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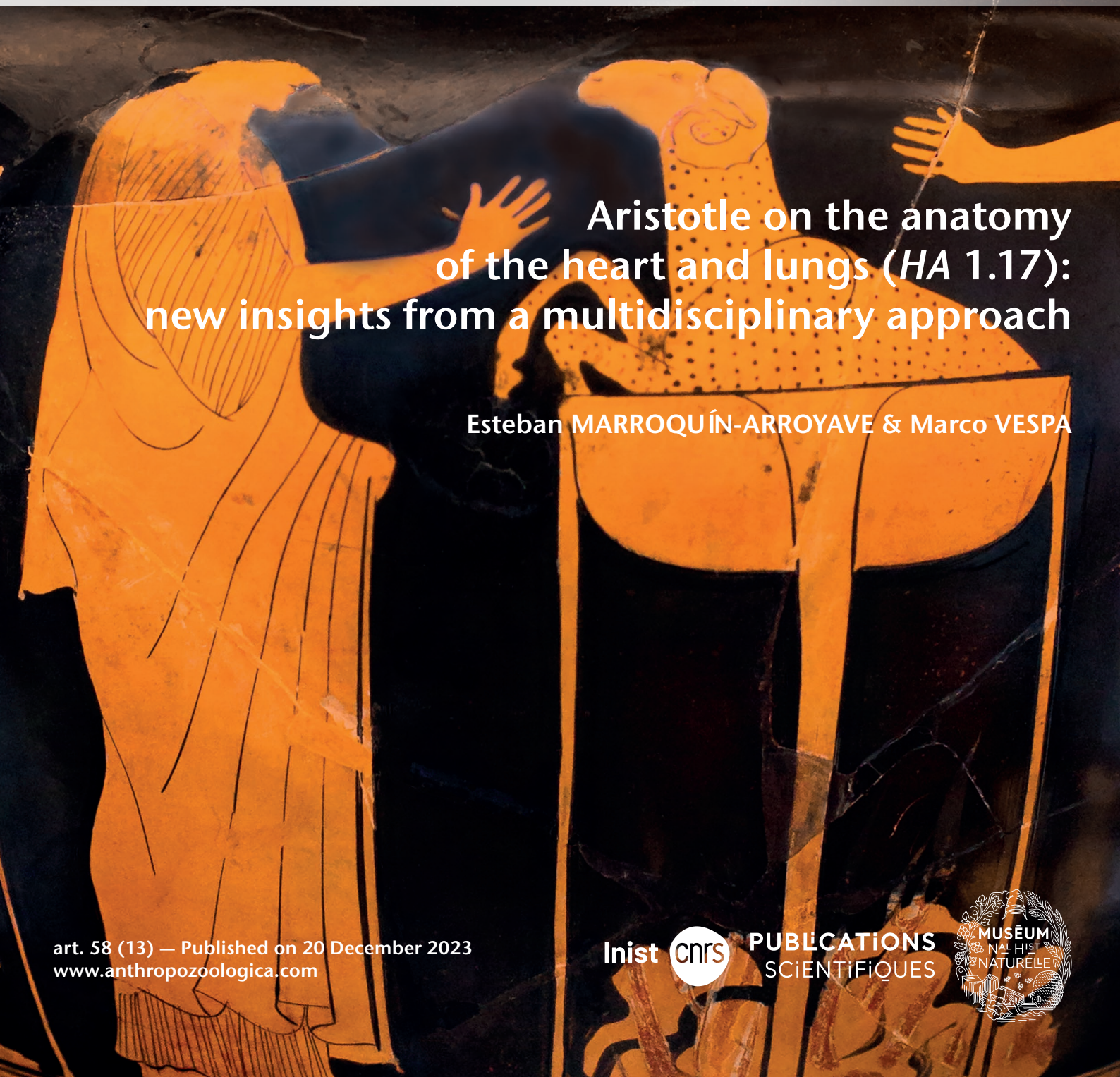
Édité par Anaelle BROSETA, Alessandra SCACCUTO & Arnaud ZUCKER



Aristotle on the anatomy of the heart and lungs (*HA* 1.17): new insights from a multidisciplinary approach

Esteban MARROQUÍN-ARROYAVE & Marco VESPA

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Aristotle on the anatomy of the heart and lungs (*HA* 1.17): new insights from a multidisciplinary approach

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ABSTRACT
This paper proposes new perspectives on Aristotle's discussion of the position of the heart and the presence of blood in the lungs. The accuracy of a detailed reconstruction of the internal topography of the human body, and of the resulting discursive presentation of its visualisation, would depend upon the specific experimental conditions from which this knowledge was derived. In particular, the difficulty or even impossibility of performing dissections on human corpses and the relative diffusion of knowledge about the anatomy of other animals resulting from sacrificial practice would play important roles in the constitution of a body of human anatomical knowledge. Our analysis will also bring to light experimental biases that could have shaped Aristotle's ideas about human anatomy. It will do so through a rigorous multidisciplinary approach that combines tools of philological and cultural-historical research on the one hand, and modern experimental data from medical science, and especially from comparative anatomy, on the other, in order to gain a better understanding of Aristotle's discussion on the human heart and lungs (*HA* 1.17).

KEY WORDS
Ancient anatomy,
classical philology,
dissection,
sacrifice,
animal experimentation.

RÉSUMÉ
*Aristote sur l'anatomie du cœur et des poumons (*HA *1.17) : nouvelles perspectives à partir d'une approche multidisciplinaire.*
Cet article propose de nouvelles perspectives d'interprétation concernant la discussion qu'Aristote consacre à la position du cœur par rapport aux poumons et à la présence de sang dans les poumons. La reconstruction d'une image détaillée de la topographie interne du corps humain à travers une présentation discursive de sa visualisation dépend très souvent de conditions expérimentales spécifiques. En particulier, la difficulté, voire l'impossibilité, de pratiquer des dissections sur des cadavres humains et la diffusion des connaissances sur l'anatomie d'autres animaux résultant de la pratique sacrificielle semblent jouer un rôle important dans la constitution d'un corpus de connaissances sur l'anatomie humaine dans l'Antiquité grecque classique. Notre étude mettra en lumière les biais expérimentaux qui ont pu contribuer au processus d'élaboration des idées anatomiques de la part d'Aristote. Elle le fera à travers une analyse pluridisciplinaire combinant les outils de la recherche philologique et de l'histoire culturelle, d'une part, et les données expérimentales modernes de la science médicale et notamment de l'anatomie comparée, d'autre part, afin de mieux comprendre la discussion d'Aristote sur le cœur et les poumons humains (*HA* 1.17).

MOTS CLÉS
Anatomie ancienne,
philologie classique,
dissection,
sacrifice,
expérimentation animale.

INTRODUCTION

The medical knowledge of the ancient Greek world was first codified in the classical period (5th-4th *c*. BCE) in a series of treatises that later converged in the so-called *Corpus Hippocraticum*, in which the experiences of therapeutic medicine, dietetics, and surgery helped to structure different and sometimes contradictory hypotheses about the internal anatomy of the human body. In the second half of the 4th *c*. BCE, Aristotle's biological *corpus* provided an important contribution to this intellectual debate, especially the *Historia animalium* (*HA*), the most comprehensive extant treatise on animal life in the ancient Greek world (Oser-Grote 2004; Bartoš 2014; Bartoš 2021).

There have not been many studies that focused on the anatomical ideas in Aristotle's work or on the ways that he examined medical tradition and developed a partially new body of knowledge, and most have been produced only in recent years (e.g., Dean-Jones 2017; Bubb 2019; Ezrohi 2023). Building upon these studies that examined Aristotelian anatomical ideas, this research work begins with a problematic passage from the *Historia animalium* (Arist., *HA* 1.17, 496a4-11 [T1]) on the place of the heart in relation to the lungs in human anatomy. The Aristotelian text in question is usually understood and translated to mean that the heart lies above the lungs. This anatomical indication is incompatible with modern knowledge of human and animal anatomy, which instead describes the heart as lying between the two lungs (König & Liebich 2020: 472). The passage has traditionally been translated without any remarks from commentators and translators, who in most cases seem not to notice any problem. This can be explained by the fact that a traditional linguistic-philological approach does not identify problems in the transmission of the text nor any major difficulties in the syntax and meaning of the passage in question.

Our aim in this article is to provide a new analysis and translation of the Aristotelian text by questioning the information that it conveys about the anatomy of the human body in comparison to previous translations and analyses. We will demonstrate that the Aristotelian text in fact describes the position of the human heart in perfect agreement with the actual natural position of the heart in human and animal anatomy.

By examining the Aristotelian text from two different analytical perspectives, one philological and cultural and the other medical and experimental, we will also shed light on another passage in the same chapter that refers to the heart and lungs in Aristotle's anatomical conceptions, but which has received little attention in studies and commentaries so far (Arist., *HA* 1.17, 496b1-8 [T2]). By comparing textual analysis and modern experimental data from anatomy and comparative anatomy, we will be better able to explain an ancient debate about the vascularisation of the human lung. We will examine what role the experimental context (i.e. both sacrifice and dissection practices) and the choice of the animal model on which the observation is carried out might have played in the observation of some physicians that there is no blood in the human lung.

Before going into the details of the two case studies under examination here, it is necessary to provide some background information on how Aristotle observed and gathered anatomical data. The anatomical study carried out by Aristotle is essentially based on observations of the bodies of nonhuman animals by Aristotle himself (Kullmann 2015: 78-112); on several occasions, Aristotle's enquiries also rely on knowledge traditions that existed before him, providing important information regarding the anatomical knowledge of Greek medical schools and veterinary and zootechnical practices (Scaccuto 2022; e.g., Arist., *HA* 7.2, 592a2, on eels' reproduction). Although Aristotle explicitly refers to first-hand observations that he made on human embryos at around forty days of age (Arist., *HA* 9.3, 583b14-20; Dean-Jones 2017: 132-140), most of his considerations about the internal organs of living beings came from the dissection of nonhuman animal bodies and from traditional cultural practices such as ritual animal sacrifices (Bubb 2022: 25-32).

The two passages we are going to analyse are both from the first book of the *Historia animalium* (Balme 2002). This is a section of the treatise that contains the most important information about the organs, or non-uniform parts in the Aristotelian lexicon, of human anatomy. The second book of the same treatise goes in the same direction, providing information on comparative anatomy and collecting data on the external parts and internal organs of the animals Aristotle called *enaima*, which generally corresponds to the modern category of vertebrates.

This detailed account of human anatomy, especially of the internal organs, is part of a systematic effort to establish a picture of the differences (*diaphorai*) that distinguish the anatomical components of all living beings, from the most complete and perfect animals (primarily humans from the Aristotelian perspective) to the *anaima*, the invertebrates or "bloodless" animals. Although his exposition in book one is about human anatomy, Aristotle explicitly points out that the study of the internal parts of the human body must be based on comparative anatomy and conducted through precise observations of the bodies of those living beings that are anatomically closest to humans.

What animals is Aristotle referring to? If we go through the text of the *Historia animalium*, we can find some answers. The comparisons drawn by Aristotle concerning the shape and size of certain internal organs always mention viviparous mammals native to the Greek-Mediterranean area[1]. Dogs and pigs are mentioned (Arist., *HA* 1.16, 495b24-496a3) in the description of certain digestive organs, especially the intestines, while cattle are mentioned when talking about the shape of human kidneys (Arist., *HA* 1.17, 496b34-35). Nonhuman

1. Although there is some evidence of dissection and vivisection practiced by Aristotle on egg-laying animals (e.g., Arist., *HA* 2.12, 503b20-21), particularly turtles and some fish, it remains difficult, though not impossible, to demonstrate how data from the study of these animals were applied to the study of human anatomy. It has been suggested, for example, that the Aristotelian description of the occipital region of the skull as brainless and empty space full of air (Arist., *PA* 2.10, 656b14-15) might have arisen from the inspection of certain reptiles and egg-laying animals, such as some fish, in which such biological structures would be found (Clarke & Stannard 1963: esp. 140, 141).

primates were certainly among the animals whose internal anatomy was studied by Aristotle, particularly macaques and baboons for the classical Greek world (Vespa 2021: 95-117). Although the internal anatomy of monkeys is not mentioned in the first book as a comparative reference for the study of human anatomy, elsewhere Aristotle explicitly reports (Arist., *HA* 2.8, 502b 25-26) the strong resemblance, if not identicalness (*homoia*), of the internal organs of nonhuman primates to those of humans. Considerations of this kind are explicitly referred to by Aristotle in dissections of primate bodies (*ta d'entos diairethenta* [the dissected internal parts]).

ABOVE OR INTERNALLY TO THE LUNG(S)? A NEW HYPOTHESIS ON THE SEMANTICS OF THE ADVERB *ANŌTERŌ* IN ARISTOTLE'S *HA* 1.17

After a brief sketch of the main internal anatomical structures related to the digestive and respiratory processes in humans (Oser-Grote 2004: 90-95), Aristotle gives a general description of the topography of the heart region as follows:

> Ἡ δὲ καρδία ἔχει μὲν τρεῖς κοιλίας, κεῖται δ' ἀνωτέρω τοῦ πλεύμονος κατὰ τὴν σχίσιν τῆς ἀρτηρίας, ἔχει δ' ὑμένα πιμελώδη καὶ παχύν, ᾧ προσπέφυκε τῇ φλεβὶ τῇ μεγάλῃ καὶ τῇ ἀορτῇ. Κεῖται δ' ἐπὶ τῇ ἀορτῇ κατὰ τὰ ὀξέα. Κεῖται δὲ τὰ ὀξέα κατὰ τὸ στῆθος ὁμοίως ἁπάντων τῶν ζώων ὅσα ἔχει στῆθος. Πᾶσι δ' ὁμοίως καὶ τοῖς ἔχουσι καὶ τοῖς μὴ ἔχουσι τοῦτο τὸ μόριον εἰς τὸ πρόσθεν ἔχει ἡ καρδία τὸ ὀξύ· λάθοι δ' ἂν πολλάκις διὰ τὸ μεταπίπτειν διαιρουμένων. (Now the heart has three cavities, and it lies above the lung at the point where the windpipe divides into two, and has a fat, thick membrane at the place where it is attached to the Great Blood-vessel and the Aorta. And it lies with its pointed end upon the Aorta. This end lies towards the chest in all animals which have a chest. And in all animals, whether they have a chest or not, the pointed end of the heart is always forwards, though this fact may very likely escape observation owing to some change in position while dissection is in progress.) (Arist., *HA* 1.17, 496a4-11 [T1])[2]

From a purely text-critical or semantic perspective, this passage has rarely been problematic for the translators and commentators who have analysed it in turn over the last century and a half (e.g., Aubert & Wimmer 1868: 237, "das Herz hat drei Höhlen und liegt oberhalb der Lunge […]" [the heart has three cavities and lies above the lung]; Thompson 1910: *ad loc.*, "the heart has three cavities, and is situated above the lung"; Louis 1964: 29, "[…] il est situé plus haut que le poumon, à la bifurcation de la trachée-artère […]"; Carbone 2011: 129; differently Zierlein 2013: 350, "die Positionierung des menschlichen Herzens oberhalb der Lunge ist falsch […]" [the positioning of the human heart above the lungs is incorrect]). This passage should, however, raise questions if one compares the overview provided by Aristotle with modern observations concerning the exact position of the heart (Shaw 1972: 367, 368). The surface of the heart, which is located in the thoracic cavity, is mostly covered by the lungs (König & Liebich 2020: 472). This is in open contradiction to the modern translations and interpretations of the passage that ascribe to Aristotle a higher position (*anōterō*) of the heart than of the lungs.

In the past, a few scholars have tried to explain the Aristotelian text on the basis of errors made in the transmission of the text (*librariorum culpa*). One of the most authoritative and important commentators on the Aristotelian text in modern times, Julius Caesar Scaliger (1484-1558), argued that the text was corrupt and that the passage should be understood as "the heart is located in the area of the uppermost part of the lung" by inserting the words *pros ta* before the transmitted *anōterō* (Scaliger 1619: 133): πρὸς τὰ ἀνωτέρω τοῦ πλεύμονος. In contrast, one of the most important translators and exegetes of the Aristotelian corpus in nineteenth-century France, Jules Barthélemy-Saint-Hilaire (1805-1895), held that the surviving text is valid but should not be understood literally ("[…] ne doit pas être pris à la lettre"). The French scholar believed that Aristotle's location of the heart in relation to the lungs should be understood in terms of the position of both of these two organs relative to the diaphragm: the tip of the heart would be higher than the bottom of the lungs when one considers their distance from the diaphragm (Barthélemy-Saint-Hilaire 1883: 83, 84).

A tentative hypothesis: the collapse of the lungs

Before proceeding to our main hypothesis and the consequent proposal of a new translation for *anōterō*, it may be useful to offer a few remarks on another possibility that might explain Aristotle's description of the heart as higher than the lungs. This explanation is rooted in the material conditions of the experiment, which, especially in the case of the dissection of an animal body, can influence the outcomes of an ancient anatomical study.

Aristotle's claim that the heart is above the lungs can be explained as a result of the collapse of the lungs. In the dissection of certain animal species (e.g., dogs), when opening the thoracic cavity it is common to find the lungs collapsed sideways and backward if the subject is laying in supine position (Fig. 1). In this situation, the back or upper side of the animal is seen as the bottom and what is closer to the observers as the top. This leads the dissectors to believe that the heart is protruding above the lungs, as it remains fixed in its position thanks to the pericardium and the connective tissue of the mediastinum, while the lungs are collapsed and no longer covering it (Fig. 1). It is important to note that this happens when the subject is positioned dorsally (supine). Since the Aristotelian text relies on visual information taken from animal dissections (Lloyd 1975; Bubb 2022: 25-32), it seems reasonable to assume that the experimental setting could imply an animal subject laying dorsally on a dissection table (cf. Arist., *HA* 8.50, 632a15-18 for the description of the technical operation of castration of young bulls, in which the animal is placed in the supine position, *kataklinō*).

2. The Greek text of the *Historia animalium* is given here and below according to the critical edition by Balme 2002. Unless otherwise stated, the translation of the *Historia animalium* is taken from Peck 1965, from the Loeb collection.

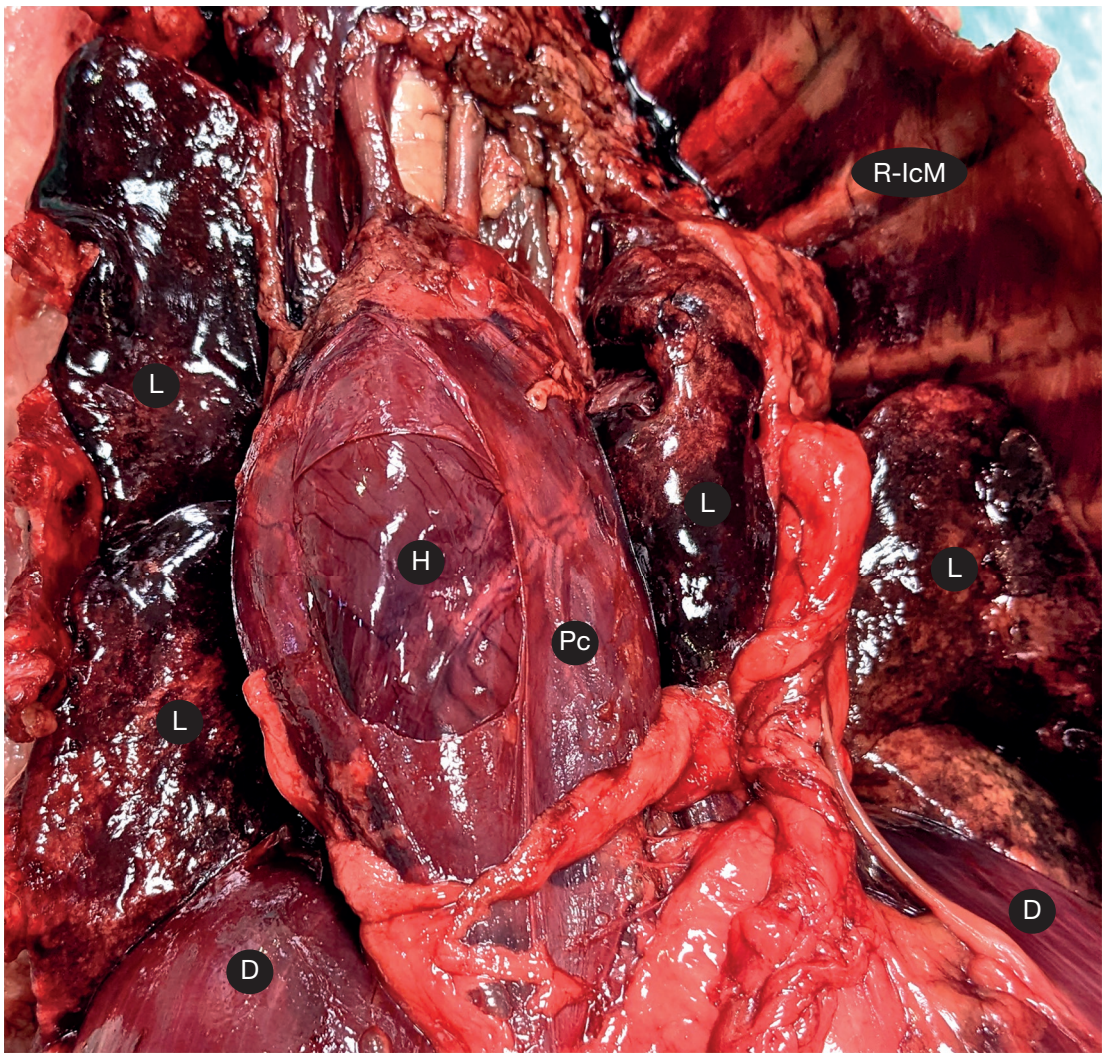

Fig. 1. — Dissection of the thoracic cavity of a dog positioned dorsally (on its back or upper side). The heart (**H**) can be seen located above the lungs (**L**) and slightly towards the right side. The lungs have collapsed to the sides of the thoracic cavity, which is limited laterally by the ribs and intercostal muscles (**R-IcM**). The heart is surrounded by the pericardium (**Pc**), partially cut to create a window, while the diaphragm (**D**) lies below. Credit: image by ATLOMY.

It is important to understand how the lungs collapse, and this can be explained through the anatomy and physiology of the thoracic cavity. The heart occupies a position in the thoracic cavity between the lungs (König & Liebich 2020: 472), whether the animal stands upright, like primates, or in a four-legged posture, as other mammals do (Fig. 2A, B). As the lungs cover the heart, they expand and contract to permit gas exchange due to the existence of a potential space called the pleural cavity (Singh 2018: 198). The pressure within this cavity is negative in a normal resting position, and it decreases during inspiration to allow the lungs to expand (Fig. 3A). During expiration the opposite happens, as the pressure inside the cavity increases and the lungs' volume decreases as air comes out (Fig. 3B). During a dissection, the chest wall is punctured or perforated, allowing an inrush of air, thus producing the loss of the prevailing negative pressure inside the pleural cavity (Singh 2018: 198). Due to this, the lungs collapse, and as a result the heart appears to be on top of them.

This first consideration could explain the expression "above the lungs" by hypothesising that the material conditions resulting from dissection could have influenced Aristotle's observation of the heart. The changes that occur in the anatomy of the internal organs as a result of manipulation of the body by the experimenter, as well as the intervention of other external agents in relation to the body under study, may alter the natural state of the organs.

Nevertheless, we consider this first explanation unlikely for two main reasons. The first relates to Aristotle's terminological and conceptual precision here, which demonstrate that he is fully aware of the different spatially-oriented body patterns that distinguish quadrupeds from humans (Carbone 2011: 139-146). The precise arrangement and topological distribution of the internal organs in relation to spatial reference points such as "above" and "below", "forward" and "backward", are consciously taken into account by Aristotle in his biological writings (e.g., Arist., *HA* 1.1, 497b-498b). Furthermore, the passage under study in our text, T1, devotes some space to considering the difficulties in determining the exact position

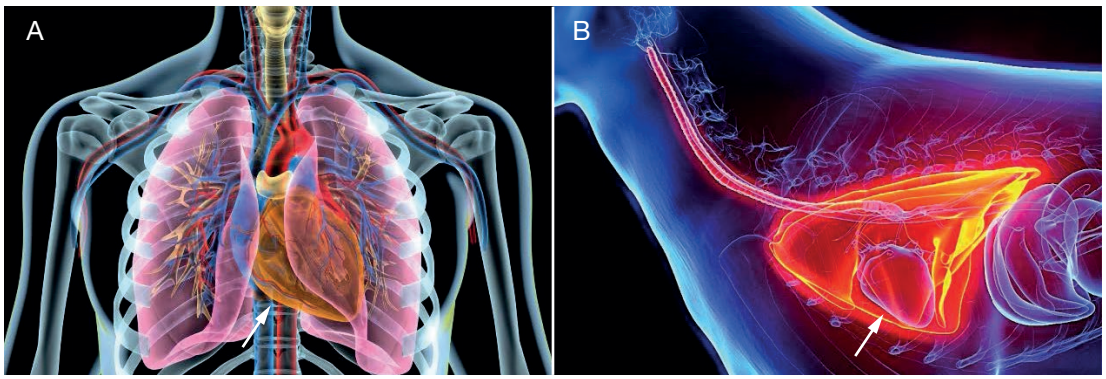

FIG. 2. — The position of the heart in mammalian animals: **A**, the human heart (white arrowhead) is positioned in the midline of the thoracic cavity, tilted to the left and surrounded by the lungs; **B**, the heart of a dog (white arrowhead) is also located in the thoracic cavity where it is surrounded by the lungs, as is the case in four-legged animals. Credits: images by A, Matis75; B, SciePro, taken and modified from https://www.shutterstock.com, last consultation on 4 December 2023.

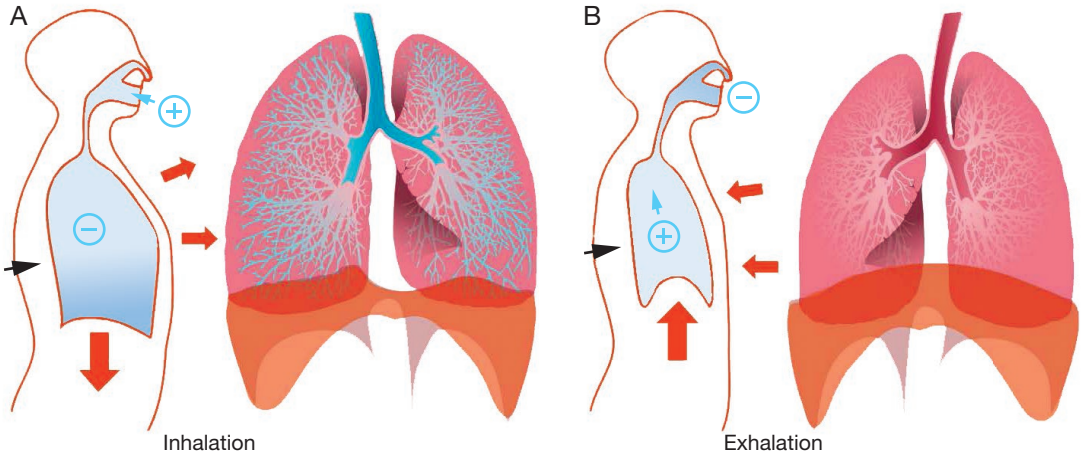

FIG. 3. — The process of breathing for gas exchange and the pressure change in the pleural cavity: **A**, during inspiration, air enters the lungs (light blue arrow), the negative pressure inside of the pleural cavity (black arrowhead) decreases and the thoracic cavity expands (orange arrows), while the lungs increase in volume; **B**, in exhalation, as air comes out of the lungs (light blue arrow) the pressure inside the pleural cavity (black arrowhead) increases, the thoracic cavity contracts (orange arrows), and the volume of the lungs reduces. Credit: image by Mariana Ruiz Villareal [LadyofHats], modified and taken from https://commons.wikimedia.org/, last consultation on 4 December 2023.

of the internal organs in the thoracic cavity, due to changes that could occur during the dissection. Aristotle uses the verb *metapiptein* to express the very notion of anatomical change. The semantic value of this verb is closely related to the idea of throwing objects such as knucklebones, dice, or potsherds, which can show a different side or face when they fall (*piptō*). The adverbial prefix *meta-* indicates a change of an object to a different form (Liddell *et al.* 2011: *s.v.* μεταπίπτω; on the preposition *meta,* see Luraghi 2003: 244-255). This complicates the assumption that Aristotle could have simply accepted the superior position of the heart after the collapse of the lungs in a quadruped's body, dissected in the supine position, as the state of the human body in an upright, bipedal position.

The second reason that makes this explanation implausible arises from Aristotle's full recognition of the changes that occur after and as a consequence of the dissection of an animal body. As we shall see below in relation to the lungs, Aristotle mentions the possibility of errors being introduced into the experimental results of dissections if one does not consider the changes that the practice of dissection can cause to internal anatomy (Arist., *HA* 1.17, 496b4-6; on dissection as a form of expertise, see Lennox 2018).

A NEW READING OF THE SEMANTICS OF *ANŌTERŌ*: THE INTERNAL POSITION OF THE HEART

For this reason, we will provide a new, unprecedented interpretation of the Aristotelian text, which enables a new translation of the passage through a semantic analysis of the adverb *anōterō*. This will make it possible to read the Aristotelian passage as a reference to the central position of the heart within the space created by the lungs and not, as previously understood, as a reference to a position of greater height of the heart in relation to the lungs. This new explanation fully agrees with modern medical knowledge about the position of the heart, which does not lie above the lungs but rather is surrounded and protected by the lungs.

Our explanation is based on different statements concerning the location of heart and lungs in different animals. In a passage from the second book of *Historia animalium* where he

is summarising the most important elements of the internal anatomy of living beings, Aristotle states that all breathing animals are endowed with the same essential organs, namely the trachea, oesophagus, lungs, heart, and diaphragm. Although these organs are the same in all breathing creatures, their morphological make-up and relative position may vary. Some of these organs, especially the trachea and the oesophagus, always have the same relative position (*thesis*), the trachea being in front of the oesophagus, and only their shape (*eidos*) changes from living being to living being. In the case of the lungs, on the other hand, the variation among breathing animals' anatomies entails not only the shape of this organ, but also its relative position in relation to the trachea and the heart (Arist., *HA* 2.15, 506a1-5).

This also applies within particular groups of living beings, as Aristotle claims a few lines earlier when he states that viviparous quadrupeds – a taxonomic designation very close to the modern definition of mammals (Zucker 2005) – show very similar, if not identical, anatomical traits to those of humans (*keimena hōmoiōs*; Arist., *HA* 2.15, 505b32-34). This is, indeed, what Aristotle says about the lungs in his study of the functions of and reasons for the existence of each organ and their mutual relations in the anatomy of a living being. In the third book of the treatise *On the Parts of Animals* (*PA*), devoted to the study of the nonuniform parts of the living body, Aristotle points out that the lung is an organ that varies greatly (*diapherei de ho pleumōn poly*) according to the animal under consideration (Arist., *PA* 3.6, 669a23-24).

In the same paragraph, it is noted that the function of the lungs is essentially to reduce the internal heat generated by the blood that comes from the animal's heart. Refuting a claim made by others, especially Plato (*Tim*., 70c-d), that the lungs have a shock-absorbing function in relation to the heart, Aristotle points out that this function is not the real reason for the existence of the lungs. As evidence for this, he points out that there is a significant difference in the relative position of the heart with respect to the lungs in most living beings compared to humans; the lungs cannot cushion the beats and shocks of the heart in most living creatures because they are too distant from the heart, which is *anōterō* than the lungs (Arist., *PA* 3.6, 669a17-23; Lennox 2001: 266)[3].

This passage from *On the Parts of Animals* contains the same expression as the text we examined above from the *Historia animalium* (*anōterō tou pleumonos*), but here Aristotle attributes this anatomical situation to a large number of living beings, but not to humans who, on the contrary, would be an isolated case[4]. According to Aristotle, it is only in humans that the heart is located near the lungs rather than above and far from them[5]. In the light of this text, it would be possible to explain the exegetical problem posed by the passage in Arist., *HA* 1.17 (T1) by assuming that Aristotle was referring to the internal anatomy of other animals and not to humans. Aristotle would have described the location of the heart in terms of the information he himself had gathered about other breathing animals, which he reproduced with the same expression in *PA*: the heart would be located higher than the lungs. Yet such an assumption would not take into account that Aristotle himself points out in the first book of *HA* that the information collected is primarily about human anatomy, which was reconstructed on the basis of a comparative study of the internal organs of other animals most similar to humans but with the aim of describing human anatomy in detail (Arist., *HA* 1.17, 497b1-2).

If we are reluctant to admit that, in a passage describing human anatomy, Aristotle instead provided information about the relative position of the heart and lungs in non-human animals, then another passage from the *PA* might prove decisive. In book III, Aristotle hints at the position of the lungs in relation to the heart immediately after describing the reciprocal location of the trachea in all breathing animals, which is found anteriorly to the oesophagus, and the oesophagus itself, the location of which is necessarily posterior to the trachea. By using the anatomical model provided by humans, Aristotle points out that the lungs are located in the region of the heart and more precisely *peri tautēn* (Arist., *PA* 3.3, 665a9-17).

How can this expression be rendered into a topographical and visual representation of the relative positions of the heart and lungs? Only with great difficulty and by forcing the semantics of the preposition *peri* with an accusative object would it be possible to understand this *iunctura* as depicting the idea that the heart lies higher than the lungs. The semantic values of *peri* with an accusative used with verbs that do not indicate movement are related to the idea of proximity. It often implies no direct contact between the object that is near and the object that is surrounded (Luraghi 2003: 268-283). In no case does the meaning of *peri* with an accusative refer to an object located on the vertical axis "above/below". In the Aristotelian passage, then, the meaning of the expression is clear: the lungs are close to and surround the heart. Such proximity of the lungs to the heart is also perfectly consistent with the aforementioned passage from *PA* (3.6), which on the one hand deals with the distinction between the anatomical models of humans, in which the heart is close to the lungs, and on the other hand deals with many other animals, in which the heart is far away and higher than the lungs.

3. Τὸ δὲ πρὸς τὴν ἅλσιν εἶναι τὸν πλεύμονα τῆς καρδίας οὐκ εἴρηται καλῶς· ἐν ἀνθρώπῳ τε γὰρ συμβαίνει μόνον ὡς εἰπεῖν τὸ τῆς πηδήσεως διὰ τὸ μόνον ἐν ἐλπίδι γίνεσθαι καὶ προσδοκίᾳ τοῦ μέλλοντος, ἀπέχει τ' ἐν τοῖς πλείστοις πολὺν τόπον καὶ κεῖται τὴν θέσιν ἀνωτέρω τοῦ πλεύμονος, ὥστε μηδὲν συμβάλλεσθαι τὸν πλεύμονα πρὸς τὴν ἅλσιν τῆς καρδίας. (The theory that the lung is provided as a cushion for the throbbings of the heart is not correct. This leaping of the heart is practically not found except in man, and that is because man is the only animal that has hope and expectation of the future. Besides, in most animals the heart is a long way off from the lung and lies well above it, and so the lung cannot be of any assistance in absorbing the throbbings of the heart.) (The translation of the passage is given according to Peck 1955).

4. In the Aristotelian text, the expression *en tois pleistois* is used – literally "in the majority of animals" – which could mean that humans are included (but could also mean that they are not). In fact, the Greek expression can be used in a similar way as *en tois allois zōiois*, to indicate a contrast between the situation found in most living beings and that one observed in humans, e.g., Arist. *Probl.* 10.1, 891a9-10 (πότερον τῷ εἰς ἄλλο τι τρέπεσθαι τοῖς πλείστοις ζῴοις τὸ περίττωμα, ἀνθρώπῳ δὲ δεῦρο; [Is it for the fact that in most animals the residue goes to some other place while in humans it goes here?]).

5. Peck 1955 explains in a footnote that, "in quadrupeds the lung is above the heart, but not in man, owing to the difference of posture." Cf. Ogle 1882: 206, "In saying that in most animals the heart lies above the lungs, A. means, I imagine, that in birds and reptiles the lung extends far down below the site of the heart; which is in fact the case, if we allow, as A. did, that the air-sacs form part of the bird's lung."

In the light of what has been said, one can argue that there could be another interpretation that explains the semantics of the expression *anōterō tou pleumonos*, thus conveying a meaning very similar to that of *peri tautēn* in relation to the location of the lungs given in *PA*. The semantic range attested for the adverb *anō*, in classical Greek, is not limited to the meaning of "above" or "up" to qualify the position or movement of an object on a sagittal axis (Liddell *et al*. 2011: *s.v.* ἄνω). In historiographical and geographical texts, this adverb was also used to denote a landmark that was on the same depth axis for the observer standing in a determined position in front of it (DGE 1986: *s.v.* ἄνω, II.4, *en el interior*, *tierra adentro* [in the interior, inland]). This meaning seems to be discernible in Herodotus' description of the Persians' fear of crossing the island of Samos (*anōterō Samou*) from Ionia, since they were unaware of the spaces and islands that lay further west and in the innermost (= *anōterō*) part of the Aegean (Herodotus, 8.132). In some cases, this adverb was used to refer to a position further inland from the coast, and it can also function as an explicit reference to the hinterland of a given territory, the space furthest from the coast and sometimes also at a higher elevation[6]. This seems to be the value Thucydides assigns to the phrase *hē anō polis,* which he uses to refer to the part of the city of Athens that was further inland than the coastal area of Piraeus and to which the contagion of the plague striking the city would have been directed (Thucydides, 2.48.2). The inland part of the city was also, at least in part, an area that was higher than the coastline of Piraeus, due to the elevation of the Acropolis and the hills of Lycabettus and Hymettus.

Finally, of particular interest here is the use of the term *anō* followed by the genitive in the court speech of Aeschines on the legation from Athens to Philip II of Macedonia, in which he had participated together with Demosthenes. Not without a certain malign interest, Aeschines presents to his audience the extreme disappointment after Demosthenes' speech, which they had expected to be a great diplomatic oration before the Macedonian court. If the introductory part – the threshold, so to speak, of Demosthenes' speech (*pro-oimion*) – had already been disappointing, Aeschines argues, the worst came when Demosthenes got to the heart of the subject by *delving into*, and not above, the important questions, *anō tōn pragmatōn* (Aeschines, *On the Embassy*, 34). In these cases, translating the adverb *anō* as "above" or "higher" would make little or no sense.

The use of the adverb *anō* to indicate the position of an object or the direction of a movement inwards or further inside is also attested in an anatomical context a few centuries after the Aristotelian passage (cf. López Férez 1996, for an insight into *anō* and *katō* as employed in the *Corpus Hippocraticum*). In his *On the Organ of Smell* (on this treatise, see recently Boehm 2018), a short treatise probably written after *On the Usefulness of the Parts*, Galen describes the anatomy of the internal nasal cavities to show that the olfactory function is not located in the nose itself, but in the frontal region of the brain, in what he calls the anterior concha or cavities (*prosthiai koiliai*). Galen wants to show how the air channels that constitute the interior of the nasal cavity are in fact characterised by branching. What looks like a single passageway, a single *poros* for each of the two nostrils, separates and leads to two distinct ducts, one of which is strictly responsible for the physiological process of respiration, while the other is related to the olfactory function, the operations of which are carried out in the cerebral area.

But where in the anatomy of the nose does the division of the single passageway into two distinct ducts originate? Galen's text gives a clue to the area referred to as the middle or median part of the nose:

> Τῆς τοίνυν ῥινὸς ἐχούσης μέσον διάφραγμα καὶ πόρους ἀξιολόγους δύο, τούτους δὴ τοὺς φαινομένους ἕνα καθ' ἑκάτερον μυκτῆρα χρὴ γινώσκειν ἀνωτέρω τῶν μέσων τῆς ῥινὸς ἑκάτερον αὐτῶν δίχα σχιζόμενον. ἥκει δὲ τῶν μερῶν τὸ μὲν ἕτερον εἰς τὸ τοῦ στόματος ἔνδον, τὸ δ' ἕτερον ὄρθιον, ὡς ἐξ ἀρχῆς ἐφέρετο, πρὸς αὐτὸν ἀναβαίνει[ν] τὸν ἐγκέφαλον. (If the nose has a central partition and two remarkable channels, which appear to be a single channel for each of the two nostrils, it must be recognised that both divide into two parts internally beyond the middle part of the nose (*anōterō tōn mesōn tēs rhinos*): one runs towards the inner cavity of the mouth, the other is vertical and begins to ascend towards the brain at the very beginning.) (Gal., *Odor.* 2.1 = 2.859 K.; Kollesch 1964; translation by the authors)

This text deals with the internal topography of the human nose, first describing the nostril, which forms a long internal canal, then the location of a point within the nose where this single canal divides into two parts, and finally the continuation of these two canals, one of which ascends to the brain area while the other runs horizontally, connecting the floor of the internal nostril to the mouth. The first ascending duct corresponds to the area known today as the membrane and the olfactory bulb in the region of the ethmoid bone at the upper end of the nose. The second duct, on the other hand, corresponds to the anatomical part now known as the choana, which provides the transition between the nasal and oral cavities.

Whereas the expression *anōterō tōn mesōn tēs rhinos* is understood by translators as referring to an anatomical region lying higher in the centre of the nose (Kollesch 1964: 37), it seems to make more sense for it to refer to a deeper, inner part of the nasal cavity, not visible to the naked eye. The reference to the central area of the nose seems connected not to the upper duct leading to the brain but rather to the point in the nose where the bifurcation originates, the point where the original duct splits into two. This reading is supported by the fact that the description of the ascending duct locates it as lying on the other end of a vertical (*orthios*) and an ascending (*anabainō*) span of the olfactory ducts towards the brain. In this Galenic passage, it is therefore at least possible, if not very probable, to read the comparative form of the adverb *anō*

6. Perhaps the most famous instance of the same semantic representation is found in the title *Anabasis* (< *ana, bainō*), transmitted for Xenophon's work, which describes the march of Greek mercenaries in the service of Cyrus the Younger inland, into the interior part of the ancient Mesopotamia, particularly from the Black Sea coast towards Babylon (Brownson 1998).

in its sense of "innermost, internally, further inside", which we have highlighted in the new interpretation of the same adverb in the Aristotelian passage on the position of the lungs.

On the basis of a comparison with other passages in Aristotle's biological writings on the position of the heart in breathing living beings, and by taking into account some specific semantic values of the adverb *anō*, it is possible to offer a new reading of the syntagm *anōterō tou pleumonos*. This expression in *HA* 1.17 would therefore not indicate that the heart is higher than the lungs but rather that the heart lies within the lungs, with the lungs surrounding and protecting it.

Further support for the hypothesis that the heart is located inside (i.e. within) the lungs can be derived from linguistic considerations of how the lungs are named and classified in Aristotle's biological writings. While the lungs are normally referred to as respiratory organs in the plural in modern medical science, Aristotle consistently and exclusively uses the singular[7]. In Aristotle's own technical vocabulary and in part of the ancient Greek medical tradition, the lungs are referred to as *pleumōn*, "lung", in the singular. References to the lungs are always in the singular because Aristotle considered them to be a single organ and not a double one, just like the heart (Arist., *PA* 3.7, 669b13-15). If one considers the lungs as a single organ, one can better understand the relevance of the reference to the position of the heart as "internal" to them. Although referring to the heart as internal to the lungs might seem to imply one organ within another, it is, in fact, compatible with the linguistic and conceptual framework outlined by Aristotle. What for modern Western speakers would be expressed by the phrase "the heart is located between the two lungs" would be formulated in ancient Greek as "the heart is located in the lung", since *pleumōn* refers to the respiratory organ as a whole. This linguistic datum provides a better understanding of how the actual position of the heart between the two lungs could be conceptualised in ancient Greek language, namely within and (deep) inside the lung.

On the basis of what has been proposed so far, we wish to put forward a new translation of the Aristotelian passage that differs markedly from previous interpretations of this passage with regard to the position of the heart in relation to the lungs:

> "The heart has three cavities, and it lies more internally to the lung (or deep inside the lung) at the point where the windpipe divides into two, and has a fat, thick membrane at the place where it is attached to the great vessel and the aorta. And it lies with its pointed end upon the aorta. This end of it lies towards the chest in all animals which have a chest. And in all animals, whether they have a chest or not, the pointed end of the heart is always forwards, though this fact may very likely escape observation owing to some change in position while dissection is in progress."

7. "Ἐν δὲ τοῖς ᾠοτόκοις, οἷον ὄρνισι καὶ τῶν τετραπόδων ὅσα ᾠοτόκα, πολὺ τὸ μέρος ἑκάτερον ἀπ' ἀλλήλων ἔσχισται, ὥστε δοκεῖν δύο ἔχειν πλεύμονας" (The respiratory organ is one, but in some species it is so constituted that it might be thought to be two organs, so great is the distance between the two articulations of the lung, as is the case with the oviparous animals […]) (Arist., *HA* 1.16, 495b2-5). In this case, Aristotle uses the plural form to indicate a borderline case in which anatomical observation in some animals might lead to information that he believes to be false because the lungs are a single organ.

This new interpretation and translation of the Aristotelian passage also has the advantage of fitting better with Aristotle's schematic representation of the heart, which envisages a central and inner position of the heart as the source of the inner warmth necessary for life, an aspect that Aristotle recalls in several places by comparing it to the domestic hearth sheltered in the innermost part of the house (Arist., *PA* 3.7, 670a22-26; on the metaphors used by Aristotle to describe the position and the functions of the heart, see Vegetti 1988; cf. Carbone 2011: 129-131).

NEW INSIGHTS INTO THE ARISTOTELIAN CRITIQUE OF THE LUNG AS A BLOODLESS ORGAN

In the same context as his presentation of the anatomy of the human heart in the first book of *HA*, Aristotle points out that, strictly speaking, only the heart can be defined as an organ containing blood in its own cavities (*en hautōi*), even though other organs could receive blood as well. This is the case for the lungs, which are supplied with blood by an extensive network of blood vessels:

> Αἷμα δὲ πλεῖστον μὲν ὁ πλεύμων ἔχει τῶν ἐν τοῖς ζῴοις μορίων τοῖς ἔχουσί τε πλεύμονα καὶ ζωοτοκοῦσιν ἐν αὑτοῖς τε καὶ ἐκτός· ἅπας μὲν γάρ ἐστι σομφός, παρ' ἑκάστην δὲ τὴν σύριγγα πόροι φέρουσι τῆς μεγάλης φλεβός. Ἀλλ' οἱ νομίζοντες εἶναι κενὸν διηπάτηνται θεωροῦντες τοὺς ἐξηρημένους ἐκ τῶν διαιρουμένων τῶν ζῴων, ὧν εὐθὺς ἐξελήλυθε τὸ αἷμα ἀθρόον. Τῶν δ' ἄλλων σπλάγχνων ἡ καρδία μόνον ἔχει αἷμα. (Of all the parts in the body, so far as those animals are concerned which have a lung and are both internally and externally viviparous, the lung is the part which contains most blood, for the whole substance of the lung is spongy, and alongside every duct passages lead from the Great Blood-vessel. Those who suppose the lung to be empty are quite misled: they have observed lungs which have been removed from animals while being dissected, and the blood has rushed out from them immediately upon killing. The only other one of the viscera which contains blood is the heart.) (Arist., *HA* 1.17, 496b1-7 [T2])

The lungs, which are bilateral organs located in both sides of the thoracic cavity, are in charge of the gaseous exchange of the body (O_2-CO_2). They are elastic, air-filled organs with a soft, spongy texture and are red in colour, which coincides with Aristotle's description of them (Singh 2018: 199; König & Liebich 2020: 412). They are supplied with blood by an extensive network of blood vessels composed of branches of the bronchial veins and arteries, which bring nutrition to the lungs, and the pulmonary veins and arteries, which are in charge of gas exchange (Singh 2018: 202, 203; Fails & Magee 2018: 363; König & Liebich 2020: 416). Therefore, it is quite possible that the opinion of some ancient physicians who claimed that the lungs were "empty" could depend on the observation of anatomy that had been altered during dissection.

In T2, Aristotle tries to explain why some physicians or philosophers considered the lungs to be a bloodless organ. The bleeding of the animal during and after dissection could, in his eyes, explain the error of those who confused the effects of a human operation with the natural state of the organ. Aristotle does not provide any specific information about the contexts or material conditions that would have led careless observers not to recognise that a major bleeding process is capable of causing substantive changes in the shape and colour of the lungs of the animal under study. However, a clearer picture could emerge from some linguistic observations on Aristotle's chosen wording of the text. In particular, the middle passive participle *exēirēmenos*, which is used to refer to the lungs of the slain animal as having been "pulled out" and "taken away", probably indicates that the examination of the animal's internal organs was not carried out while they were still connected, but only after the organs had been removed from their natural position.

The reference to organ extraction could be a fairly direct reference to traditional Greek sacrifice (e.g., Xen., *Anab*. 2.1.10), which must be considered to be one of the most important experimental contexts of anatomical investigation in the classical period. This linguistic clue is of particular value when we consider one of the most important features that characterises the tradition of Greek ritual sacrifice known as *thysia*[8]. In Greek ritual practice of the classical era, the sacrifice of an animal consecrated to the gods also involved the removal of certain internal organs for divinatory purposes (Van Straten 1995: 115-128; e.g., Xen., *Anab*. 2.1.10, *ta hiera exēirēmena*).

The practice of consulting the divine took place as part of the sacrificial ritual and involved the presence of diviners alongside the cult priests. It is very important to remember that this type of divination – *ex situ* as it were – was not the only one envisaged in antiquity; other cultural traditions, such as Roman, practised extispicy, in which the corpse was opened by ritual experts and the internal organs were left in their original position to be inspected for divinatory purposes (Maggiani 2005: 54-59; Collins 2008). In this context, Aristotle could be referring to the profound and important bleeding process that victims undergo when their organs are extracted for anatomical observation. This point is well expressed by the resultative perfect of the verb *exerchomai*, which emphasises the release of large amounts of blood from the slain animal.

This remark by Aristotle can provide important context for understanding the observation that some of those involved in sacrificial practices in which blood played a central role mistakenly considered the lung to be bloodless. As has also been shown through iconographic sources, blood played a central role in the ritual distribution of the sacrificial victim's parts between gods and humans (Ekroth 2002: 303-340). Both the presence of a vase for blood, called the *sphageion,* and distinctive colourful patches in the representation of many altars that depict a sprinkling of blood (*haimassō*) as a tribute to the gods, clearly show how the process of exsanguination of the animal was an integral part of the sacrificial ritual (Ekroth 2005).

The dissection of animal bodies for anatomical investigation must not have been so widespread in the period prior to the Aristotelian school, and much information concerning the internal organs may have come, at least in the first instance, from observing the internal anatomy of sacrificed animals following the extraction of the viscera (Lloyd 1992: esp. 119).

After all, Aristotle incorporates into his own account of the gallbladder and liver some observations about the lack of these organs in some animals drawn precisely from the context of ritual sacrifice (Arist., *HA* 1.7, 496b24-29; on this point, see Durand 1979). Even in this case, a few lines after the passage about the lung that interests us here, Aristotle integrates information from sacrifices to remind his pupils and readers that a perfectly natural situation, such as the increased size of the gallbladder in some populations of quadrupeds at Naxos, should not be mistaken for an exceptional event – or, even less, for an ominous portent (*idion… sēmeion*), as was thought by some participants in ritual sacrifice on the Greek island.

Even in modern day practice, the bleeding of an animal can lead observers to believe that lungs are empty when in fact they are blood-filled organs. This is possible because the lungs of some animals killed in slaughterhouses appear pale pink as opposed to their normal deep red colour (Singh 2018: 199; König & Liebich 2020: 412) (Fig. 4A, B). This change is due to the action of exsanguination, which is done in slaughterhouses to drain the animal's blood. Cutting the carotid arteries and jugular veins while the animal hangs from its hindlimbs is a modern-day technique to facilitate blood loss. If done correctly it can drain 40-60 % of total blood volume in 100-180 seconds (Von Holleben *et al.* 2010), which amounts to about 4 % of the body weight in animals like cattle, sheep, and goats (Sabow *et al.* 2016). The total volume of blood loss can be increased if the animal is not stunned before bleeding, which is still the common practice in Halal and Kosher slaughters (Farouk *et al.* 2014). A lack of pre-sacrifice stunning, as could have happened in antiquity (the stunning and killing of the animal by a blow on the neck seems to be attested in classical Greece mainly for the sacrifice of cattle but not of other animals, cf. Berthiaume 1982: 17-19), would produce an even higher percentage of blood loss and render the lungs paler. Therefore, the change of colour due to exsanguination may explain the observation by some ancient physicians or ritual operators that the lungs are bloodless.

Apart from the elucidation explicitly provided by Aristotle, however, it is possible to offer another explanation of the erroneous assessment of the observers criticised by the philosopher. This second argument arises from a passage from *On the Parts of Animals* (3.6, 669a23-b12) in which Aristotle describes the differences that characterise lungs in the animal kingdom. Aristotle mentions that there is a visible contrast between the lungs of viviparous and oviparous breathing animals. His discussion of the differences in lung size and structure among living beings is closely connected to the greater development of limbs and certain anatomical structures in viviparous animals than in oviparous ones. This is

8. With regard to the Aristotelian passage, Barthélemy-Saint-Hilaire (1883: 88) also believes that Aristotle could be referring to both dissections and organ inspections during and after the sacrificial process.

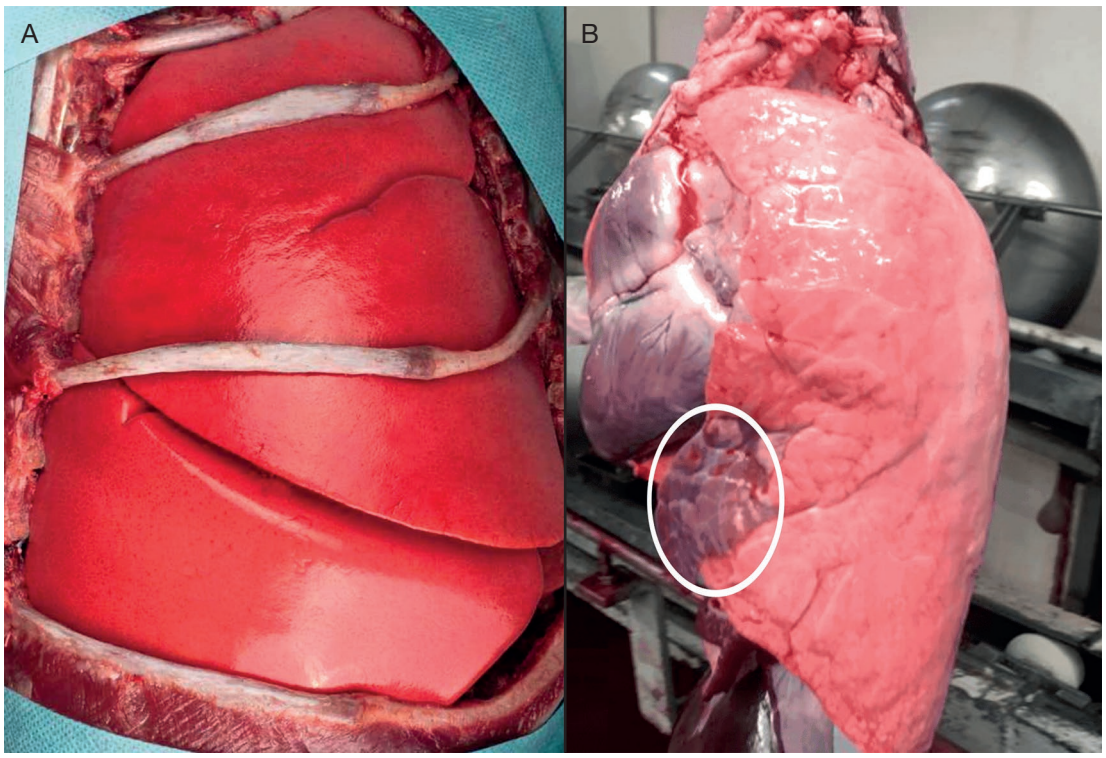

FIG. 4. — **A**, Lateral view of the left lung of a dog. The organ is deep red in colour, as the animal has not been exsanguinated with the modern-day technique applied in slaughterhouses; **B**, lateral view of the lung of a pig in a slaughterhouse. The pale pink colour is a result of exsanguination, applied as part of the slaughterhouse method. Notice a lesion compatible with Enzootic Pneumonia in the middle lobe of the lung (**white circle**) and the heart behind it. Credits: A, image taken and modified from Singh 2018: 201; B, image taken and modified from Bonicelli *et al*. 2021.

explained by the presence of greater internal heat in viviparous animals than in egg-laying animals, an internal heat directly caused by the greater presence of blood in the heart, where it is produced, and in the other parts of the body, the lungs being first and foremost adjacent to the heart.

Thus, if the lungs of viviparous animals are characterised by strong vascularisation, due to the increased supply of heat from the heart and the production of the blood necessary for the development of the anatomy of the living being, the situation is quite different in egg-laying animals. The lungs of egg-laying terrestrial animals, such as lizards or turtles, and even more so of birds, are less developed, smaller, and spongy, and can contract and expand depending on the amount of air taken in by the animal. The lungs of egg-laying animals are explicitly defined by Aristotle as "bloodless" (*anaimos*).

This assertion by Aristotle seems to contradict what is written in the passage we have analysed in *HA* 1.17 (T2), where the lungs are depicted as permeated by vascular structures. It is difficult to reconstruct the identity of those who, according to Aristotle, were mistaken. It may be that they made their judgement by observing the structure and colour of the lungs of a bird, e.g., a chicken or a hen – cheap sacrificial victims that were very common in cultic practices, especially in fourth-century Athens (Villing 2017). We know that mammals and birds are two animal classes that share certain characteristics (Scanes *et al.* 2022), but are also clearly differentiated in many features, especially in the respiratory system. The external morphology of the lungs is particularly different as bird lungs are small, soft, unlobed, non-expansile, and fail to cover the heart completely. Most importantly, they have a bright or pale pink colour (Singh 2018: 987). When looking at a chicken lung compared to that of a viviparous quadruped, such as a cow or a dog, a distinct difference in colour can be seen. In the case of a non-exsanguinated bovine, pig, or canine lung, a deep red colour, almost wine-red in places, is noted immediately after the animal has been dissected, whereas the external colouring of the chicken lung has a pale pink hue that could easily have led an observer to believe that it was not vascularised (Fig. 5A, B), as Aristotle explicitly stated in *PA*. It is precisely this difference in colour that could have misled those physicians whom Aristotle criticises in the passage of *HA* 1.17 (T2) which is the object of the present study.

CONCLUSIONS

The multidisciplinary approach adopted in this study has made it possible to offer innovative interpretative perspectives on certain passages in Aristotle's discourse on human anatomy. Comparisons with modern medical knowledge of the internal anatomy of the human body and of other mammals has opened new avenues of linguistic and historical-philological research and enabled new exegetical hypotheses about the Aristotelian text.

We have studied the Aristotelian passages using an analytical approach that combines linguistic and philological tools with scientific medical knowledge of comparative anatomy.

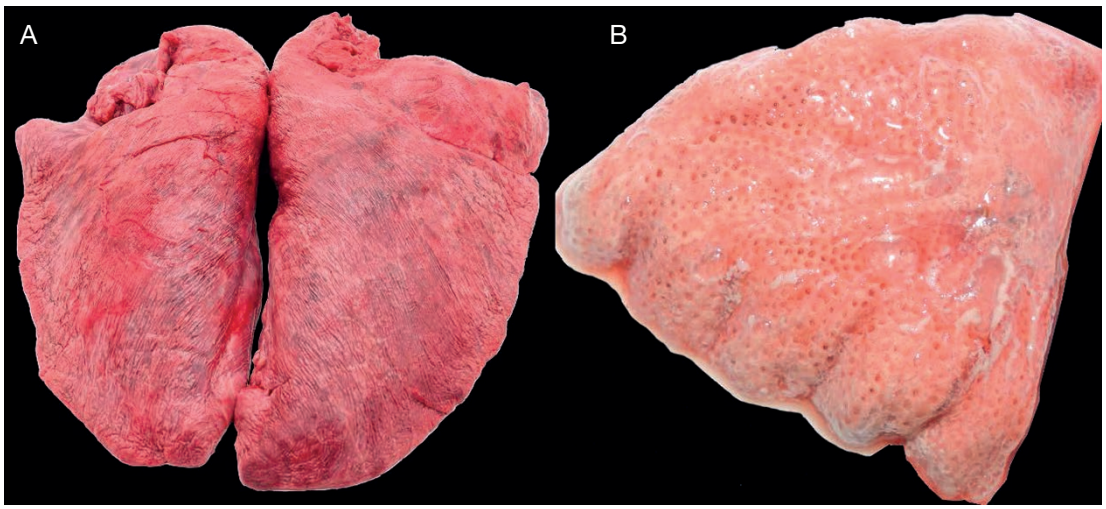

Fig. 5. — **A**, Fresh lungs of a pig. The colour of the lungs is deep red, as is the case for the lungs in mammals; **B**, lungs of a chicken. Notice the pale pink colour of the lungs, which coincides with most anatomical descriptions of a chicken's lungs. This image is magnified for viewing purposes. Credits: A, Oleksandr Lytvynenko; B, E-Iona; taken and modified from https://www.shutterstock.com/, last consultation on 4 December 2023.

While modern knowledge of internal anatomy has often been used heuristically in the search for new explanations of the text, the data provided by medical science have not been used mechanically to explain the Aristotelian text. We have critically and philologically scrutinised Aristotle's descriptions of human anatomy from the perspective of modern medical science through the careful consideration of the discourse context in linguistic and cultural terms, taking into account experimental practices and experiences characteristic of the Greek culture in which Aristotle lived.

This was illustrated by the analysis proposed for the expression *anōterō tou pleumonos*. An initial hypothesis, arising from the possibility that Aristotle's dissection practices may have influenced the internal anatomical data he obtained, could have provided an explanation and justification for accepting the usual translation of the Aristotelian expression ("the heart lying above the lungs"). However, consideration of Aristotelian anatomical thought, the distinctions Aristotle made regarding the different anatomies of humans and other animals, and Aristotle's warnings for the correct assessment of organ changes after dissection and sacrifice, have led us to propose a new translation that explains the position of the heart as "internally to, (deep) inside the lungs". This new interpretation of the phrase *anōterō tou pleumonos* allows for a reading of Aristotle that not only is consistent with current medical knowledge about the location of the human heart, but which also fits coherently within the framework of distinct anatomical models that Aristotle provides for humans and non-human animals.

By bringing together experimental data from modern medical science and linguistic considerations, we have demonstrated the importance of considering the ways in which material biases could be introduced during experimentation, thereby impacting the results obtained by physicians or ritual sacrificers while dissecting animal corpses. We have shown how the study of the experimental variables from which anatomical knowledge of the internal organs can be derived – in particular the processes of exsanguination during ritual sacrifice and the apparent differences in the colouration and texture of the lungs between some viviparous and other oviparous animals – has a decisive influence in making the ancient debate on the anatomy of the living more intelligible. Through all of these considerations, it was possible to shed new light on some Aristotelian claims about the reasons why some mistakenly considered (human) lungs to be an organ devoid of blood.

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