SCIENCE IN ARISTOTLE'S NATURAL TREATISES

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Resumen: Aristóteles fue el primer pensador en articular una taxonomía del conocimiento científico, la cual él propuso en sus *Analíticos Posteriores*. Además, las "ciencias especiales", i.e., biología, zoología y las ciencias naturales en general, se originaron con Aristóteles. Una cuestión clásica es si el método matemático axiomático propuesto por Aristóteles en los *Analíticos* es independiente de las ciencias especiales. Si fuera así, Aristóteles hubiera sido incapaz de ajustar a las ciencias naturales con los patrones científicos que él propuso en los *Analíticos*. En este artículo, refuto la aproximación pesimista hacia el valor científico de las ciencias naturales. Yo creo que hay indicios de biología en los Analíticos tanto como hay indicios de los *Analíticos* en sus tratados naturales. Por lo demás, para mayor claridad sobre la cronología, yo creo mejor unificar el modelo de investigación científica de Aristóteles, el cual incluye a los *Analíticos* y a las ciencias naturales juntas.

Descriptores: Aristóteles · Tratados naturales · Conocimiento científico · Demostración · Definición

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 there are traces of the *Analytics* in natural treatises. Furthermore, for a lack of chronological clarity, I think better to unify Aristotle's model of scientific research, which includes *Analytics* and the natural sciences together.

Keywords: Aristotle · Natural Treatises · Scientific Knowledge · Demonstration · Definition

Enviado: 02/07/2015 Aceptado: 28/08/2015

Introduction

In the *Posterior Analytics*, Aristotle establishes the criteria which a discipline must fulfil to be considered "science" (*episteme*).[2] According to Jonathan Barnes (1982), p. 86, "His greatest achievement was surely his biology; by the work

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[2] *Posterior Analytics* I 2, 71b19-23. See Angioni (2002), p. 1. The Greek words are transliterated with respect to the standards published in *Archai* n. 12, p. 193-194. http://periodicos.unb.br/index.php/archai/article/view/10149/7457.

recorded in the *Researches,* the *Parts of Animals* and the *Generation of Animals*, he founded the science of biology."[3] However, whether Aristotle's science of biology conforms to the normative patterns stipulated in the *Analytics* is a subject of debate.

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.

In this paper 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 sciences.[4] On the other hand, in the *Posterior Analytics* Aristotle uses examples drawn from meteorology,[5] botanic[6] and zoology[7] together with mathematical examples. Moreover, in *Posterior Analytics* II 12, 96a12-19 the philosopher explicitly introduces the demonstration of events that come to be usually rather than universally.[8]

My argument 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

[3] For an overview of the scientific statute of the natural treatises, see Balme (1987), pp. 9-29; Devereux and Pellegrin (1990); Gotthelf (1997); Gotthelf and Lennox (1987); Kullmann (1999); Lennox (2001); Pellegrin (1985); Lloyd (1996).

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

[5] Cf. *Posterior Analytics* II 1, 89b27-31; II 2, 90a1-5; 90a14-25; II 8, 93a22-25; 93a30-35; 93b8-15; II 10, 94a3-4; 94b31-37; II 11, 95a15-22; II 14, 98a30-35.

[6] Cf. *Posterior Analytics* II 14, 98a37-98b16; II 16, 98b34-99a1; II 17, 99a24-30.

[7] Cf. *Posterior Analytics* II 1, 89b43-35; II 4, 91a25-30; 91a37; 91b5-8; II 5, 91b18-20; 92a1-3; 6, 92a30-35; II 12, 94b10-25; II 13, 96b33-97a5; 97a35; II 14, 98a3-23; II 15, 98a37-98b25; II 17, 99b5-7.

[8] *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 for the most part events must also describe states or processes which are for the most part".

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 and the statement of definition in natural treatises.

§ 1) Status Quaestionis

There are strong arguments that support doubts about the natural treatises' scientific character.[9] The position defended by the scholars is that a) in natural treatises there is not demonstration of the type Aristotle has exemplified from geometry in the *Analytics*;[10] b) Aristotle's natural works do not include definitions apt to becoming premises in a syllogistic structure of demonstration.

1.1) The first objection

The differences between the canonical model of demonstration proposed by the *Analytics* and the inquiries conducted in the natural sciences are evident. In the *Analytics* Aristotle explains that the movement of the substances which are object of scientific investigation is necessary and without variation (Angioni, 2002, p. 2).[11] In the *Analytics* he never mentions conditional necessity (*ex hipotheseos he anagke)*, even in his short discussion of natural processes.[12] Additionally, in *Generation and Corruption* II 11, 338b6-11, Aristotle explains that conditionally necessary 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.[13]

Because natural entities are composed by matter, which is, by definition, a principle of movement and accidental change, natural entities do not exhibit an unchanging behaviour.[14] Therefore, it is impossible to study them scientifically

[9] Barnes (1969) presents the problem in detail, discusses three solutions and article offers his own solution to the problem: "The problem only arises if it is assumed that the theory presented in the *Posterior Analytics* was intended by Aristotle to give an account of the sort of activities which his treatises report. Although this assumption has not often been expressed it is clear that without it no Problem arises: for if the *Posterior Analytics* was never intended to provide the theoretical structure for Aristotle's scientific research, then there can be no question of inconsistency between the research and the theory" (p. 137). I'll discuss Barnes' solution in the section 2.1) of my text. Lloyd (1991) provides an overview of experts' positions on this problem.

[10] See Lloyd (1996), pp. 7-37.

[11] Cf. *Posterior Analytics* I 4, 73a21; I 6, 74b5; I 8, 75b24.

[12] *Posterior Analytics* II 11, 94b27-95a9.

[13] Cf. *Parts of Animals* I 1, 639b29-640a9; *Physics* II 9, 200a15-30; *Generation and Corruption* II 11, 337b14-25; 338b10-11.

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

because only in that "which cannot be otherwise", which is eternal and necessary, does science exists. 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"(*Posterior Analytics* I 33, 88b32-34).[15]

Another important point supporting the incompatibility of scientific theory and natural science addresses the role that causality plays within demonstration. For Aristotle, scientific knowledge is knowledge of causes achieved through demonstration.[16] However, as Angioni (2002) pp. 9-10 observes, the theory of the four causes established in *Physics* II 3 and reprised in *Metaphysics* I, *On the Soul* and the biological works is unsatisfactorily discussed in Book II, 11, 940a36-b8 of the *Posterior Analytics*. According to Lennox (2001), p. 99, "It appears to be enigmatic on how its prescriptions would apply to a natural science (as opposed to mathematics) – it never mentions a distinction between matter and form and never raises the question of whether a proper definition of a natural object or its parts should include reference to its material nature". Moreover, according to Barnes (2005) p. 193, and pp. 228-229, the two examples in *Posterior Analytics* II 11 involving change hardly look like scientific demonstrations at all.[17] Finally, the philosopher does not clarify how final causes fit into a rigid structure in which the cause is the syllogism's middle term.[18]

1.2) The second objection

According to Bolton (1987) p. 121, "The *Analytics* restrict knowledge to what has been demonstrated from self-evident first principles; the natural treatises seem to secure their results without such demonstrations".

In the nature it is difficult to identity a principle that can be used as a premise in a scientific demonstration. In an apodictic syllogism, the premises include axioms, hypotheses and definitions[19] and the definitions play the most important role as the first and immediate premises of the science constructed by the *Analytics*.[20]

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[15] All the translations are from: *The works of Aristotle*. Chicago: Encyclopaedia Britannica, 1952, unless indicated otherwise.

[16] *Posterior Analytics* I 2, 71b 9; b16-19; cf. *Prior Analytics* I 4, 25b26-31.

[17] See Leunissen (2010), pp. 36-37.

[18] See Barnes (2005), p. 92.

[19] Cf. *Posterior Analytics* I 2, 72a14-17; I 7, 75a38-b2; I 10, 76a37-b11; 76b11-22; I 10, 76b24-34; I 11, 77a26-35; *Metaphysics* IV 3, 1005a19-29.

[20] Cf. *Posterior Analytics* I 1, 71a11-17; I 2, 72a18-24; I 8, 75b30-32; I 10, 76b35-77a4; I 14, 79a24-29; II 3, 90b24-27; *Top* VIII 3, 158a31-b4; *DA* I 1, 402b25-403a2; *Metaphysics* VII 9, 1034a30-32; IX 7, 1064a4-8; IX 7, 1064a19-20; XIII 4, 1078b24-25; XIII 4, 1078b27-30.

Several interpreters (Pellegrin, 1985; Lennox, 2001) have noted that Aristotle's biological works include no definitions that could be premises in an apodictic syllogism, and Angioni (2002), p. 7 observes that "tampouco vemos o mesmo Aristóteles se pronunciar de forma satisfatória como se tivesse achado uma definição definitiva do assunto tratado". Pierre Pellegrin (1985), p. 99 thinks that Aristotle's explanation of natural entities only contains partial definitions.

Lloyd (1991), p. 394 concludes that "It is not just that actual explanations set out in syllogistic form are difficult to find: the whole discourse of the practising natural scientist resists, one might say, being recast in the mould of the ideal formal language that the *Organon* desiderates".

§ 2) The form of scientific knowledge

An examination of all the details of this controversy is beyond the scope of this paper[21]. However, two points should be emphasised to prevent the biological works from being considered a form of weak knowledge inferior to the strength of mathematic axiomatic science.

2.1) Syllogistic structure as the form of demonstration

The first point is that the *Analytics* theory of deduction should not be reduced to an abstract method for the ideal systematisation of scientific knowledge but should be thought as the form of scientific knowledge itself. The Aristotelian idea that science is a type of demonstrative knowledge implies that it should be presented in the form of a systematic chain 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 (1993), p. XII is that Aristotle conceived the *Analytics* 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* I 1, 71b16-19, 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". The syllogism is the form specific to scientific

[21] For more details see Lennox (2001).

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 true.[22] Aristotle offers more scientific contributions, as opposed to philosophical contributions, when the discussion turns to zoology (Angioni, 2002, p. 1), and in the zoological treatises Aristotle"states explicitly that he aims at generating demonstrations" (Leunissen, 2010, p. 32).[23] 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.

It is also important to remember, that the doctrine of the syllogism occupies only the first twenty-six chapters of the *Prior Analytics,* i.e., less than a third of the work. The remainder of the work illustrates the function of the theoretical structures in the effective practice.[24] Crubellier (Crubellier & Pellegrin 2002), p. 54 writes, "L'analytique est un ensemble complet et particulièrement cohérent de compétences à la fois théoriques et pratiques – ou plutôt, pour parler comme Aristote, productrices: connaître les syllogismes et être capable de trouver ceux qui permettront de résoudre un probleme donné. La partie theorique se subdivise en deux taches: la première consiste dans la construction *a priori* d'un nombre fini de types simples; la seconde, *a posteriori*, c'est-à-dire dans la pratique effective".

This statement expresses the fundamental difference between the scientific method of the Platonic dialectic and the Aristotelian procedure. If Plato considers the dialectic as a way of knowing, Aristotelian inference provides the instrument to achieve scientific knowledge. Investigation begins, according to the philosopher, not with contrary opinions, but with necessary and universal principles and laws of thought as well as empirical data.

2.2) The position of zoology in the development of scientific knowledge

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.

[22] See Crubellier and Pellegrin (2002), pp. 51-52.

[23] Cf. *History of Animals* I 6, 491a7-13; *Parts of Animals* IV 10, 689a9-13; *Generation of Animals* II 6, 742b23-36; IV 9, 769a14-25.

[24] *Prior Analytics* I 27, 43a16; I 32, 46b38; see also II 22, 68a25.

As Berti (1998) p. 48 noted, the distance between the *Analytics* and the biological and zoological works is created by the more "relaxed" (*malakoteron*)[25] form of rationality of natural sciences, although this does not indicate an inferior degree of scientificity. In Book VI of *Metaphysics*, Aristotle identifies the object of natural sciences as "that substance that is for the most part (*hos epi to poly*) according to form, but is not separated" (*Metaphysics* VI 1, 1025b26-28). Natural substances are determined by form; however, because the 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. To use a contemporary expression, we can attribute to natural science a "weak rationality" and to the science of the *Analytics* a "strong rationality" (Berti, 1998, p. 49 and p. 54), but the intent of this terminology is not to deny the scientific value of zoology. This weakness is justified by the object that the natural inquiries and allows to natural substance to be more closely and deeply known.

The second misunderstanding concerns the biological treatises' position in 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. Aristotle was inaugurating a new science: zoology. A substantial amount of information was to be collected, selected, recorded and systematised (Barnes, 2005, p. 27; see also p. 22). In his observations on astronomy, meteorology, and chemistry and especially in his work on biology and zoology, Aristotle presents the results of his inquiries and the information came up by written sources.[26] All of these elements constitute preliminary data for developing the science that justify *why* what is known is true. Angioni (2002) p. 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 definitions. In the *Posterior Analytics* II 8-10, Aristotle recognises that there are different types of definitions that reflect the distinction between different levels of knowledge. 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. A preliminary definition consists "of what the name means" (*tou ti semainei to onoma*); the real definition is the statement that "expresses the reason why-it-is" (*ho delon dia ti estin*). Bolton (1976), pp. 514-545, especially p. 515 and p. 520 shows that the difference between the two definitions does not lie in the diversity of their respective objects but in the

[25] *Metaphysics* V 1, 1025b13.

[26] See Anonymous, *Vita Aristotelis Marciana* 6, in Düring I., *Aristotle in the Ancient Biographical Tradition,* Göteborg 1957, p. 98 cited in Barnes (2005), p. 27; Strabo, *Geography* XIII 1, 54.

role that each of them plays in the development of scientific knowledge.[27] Mesquita (2007), p. 152 adds that "a definição nominal é tanto definição de uma coisa como a definição real; o que sucede é que ela define o que a coisa é por meio de uma descrição daquilo que o seu nome significa. [...] As definições nominal e real não dizem respeito a dois tipos diferentes de entidades. Ao invés, são antes dois tipos diferentes de descrições das mesmas entidades – as coisas".

§ 3) Scientific structure in natural treatises

In the following, I will examine the extent to which the scientific method enters the demonstration and the definition in natural treatises.

3.1) Demonstration in natural treatises[28]

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 part.[29]

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 effect.[30]

Aristotle illustrates 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 differ.

For instance, the eye-colour changes simultaneously (*symmetaballei)* with the level of water in the eyes.[31] Schematically we get:

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

[27] See Mesquita, 2007, p. 151.

[28] My discussion is greatly in debt to Leunissen (2010), who offers an excellent analysis of *Posterior Analytics* II 11-12 and suggests the relevance of Aristotle's treatment of demonstration in these chapters for his natural philosophy.

[29] *Parts of Animals* I 1, 639a12-15; 640a1-9; 640a33-b3; 642a32-b2.

[30] Cf. *Generation of Animals* II, *Posterior Analytics* II 12 95b13-15, b 19-20, b 24-25, b 31-37. See Leunissen, 2010, p. 48-54.

[31] *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.

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.

Leunissen (2010), p. 38 shows that Aristotle distinguishes the demonstration of being from the demonstration of processes that occur simultaneously in *Posterior Analytics* II 12, specifically in II 12, 95a10-24. The demonstration of processes justifies the presence of an attribute belonging to a certain subject and is formally the same as demonstration of being. Aristotle's example is the process of eclipsing, that occur simultaneously (*hama gignetai)* with "obstructing by the earth" (*Posterior Analytics* II 12, 95a22-25).

In the biological works, explanations that pick out causes that not occur simultaneously with the effect are more common than simultaneous processes. 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 modal;[32] 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 examine in the following the three factors.

Aristotle uses a modal notion of necessity in *Partibus Animalium* I 1639b29-640a9 and *Physics* II 9 200a15-30, 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 in the general run and contingently[33].For example, in *Generation of Animals* V 3, 783a16-18, 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. Thus, 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 unqualified, because we cannot infer the effect from the presence of the cause, but we can infer from the effect the occurrence of the cause.

The second element is the inference's direction. Aristotle explains that in linear sequences in which the cause precedes the effects and does not occur in

[32] For "modal use of necessity" see Kupreeva (in press) *apud* Leunissen (2010), pp. 45-47. According to Leunissen, Aristotle uses the concept of modal necessity in *Posterior Analytics* II 12, especially 95a24-b1; 95b13-17.

[33] Cf. *Generation et 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*".

simultaneous time, the syllogism in possible only from the posterior to the prior.[34] 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 can be 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 the 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 happening.[35]

The third aspect is the chronological order of the process. In natural teleological processes, the demonstration must not only determine the primary middle term of syllogism, that is the cause of the process, but also specify the sequence's order of the events, because "order in being" and "order in generation" are different. In *Physics* II 7, 198a34-5 Aristotle says: "For with regard to generation it is mostly in this way that people investigate into the explanation – 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".

This worry for specifying the order in generation is manifest specifically in the discussion about embryogenesis. In *Generatione Animalium* 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. Aristotle writes: "Some of the early *physiologers* 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." (*Generation of Animals* II 6, 742a16-25).

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 the chronological priority and we must draw inferences from the end to what necessarily had to have occurred earlier.[36]

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

[35] See Wieland, 1975, p. 232.

[36] In *Generation of Animals* II 6, 742a35-b10 Aristotle explains that we 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 concludes that in the cases of things which always are, we have something eternal, yet there is a cause for them and they are demonstrable (*Generation of Animals* 6, 742b27). With those things, the principle is the essence (*to ti estin*) (*Generation of Animals* 6, 742b35). 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" (*Generation of Animals* II 6, 742b33-35).

In the excellent analysis of *Posterior Analytics* II 12, Leunissen (2010), pp. 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.

3.2) Definition in natural treatises

To conclude, we briefly examine the statement of definition in natural treatises. In the *Analytics,* Aristotle explains that, among facts susceptible of inquiry, the natural substances hide a complex composition of elements under an initial unity.[37]

In the final chapter of *Metaphysics* Zeta, Aristotle clarifies this statement and explains that to conduct a scientific inquiry, one must assume the presence of at least two elements; otherwise, the search is meaningless: "[...] we are not inquiring why he who is a man is a man. We are inquiring, then, why something is predicable of something (that it is predicable must be clear; for if not, the inquiry is an inquiry into nothing)" (*Metaphysics* VII 17, 1014a15-20). He continues, "The object of the inquiry is most easily overlooked where one term is not expressly predicated of another (e.g., when we inquire 'what man is'), because we do not distinguish and do not say definitely that certain elements make up a certain whole. But we must disarticulate (*diarthrôsantas*) our meaning before we begin to inquire; if not, the inquiry is on the borderline between being a search for something and a search for nothing. Since we must have the existence of the thing as something given, clearly the question is why the matter is some definite thing. [...] And why is this individual thing, or this body having this form, a man? Therefore what we seek is the cause, i.e. the form, by reason of which the matter is some definite thing; and this is the substance of the thing" (*Metaphysics* VII 17, 1014a32-b9).[38]

[37] In the*Analytics*several statements clarify this perspective, such as, for example, *Posterior Analytics* II 2, 90a31-34 and shortly before 90a12-13. However,the most explicit and illuminating passages can be found in *Metaphysics* VII 17, 1041a14-27 and especially 1041a32-b9.

[38] My translation.

From this passage we can select important advices. First, it indicates that it is typically assumed that natural substances are made of a matter with certain properties, although it remains unclear why this matter has these properties. When the cause that explains why the matter is so constituted is found, it is necessary to separate ("... we must disarticulate ...") the initial unity of substance. Then, the substance can be analyzed throughout a demonstrative structure, in which preliminary and empirical knowledge appears in syllogism's conclusion.[39]

The definition that expresses "why something is so constituted" corresponds to the statement in which the preliminary unity of substance is explained and the elements of the preliminary definition are articulated in accordance with the causal relationships that unite them[40]. This process is not about demonstrating the essence, which would be inconceivable to Aristotle[41], but about disarticulating (*diarthrôsantas*) the unity of the natural substance and revealing the principle (i.e., the *form* as cause) that justifies the conclusion.

A second issue involves the last sentence of the quoted passage: "Therefore what we seek is the cause, i.e., the form, by reason of which the matter is some definite thing; and this is the essence of the thing". Aristotle says that form is the principle that justifies why matter is endowed with certain properties.[42] Form is at the same time the principle of demonstration and the cause of entity's constitution.[43]

Aristotle's analysis of semen in *De Generation Animalium* I 17 illustrates the complex interplay of preliminary and real definition in natural treatises. Schematically we get[44]:

d (Preliminary Definition).[45]

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[39] See *Posterior Analytics* II 8, 93a14-b14.

[40] *Posterior Analytics* II 10, 93b39.These relationships are explicitly analysed in chapters 8-10 of Book II of the *Posterior Analytics*. See specifically II 8, 93b7-9; II 10, 94a1-7. A commentary of these passages is in Angioni, 2002, p. 16.

[41] Aristotle is careful in using the terms *syllogism* and demonstration in the context of defining an essence, because the *what is* (*tode* ti) can produce neither syllogisms nor demonstrations. Cf. *Posterior Analytics* II 8, 93a14-16; II 10, 94a1-2.

[42] Cf. *Physics* II 2, 194a12-27 and II 9, 200a30-b1.Angioni (2002) p. 25 writes: "Na definição será preponderante a *função*, que é a *forma* e ao mesmo tempo a *finalidade* do ente. Mas será principio justamente enquanto fator explanatório preponderante, que é capaz de explicar porque a parte restante da definição deve necessariamente apresentar tais e tais itens".

[43] The role that form plays as a primitive and prior causeis discussed in detail in Angioni, L. (2000), *A noção aristotélica de ousia*, Doctoral thesis, USP, São Paulo, (SP), Brasil,chapters 10 and 12.

[44] I use the nomenclature employed by Angioni (2002) p. 26-27 with differences.

[45] Nominal or Preliminary Definition is the definition of what the name semen means ("*what a thing is through a statement of what the name means (toû ti sêmainei to onoma*") (*Posterior Analytics* II 10, 93b30). See Bolton (1976), p. 515 n.2.

M (Matter): "Fluid residue of nourishment (*Generation of Animals* I 18, 726a20).

ff (Specific properties of the matter): in the case of natural entities it would be difficult to determine all of properties encompassed by ff, but this point has no bearing on the present study.[46]

d = M +ff

d: Semen is "the sort of stuff from which the things that take their rise in the realm of nature are originally formed" (*Generation of Animals* I 18, 724a17-20).

D (Real Definition)[47]

C (Cause): middle term of demonstration that picks out the cause of the necessary relationship between M and ff. The cause will enable us to consider more easily the functions of semen. Aristotle explains: "Nature acting in the male uses the semen as a tool, as something that has movement in actuality; just as when objects are being produced by any art the tools are in movement, because the movement which belongs to the art is, in a way, situated in them" (*Generation of Animals* I 23, 730b20-25).

M^2 (Matter with specific properties): fluid matter endowed with the movement of vital heat (*Generation of Animals* I 23, 729a17).

$D = C \rightarrow M^2$

D: semen is fluid stuff endowed with the movement of vital heat, used by the nature as a tool to stimulate female menstruation, and whose primary function is the generation and reproduction of warm-blooded animals (*Generation of Animals* I 23, 729b8; cf. I 17, 737a18).

Finally, the real definition of a natural substance corresponds to the proposition in which the primary unity of a substance is disarticulated and the major and minor terms of the preliminary definition are related in accordance with the causal relationships that unite them

Conclusion

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.

[46] Angioni (2002), p. 26 explains: "Em nosso saber prévio, apreendemos as substâncias naturais apenas como um conjunto de materiais dispostos com tais e tais propriedades, mas sem atinar com a causa que explica a necessidade de estar assim determinada a matéria. Às vezes (ou talvez até mesmo na maioria dos casos), nem sequer aprendemos todas as propriedades subsumidas na rubrica *ff*".

[47] Scientific knowledge describes a thing on what "*is more knowable in itself*" and results in a real definition *"that explains why something is (ho dêlon dia ti estin)*" (*Posterior Analytics* II 10, 93b39).

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

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 work of David Balme, Robert Bolton, David Charles, Wolfgang Detel, Allan Gotthelf, Wolfgang Kullmann, Pierre Pellegrin and James G. Lennox. Several scholars think that Aristotle's zoological treatises introduce a variety of concepts that the *Analytics* ignore.

In this paper, I have sought 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 the inquires in the biological treatises reflect scientific ideas and explanations expressed in the *Analytics*.

Aristotle explicitly states that scientific knowledge requires knowledge in the syllogistic model. Thus, the *Analytics*' theory of deduction is clearly not intended to be read as an abstract method for the ideal organisation of knowledge but as the form of scientific knowledge itself.

Although the epistemological statute of the zoological treatises differs from the epistemological construction 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 construction of science.

It is evident that, for Aristotle, many of the entities that constitute the domain of nature have the same structure and, therefore, 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.

Although the natural sublunary phenomena can be scientifically demonstrated, it is necessary a model of demonstration that incorporates into the demonstrative structure processes, developments and change.

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 orbits around a single and unitary research, scientific inquiry which encompasses empirical data together with the scientific pattern of the *Analytics*.

Let me close with the rhetorical question of James Lennox (2001) p. 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 them not aim to structure his science of animals in accordance with that theory?".

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