Parts of Animals* I 1, Aristotle introduces the model of demonstration at work in natural treatises. The sublunary phenomena involve movement, processes and change over time and hold only for the most part².

The processes can be simultaneous, when the cause and the effect occur in the same time; or can occur at different instances in a sequence, as in the case of embryogenesis. The two processes are similar but not identical. The most important difference is that in processes that occur at different instances of time, there will be a moment when the cause has occurred but not yet the effect³.

Aristotle argues about the demonstration of processes that occur in simultaneous time in *Generation of Animals* book V, where he indicates the parts of animals by which the animals differ⁴.

Let me give an example. The eye-colour changes simultaneously with the level of water in the eyes⁵. Schematically we get:

A: colour; B level of water; C: eye
 A (aC) $\approx_{\text{simultaneous}}$ B (aC)

When the natural level of water is low the eye-colour is blue; when the natural level of water is high the eye-colour is brown or black. As Leunissen suggests, Aristotle distinguishes the demonstration of being from the demonstration of processes that occur simultaneously in *Posterior Analytics* II 12, 95a10-24⁶. In the *Posterior Analytics*, the Aristotle's example is the process process of eclipsing, that occur simultaneously (*hama gignetai*)⁷ with "obstructing by the earth". In the *Analytics*, the demonstration of processes justifies the presence of an attribute belonging to a certain subject and is formally the same as demonstration of being. However, "the terms in the former [in demonstration of processes] get tensed" (LEUNISSEN 2010, 38).

In biological works, explanations that pick out causes that not occur simultaneously with the effect are more common than simultaneous processes.

¹My discussion is greatly indebt to LEUNISSEN 2010, who offers an excellent analysis of *Posterior Analytics* II 11 and 12 and suggests the relevance of Aristotle's treatment of demonstration in these chapters for his theory os demonstrations in natural treatises.

²Aristotle, *Posterior Analytics* I 1, 639a12-15; 640a1-9; 640a33-b3; 642a32-b2.

³Aristotle, *Generation of Animals* II, *Posterior Analytics* II 12 95b13-15, b 19-20, b 24-25, b 31-37. See LEUNISSEN 2010, 54-48 and Kupreeva, forthcoming, *apud* Leunissen 2010.

⁴Aristotle uses the Greek verb *symmetaballo* to indicate that cause and effect occur simultaneously. In *Generation of Animals* V 4, 784b25- 31, for instance, Aristotle explains the cause of grey hair: "There are many instances of people having grown grey hair as an aftermath of disease, but later on [...] when health is restored, people accomplish a change [...] and, in consequence, the condition also accomplish a corresponding change (*symmetaballousi*). See also V 3, 783 b 30, where Aristotle explains the cause of high-pitched voice or deep voice.

⁵Aristotle, *Generation of Animals* V 1, 779b2; V 3, 784a4-5; V 6, 785b16-22; V 6, 786a4; V 2, 781a33-34; V 3 783a11-32; V 3, 784a12-20; V 6, 786a303-34.

⁶See LEUNISSEN 2010, 38-42.

⁷See Aristotle, *Posterior Analytics* II 12, 95a22-25.

The syllogistic structure of demonstration diverges to demonstration of mathematical objects for three reasons: first, the nature of causal inference: the relationship between the cause and the effect is modal¹; second, the direction of the inference: the syllogism is possible only from the effect to the cause, that is, from the posterior to the prior; third, the chronological order of causal sequence: the order and the time of processes are important to determine the causal priority of factors.

I'll examine in the following the three factors.

First, Aristotle uses a modal notion of necessity in *Partibus Animalium* I 1 and *Physics* II 9², where he distinguishes the nature and the direction of causal inference in theoretical demonstration and in demonstration of natural processes. The expression “modal notion of necessity” concerns with the nature of causal inference, when the cause necessitates the effect only for the most part and contingently³. In *Generation of Animals* V 3, 783a16-18, for instance, Aristotle argues that the reason of hard hair is the cold temperature of environment. The cold air, a material external cause, congeals the hair and dries them. In other words, hard and earth hair is due to the cessation of heat in the environment. The relation between the cessation of heat and the solidification of the hair is not necessary, because we cannot infer the effect from the presence of the cause, but we can infer from the presence of the effect the occurrence of the cause.

Second, the philosopher explains that in linear sequences in which the cause precedes the effects and does not occur in simultaneous time with the effect, the syllogism is possible only from the posterior to the prior⁴. The inference is one-directional, as in theoretical and mathematical sciences, but the inference's direction is different: in eternal and cyclical phenomena, the cause is the prior, from which the effect is derived, and the relationship between cause and effect is necessary. In sciences that deal with natural perishable substances, the inference is only from the effect to cause, because it will not necessary follow that because it is true to say that X happened, it is also true to say that Y will happen. Other factors can prevent the effect from happening⁵.

Third, in natural teleological processes, the demonstration must not only determine the primary middle term of syllogism, but also specify the sequence's order of process. In *Physics* II 6 Aristotle says: “For with regard to generation it is mostly in this way that people investigate into the explanation –

¹For “modal use of necessity” see Kupreeva (forthcomig) *apud* LEUNISSEN 2010, 45-47. According to Leunissen, Aristotle uses a modal necessity in *Posterior Analytics* II 12. See II 12, 95a24-b1; 95b13-17.

²Aristotle, *Physics* II 9, 200a15-30; *Parts of Animals* I 1, 639b29-40a9.

³Aristotle, *Generation and Corruption* II 11, 338b9-11: “For it is not necessary, if your father came to be, that you come to be, but if you came to be, then he came to be”.

⁴Leunissen examines *Posterior Analytics* II 12, 95a29 and a32-37, where Aristotle argues about the direction of causal order (LEUNISSEN 2010, 50-52).

⁵See WIELAND 1975, 232.

what comes to be after what? And, what was the first to act or to undergo? And in this way at each step of the series”¹.

This worry for specifying the order of generation is manifest specifically in the discussion about embryogenesis². In *Generation of Animals* II 6, Aristotle clarifies that the “order in generation” and the “order in being” differ: whereas the “order in being” depends from relations in nature and in definition, the “order in generation” is depicted as a chronological order.

“Some of the early *physiologists* endeavoured to describe the order in which the various parts are formed, but they were none too well acquainted with what actually happens. As with everything else, so with the parts of body: one is, by nature, prior to another. But the term “prior” at once comprises a variety of meanings. E.g., take the difference between (a) that “for the sake of which” a thing is, and (b) that thing which is “for its sake”: of these, one (b) is prior in point of formation, while the other (a) is prior in point of being or reality”³.

The explanation of embryological development starts from what is closest to the present and from there infers the necessary prerequisites. When the process is constituted with a series of following movements, the causal priority is determined by chronological priority and we must draw inferences from the end to what necessarily had to have occurred earlier⁴.

Aristotle concludes that in the cases of things which always are, we have something eternal, yet there is a cause for them and they are demonstrable⁵. With those things, the principle is the essence⁶. But as soon as we begin to deal with those things that come into being through a process of formation,

“we find there are several first principles – principles, however, of a different kind and not all of the same kind. Among them the source whence the movement comes must be reckoned as one”⁷.

In an excellent analysis of *Posterior Analytics* II 12, Leunissen (LEUNISSEN 2010, 42-57) persuasively suggests that when Aristotle wrote this work, he had the methodological preoccupation with the chronological order of processes that come to be in nature and, at least, a notion of modal necessity. Thus, he provides the bases for the model of demonstration in natural and zoological sciences.

¹Aristotle, *Physics* II 7, 198a34-5.

²Aristotle, *Generation of Animals* II, especially II 6.

³Aristotle, *Generation of Animals* II 6, 742a16-25. See also *Parts of Animals* II 646a24-b2.

⁴We have these three things “*first of all there must of necessity exist some part in which the principle of movement resides (for of course this is a part of the End, and the supreme controlling part of it); after that comes the animal as a whole, i.e., the End; third and last of all come the parts which serve these as instruments for various employments*” (Aristotle, *Generation of Animals* II 6, 742a35-b10).

⁵Aristotle, *Generation of Animals* II 6, 742b27.

⁶Aristotle, *Generation of Animals* II 6, 742b35.

⁷Aristotle, *Generation of Animals* II 6, 742b33-35.

Conclusion

With my paper, I hope to have showed that Aristotle's scientific theory is not an austere and formal model of demonstration. The Aristotelian science is a single and unitary type of research, that encompasses experiences in the nature and the scientific patterns outlined in the logical treatises.

Although the epistemological statute of the zoological treatises differs from the epistemological method of the *Analytics*, the natural sciences do not exhibit a lesser degree of scientificity. The "weak rationality" of zoology is determined by the object of its inquiry and by its position within the structure of science. Although the natural sublunary phenomena can be scientifically studied, it is necessary to use a model of demonstration that incorporates into the syllogistic structure the movement and the change over time.

It is evident that, for Aristotle, many of the entities that constitute the domain of nature have the same structure and are subject to the same treatment as the phenomena examined in the *Posterior Analytics*, but it is necessary to think to the geometric-style of *Analytics* in a more flexible way.

Let's me close with the rhetorical question of James Lennox (LENNOX 2001, 6): "It is plausible that a philosopher as systematic as Aristotle could formulate the first rigorous theory of scientific inquiry and demonstration, pepper the treatise in which he does so with biological examples, and then not aim to structure his science of animals in accordance with that theory?".

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