Aristotle's "mistake": the structure and function of the brain in the treatises on biology

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ABSTRACT

Introduction. Many authors since the time of Galen (second century AD) have considered Aristotle's cardiocentrism, which determined his understanding of the brain, to represent an anomaly in his scientific and philosophical thought. However, the central role of vital heat and of the heart in explaining living beings has important roots in presocratic philosophy (Heraclitus, Empedocles), which Aristotle reinterpreted in the light of the rich descriptions and theoretical principles presented in the biological treatises of the Aristotelian *Corpus*.

Development. The brains of humans and animals are described in two of Aristotle's main works on biology, *Historia animalium* and *De partibus animalium*. The brain is described as a wet and cold organ, lacking vessels but surrounded by a rich vascular network, whose purpose is to cool blood from the heart (which received sensory stimuli and was the originator of movement), and working in parallel with respiration to cool the heart itself, maintaining an appropriate temperature range. This physiological explanation of brain function is consistent with the morphological and functional data available at the time, and with the fundamental principles of Aristotelian philosophy (causality, teleology, moderation).

Conclusions. In essence, Aristotle's theory of the heart and brain represents the first suggestion that the brain is involved in controlling (inhibiting) internal vital processes and behaviour.

KEYWORDS

Aristotle, brain, cardiocentrism, history, teleology

Introduction

Aristotle was born in 384 BC in Stagira (near modern Stavros), a small city in Chalkidice, Thrace, in the northeast of modern Greece (Figure 1). The 24th centenary of his birth, in 2016, highlighted the continued interest in his extant works (the *Corpus aristotelicum*) among researchers from a broad range of scientific and philosophical disciplines.[1] Enrico Berti,[2] an expert on Aristotle who studied the significance of the *Corpus* in the 20th century, highlights some of the authors who have returned to Aristotle in recent decades in their attempts to address current philosophical and scientific questions.[3]

In the fields of logic and the philosophy of language, Aristotle's logical treatises (the medieval *Organon*) were frequently cited in the 20th century, both by philosophers of the continental hermeneutic tradition (M. Heidegger, H.G. Gadamer) and by Anglo-Saxon analytical philosophers (G. Ryle, J.L. Austin, P.F. Strawson). Greater attention was also paid to works

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previously considered "minor," such as the *Topics* and *Sophistical refutations*. The *Ethics* and the *Politics* have also been at the centre of important debates, particularly in matters related to practical philosophy (H. Arendt, H.G. Gadamer), the "critical reflection between praxis and rationality," "virtue ethics" (A. MacIntyre),[4] and even the consequences for the economy and human development (A. Sen). Furthermore, Aristotle's *Rhetoric* has been recovered as a theory of rational argument in those spheres (ethics, politics, and law) in which formal logic is insufficient (C. Perelman), and the notion of catharsis as described in the *Poetics* has continued to be a fertile area in philosophy (P. Ricoeur, M. Nussbaum).
Even areas considered today to pertain to "science" or to the "natural sciences" (which must be clearly and historically distinguished from the Aristotelian concept of science or *episteme*) have turned to the *Corpus* in the search for original concepts that may shed light on current theoretical problems. The "new alliance" of philosophy and science, proposed several decades ago by I. Prigogine, shows clear echoes of the Aristotelian philosophy of nature; R. Thom, founder of "catastrophe theory," considered Aristotle's physics to be a "semiophysics" that may identify the meaning of our experience of the world. Regarding the mind-body problem, H.W. Putman's functionalist theory explicitly cites Aristotelian hylomorphism, and ideas of biological information and teleology have seen renewed interest from F. Jacob and E. Mayr, among others (reviewed by Berti[3] in 2011).

Ontology may have been the area which saw the most lively debates on the Aristotelian treatises (particularly the *Metaphysics*) in the 20th century. Numerous authors, including in Spain, have called for a recovery of "the Greek Aristotle," obscured by the interpretation of his oeuvre in the Middle Ages and subsequently.[5-7]

This article's approach makes two methodological assumptions: *1)* matters related to living things and to humans *qua* living things permeate the entire *Corpus aristotelicum* and represent one of the main axes for its interpretation; and *2)* the search for a "primary" interpretation of Aristotle's work, and revision from the perspective of modern biology, are necessary and differentiated tasks for any contemporary analysis of Aristotelian biology. Hence, we aim not to translate Aristotelian biology into a series of correct and incorrect theories, judged from the perspective of today's scientific knowledge; rather, our aim should be to recognise the original understanding of living things as presented by Aristotle throughout the *Corpus*, and consider and interpret this as the first attempt at a complete vision (*theoria*) of the living being in Western history.

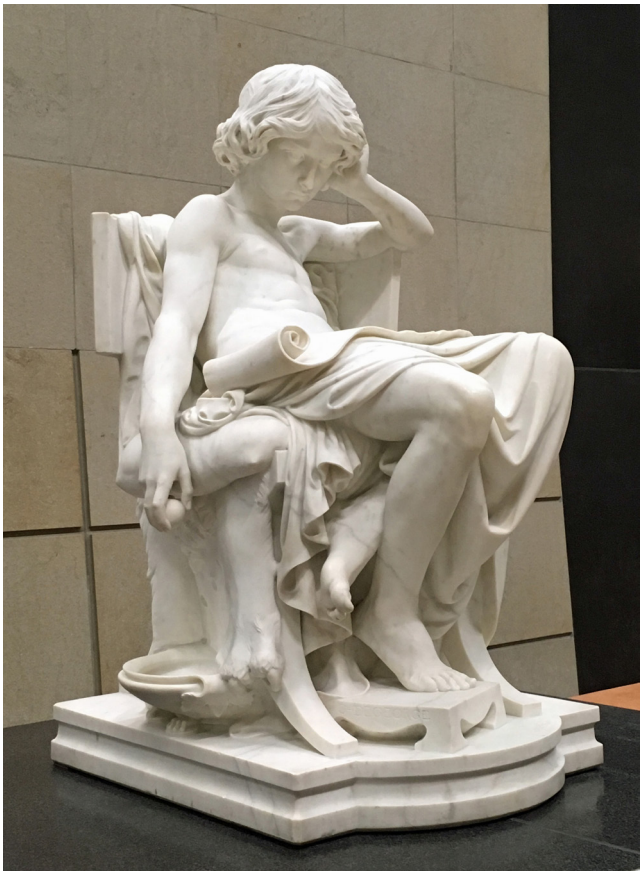

Figure 1. *The youth of Aristotle*, a sculpture by Charles Degeorge (1875) exhibited at Musée d'Orsay, Paris. Photograph by A. Rábano

Development

The biological treatises in the context of the *Corpus aristotelicum*

It should be noted that all the surviving Aristotelian texts are so-called "esoteric" writings (referred to today as "treatises"), intended to be used internally and certainly as teaching material at the Lyceum. Of his published (or "exoteric") texts, only fragments survive through the writings of other authors. The treatises on biology

account for almost one-third of the *Corpus*, and Aristotle is known to have had a keen interest in living beings throughout his life. In his early life, he lived and was educated in a medical environment (*Asclepiadae*), and during his first exile from Athens (after Plato's death in 347 BC), in Assos and Mytilene, he dedicated much time to the direct observation of animals and to learning from breeders, fishermen, hunters, and butchers. His treatises mention nearly 500 animal species, mainly food animals. The treatises specifically addressing biology (or zoology) are the following (Latin names are given, followed by the abbreviations used in the article): *Historia animalium* (*HA*), *De partibus animalium* (*PA*), *De generatione animalium* (*GA*), *De incessu animalium* (*IA*), and *De motu animalium* (*MA*).[8] In addition to these, *De anima* (*DA*) is a central text of great importance, enabling lines to be drawn between the biological treatises and the *Ethics* and *Metaphysics*; we should also consider the *Parva naturalia* (*PN*), which gathers a series of short texts. All of these texts give morphological or behavioural descriptions in varying degrees of detail and even, as we shall see, some experimental observations with elaborate theoretical discussions. As is customary, Bekker numbering is observed for references to specific texts.

The heart and the brain in Aristotle: addressing the problem

"All men by nature desire to know,"[a] reads the famous opening line of Book I of the *Metaphysics* (*Met* A 980a20); later in the treatise, Aristotle explains that this knowledge constitutes understanding in terms of causes (*aitiai*) and principles (*archai*). This desire to know, or curiosity, is stimulated by the atypical, the anomalous, that which does not fit known or predicted patterns; this urges enquiry and demands a causal explanation. In this sense, this study is guided by a primarily Aristotelian question: in the coherent, strongly consistent set of ideas about living things and biological processes he expounds in the *Corpus*, how are we to interpret Aristotle's cardiocentrism and the consequent assignation of a secondary role to the brain? Over the centuries, many authors have wondered about Aristotle's "mistake"; in the second century AD, Galen asserted, puzzled, that Aristotle had understood nothing about the brain.[9]

[a] Translator's note: all quotes from the *Metaphysics* are from H. Tredennick's translation, consulted online at: https://www.perseus.tufts.edu/hopper/text?doc=Perseus%3atext%3a1999.01.0052.

Firstly, there is a need for a broader historical focus, with cardiocentrism (and its counterpart "encephalocentrism") defined and located in the appropriate period, spanning somewhat more than two centuries (from the sixth to the fourth century BC). The underlying question is which part of the body can be identified as the seat of the ruling principle, intelligence (*nous*), reason (*logos*), or the soul (*psyché*). According to a tradition dating as far back as Anaximenes (air as the divine element), and supported by Alcmaeon, the Pythagoreans, Democritus, Diogenes of Apollonia, the author of the Hippocratic text *On the sacred disease*, and Plato, the brain was responsible for this faculty/function. Another tradition, possibly originated by Heraclitus (fire as the divine element) associated the vital principle with "vital heat," with the blood and the heart serving as the seat of intelligence and the soul. Other adherents of this tradition were Empedocles (the first to link the concepts of "heat," "the divine," and the soul), the author of the Hippocratic text *On the heart* (who considers the vital breath, *pneuma*, to originate in the blood), and Aristotle himself.[10] In book IV of the *Metaphysics*, Aristotle describes these diverging traditions as follows (*Met* Δ 1013a4-6):

> [By "beginning" we refer to] that thing as a result of whose presence something first comes into being; eg, as the keel is the beginning of a ship, and the foundation that of a house, and as in the case of animals some thinkers suppose the heart to be the 'beginning,' others the brain, and others something similar.

The classification, composition, and dynamics of living beings: key concepts

To more precisely address our question, it is beneficial to briefly review the main concepts about living beings and biological processes in Aristotelian philosophy. However, we should aim to avoid questions that remain controversial among specialists.

The central concept that explains biological phenomena, and Aristotelian ontology as a whole, is that of entity (or substance), *ousía*, which is equivalent to specific form (*eidos*), whose definition lies in its essence (*to ti en einai*). It is equally important in the biological field to consider the markedly linguistic character of ontology in Aristotle: "The term 'being' has several senses" (*Met* Z I). Scientific discourse concerns the *eidos*, not the individual (accidental). The existence of *this man* or *that horse* is explained by the essence "man" or "horse"; essence results from the combination of the four causes

presented in the *Physics*: the material (*hyle*), the efficient (agent), the formal (*eidos*), and the final (*telos*). In an artificial object, such as a bronze statue, the four causes are easily separated (bronze, sculptor, structure, and tribute, respectively), whereas in a living being, such as a human, the material cause (the fluids, tissues, and organs making up the body or *soma*) is expressed through the other three causes, which converge in the "specific form." However, this explanation involves no external artifice (such as the demiurge in Plato's *Timaeus*): a living thing, as a specific form (*ousía*, *psyché*), is its own cause insofar as it is a specific form (or structure, in today's terminology). The final cause (*telos*) of all biological processes is the regeneration of the specific form as a whole, *entelécheia* (species, in the logical sense of "class" rather than in the Linnaean sense), from parent to child, indefinitely.

In the structure of a living being, we can distinguish three levels of organisation: *1)* combination of the elemental qualities of nature (*physis*) (cold/heat, liquid/solid) gives rise to the four elements described by Empedocles (fire/air, water/earth), which mix to form the "homogeneous parts" (*homoiomeré*) or tissues of the body: blood, flesh, bone, and marrow (*PA* II 1-9); *2)* the combination of these parts gives rise to "heterogeneous parts" (*anomoiomeré*), which may be external (body parts) or internal (organs or viscera) (*PA* II 10 and III 3); and *3)* the combination of organs and viscera gives rise to the living body (*soma*), which has the capacity to reproduce itself to maintain the species (specific form). From a functional point of view (historically the initial perspective in Aristotelian biology), the soul (*psyché*), as a "form of a natural body having life potentially [*dynamis*] within it"[b] (*DA* II 412a20-21), represents the greatest expression of an organism's life, and is stratified into various levels of integration: the nutritive soul, the sensitive soul, and (only in humans) the rational soul.

Zoological taxonomy, one of the most impressive and lasting achievements of Aristotle's treatises, is based on a comparative analysis of the organs and their functions: nutrition, respiration, reproduction, locomotion, and perception. The two main groups are made up of sanguineous animals (*enaima*) and bloodless animals (*anaima*); these categories broadly correspond to the vertebrates and invertebrates in modern taxonomy. Sanguineous animals are differentiated according to their reproductive system, into vivipara (mammals) and ovipara, with the latter categorised into animals with lungs (birds) and those with gills (fish). Bloodless animals are classified according to their integument and skeleton.[10]

Description and explanation of the brain in the Aristotelian treatises

Besides occasional references in the non-biological treatises, the main references to the brain and its function are in *Historia animalium* and *De partibus animalium*. In both cases, the place of the brain in the development of each treatise is of equal importance to the content of the text. In *HA*, the order of presentation is anatomical, from top to bottom and from the exterior to the interior. Aristotle mainly refers to humans: the reference for all other living things, the norm, the first and highest in the series of all living things. While "man is the animal with which we are all of us the most familiar"[c] (*HA* 491a20), his internal organs are the least understood, and hence "we must have recourse to an examination of the inner parts of other animals whose nature in any way resembles that of man" (*HA* 494b20). Book I of *HA* addresses the parts of the (human) skull, the neck, the trunk, the genitalia, and the upper and lower limbs. Aristotle subsequently addresses the brain, although probably not (at least exclusively) the human brain, and its relationship with the eyes. In book II of *DA*, he explains the elements, the homogeneous parts, and finally the heterogeneous parts. Before the presentation of the homogeneous parts, and in reference to the elements, he explains that the heart as the "primary seat of these principles shall […] in its character of general sensory recipient, be one of the simple parts; and on the other hand shall, in its motor and active character, be one of the heterogeneous parts"[d]; bloodless animals have an organ "analogous" to the brain (*PA* 647a27-31). Following a lengthy digression on heat and coldness, the solid and the fluid, and the nutrition and growth of animals, he discusses at length the blood and serum, lard and suet, bone marrow, and finally the brain. In fact, the brain is "continuous" with the spinal

[b] Translator's note: all quotes from *De Anima* are from J.A. Smith's translation, consulted online at: http://classics.mit.edu/Aristotle/soul.html.

[c] Translator's note: all quotes from *Historia animalium* are from D.W. Thompson's translation, consulted online at: http://classics.mit.edu/Aristotle/history_anim.html.

[d] Translator's note: all quotes from *De partibus animalium* are from W. Ogle's translation, consulted online at: http://classics.mit.edu/Aristotle/parts_animals.html.

cord (the marrow of the vertebrae)(*PA* II 652a25-26). We should note that neither the brain nor the heart is considered to be homogeneous or heterogeneous; rather both parts are *sui generis*.

The anterior or frontal part of the head, both in humans and in other sanguineous animals, contains the brain, whereas the posterior or occipital part is hollow (*HA* 491a35 and 494b25 et seq.; *PA* 656b13). The brain is covered by two membranes, one harder and the other less robust, consists of two parts (*HA* 494b25 et seq.; *PA* III 7, 669b22), and contains a small central cavity. Behind the brain is the cerebellum. The brain lacks blood and blood vessels, although the surrounding membrane is rich with vessels (*HA* 495a5 et seq.; *PA* II 652a24 and 653b8). The brain is wet (*PA* II 656b1-2) and cold to the touch (*HA* 495a5 et seq.), and is larger (relative to height) and wetter (*HA* 494b25 et seq.) in humans than in other animals. Men's brains are larger than those of women (*PA* II 653a27-8).

The brain is the coldest part of the body (unlike the marrow, which is hot) (*PA* II 652a27-8); its function, for the purposes of conserving the animal (*PA* II 652b6-7), is to cool the blood that arrives through the aorta from the heart and is distributed through the vessels surrounding the brain (*PA* II 652b22 et seq.). To fulfil this function, the brain is made up of an appropriate composition of water and earth; when it is boiled (evidence that Aristotle performed experimental studies), it becomes hard and solid (*PA* II 653a22-3). If the brain becomes harder or more fluid than normal it cannot function, resulting in various forms of disease, madness, or death (*PA* II 653b4-5).

In his treatises, Aristotle refutes any relationship between the brain and the sensory organs, which he studies thoroughly, noting that they are richly connected to the heart by blood vessels. Aristotle groups the nerves (*neuron*) with the ligaments and tendons; just a few decades later, Herophilus of Chalcedon and Erasistratus of Chios described the sensory and motor nerves and their relationship with the brain.

[e] Translator's note: all quotes from De Generatione Animalium are from A.L. Peck's translation, consulted online at: https://ia902606.us.archive.org/30/items/generationofanim00arisuoft/generationofanim00arisuoft.pdf

The heart-brain axis and animal life

It is difficult, on the basis of the extant texts, to evaluate to what extent Aristotle is convinced of his own account of the facts (*to hoti*, the that) and underlying principles (*to dioti*, the reason why); this matter has been analysed in detail by contemporary authors.[11] According to I. Düring,[12] W. Ogle (the English translator of *PA* and a friend to Darwin, who shared with Ogle his admiration for Aristotle's biological texts) argues that for Aristotle, brain function is a consequence of the anatomical structures and phenomena described in his treatises. According to T. Manzoni's[9] excellent book on the subject, the keys to the Aristotelian understanding of the brain lie in the origin of movement and vital heat, the central questions of the Aristotelian concept of life (*zoé*).

Sensations from the sense organs converge in the heart, the seat of *sensus communis* (*koinòn aisthetérion*) (*DA* II; *PN* 469a11-13); the heart, in turn, is the principle of motion (*PA* 665a10-15). It should be noted that Aristotle considers natural beings (*physei*), of which living beings constitute the paradigmatic example, to be those that have an internal principle of motion (*Physics* book II). Sensation also involves movement (*DA* II), with blood vessels carrying these signals in both directions (afferent and efferent). In voluntary movement, the signal is transmitted by dilation or contraction of the *symphiton pneuma* (*PA* 667a28), a special substance that is distinct from the four elements and is "analogous to the substance which belongs to the stars"[e] (*GA* 736b38).

The heart, located in the centre of the body, is the source of blood and the organism's vital heat (*PA* 666a8). Heat is responsible for digesting food (*pepsis*), and blood for nourishing different parts of the body (*PA* 650a3-b 10). Thinner, colder blood, found in the superior part of animals, favours perception and intelligence (*PA* 648a3-11 and 650b19-21; *GA* 744a25). Like other classical authors, Aristotle considers the purpose of respiration to be maintaining vital heat within tolerable limits by delivering air directly to the heart (*HA* 495b5-12). According to Aristotle's account, the brain cools the blood that arrives into the surrounding network of vessels; secondarily to this, it cools the heart through a process analogous to rain, with the vapours produced during digestion condensing upon contact with the brain (*PA* 653a5-10).

Conclusions

As mentioned above, there is little sense from a hermeneutic perspective in evaluating Aristotle's neurobiology according to its accuracy in terms of today's neuroscientific knowledge. Detailed examination of his work reveals some level of correspondence with other classical interpretations; for example, Plato's tripartite theory of soul (*Timaeus* 69c et seq.), in its mythical narration, proposes a constant battle between the brain (reason) and the heart (desire, passion). In addition to contributing detailed empirical descriptions (according to the technical capacities of the fourth century BC), Aristotle's interpretation is characterised by an elaborate theoretical framework: *1)* the central role of the heat-blood-life axis (according to A. Marcos,[13] blood is the nearest approximation to an elemental material of life in Aristotle's worldview); *2)* the (teleological) need to define a function for the brain (*PA* II 625b6-7): its benefit, alongside other body parts, for the full life (*energeia*) of the animal; and finally, *3)* the search for moderation (*mesothés*) (*Nicomachean Ethics* II 1104a12 et seq.) and appropriate mixture (*eukrasía*) (*GA* II 6 744a28-31) of hot and cold to maintain the balance between desire (*orexis*) and intelligent action. It could be said that the biological treatises represent the first attempt to explain (*theoreia*) the nervous system as an organ (in the etymological sense, meaning instrument) for the (inhibitory) control of the organism's internal and external action; while this explanation is very elementary, it remains essential and original. We may also assert, using a metaphor from the arts (as Aristotle so frequently does in his treatises), that the Aristotelian understanding of the brain is inscribed in a "well-tempered" cardiocentrism.

Conflicts of interest

The author has no conflicts of interest to declare.

References

1. Sfendoni-Mentzou D, ed. Aristotle — contemporary perspectives on his thought. Boston: De Gruyter; 2018.
2. Berti E. Aristotele nel novecento. Bari (IT): Laterza; 1992.
3. Berti E. The contemporary relevance of Aristotle's thought. Iris. 2011;III: 23-35.
4. Calvo T. Aristóteles y el aristotelismo. Madrid: Akal; 2008.
5. Aubenque P. El problema del ser en Aristóteles. Madrid: Taurus; 1987.
6. Oñate y Zubía T. El criticismo aristotélico en el siglo XX: hacia un cambio de paradigma. Logos. Anales del Seminario de Metafísica. 1998; 1: 251-69.
7. Oñate y Zubía T. Para leer la Metafísica de Aristóteles en el siglo XXI. Madrid: Dykinson; 2001.
8. Marcos A. Introducción. In: Aristóteles. Obra biológica: de partibus animalium: de motu animalium: de incessu animalium. Bartolomé R, trans. Oviedo (ES): KRK Ediciones; 2018. p. 12-84.
9. Manzoni T. Aristotele e il cervello. Le teorie del più grande biologo dell'antichità nella storia del pensiero scientifico. Rome: Carocci; 2007.
10. Vegetti M. Biologia. In: Berti E, ed. Guida ad Aristotele. Bari (IT): Laterza; 1997.
11. Gotthelf A. Teleology, first principles, and scientific method in Aristotle's biology. Oxford: Oxford University Press; 2015.
12. Düring I. Aristóteles. Mexico: UNAM; 1990.
13. Marcos A. Aristóteles y otros animales. Barcelona: PPU; 1996.