Nota HISTÓRICA

Aristoteles and the anatomy of the nervous system

Aristoteles e a anatomia do sistema nervoso

Eliasz Engelhardt[1][https://orcid.org/0000-0003-4168-1992]

ABSTRACT

Aristoteles was probably the first anatomist in the modern sense of this term. He wrote on human anatomy relying on the external aspects, and the lacking data on internal structures were generalized through the study of lower animals. The different body regions were described according to a precise topography, and his contribution to the development of anatomy was extensive, as he correctly described many organs and introduced new terms to indicate anatomical structures. Regarding the nervous system, he identified the brain and the two hemispheres, the cerebellum, and the spinal cord. The brain coverings, the meninges, were identified, a tougher external, and a delicate internal, and the related blood vessels. He described the bony casing, the skull and part of its bones and sutures, as well as the vertebral column formed by distinct holed vertebrae. The sensory organs were also defined, but he overlooked the presence of nerves, confusing such structures with vessels, tendons, ducts, among other similar structures. Additionally, he explained the functions of the brain, to which he attributed an important role, despite his cardiocentric standpoint. More than twenty and three centuries have elapsed since Aristoteles began his biological investigation, and his work was and continues to be admired, despite the inaccuracies that were pointed out by later authors. Evidently, knowledge on anatomy of the nervous system before Aristoteles was very scant, thus, it must be recognized that the pioneer anatomical studies he performed may be seen as fundamental, leaving a solid ground for future research on anatomy.

Keywords: Aristoteles, anatomy, nervous system, brain, cerebellum, sensory organs

RESUMO

Aristóteles foi provavelmente o primeiro anatomista no sentido moderno deste termo. Escreveu sobre anatomia humana baseado nos aspectos externos, e os dados em falta sobre as estruturas internas eram generalizados através do estudo de animais inferiores. As diversas regiões do corpo foram descritas de acordo a uma topografia precisa e sua contribuição para o desenvolvimento da anatomia foi extensa, considerando que ele descreveu corretamente muitos órgãos e introduziu novos termos para indicar estruturas anatômicas. Considerando o sistema nervoso, identificou o cérebro e os dois hemisférios, o cerebelo e a medula. As coberturas cerebrais, as meninges, foram identificadas, uma externa resistente, e uma delicada interna, e os vasos sanguíneos relacionados. Descreveu o invólucro ósseo, o crânio e parte de seus ossos e suturas, assim como a coluna vertebral formada por vértebras perfuradas distintas. Os órgãos sensoriais também foram descritos, mas a presença de nervos foi ignorada, confundindo tais estruturas com vasos, tendões, dutos, entre outras estruturas similares. Adicionalmente, descreveu funções do cérebro, ao qual atribuiu um papel importante, apesar do seu ponto de vista cardiocêntrico. Mais de vinte e três séculos decorreram desde que Aristóteles começou suas investigações biológicas, e sua obra foi e continua sendo admirada, apesar das imperfeições apontadas por autores que se seguiram. Evidentemente, o conhecimento da anatomia do sistema nervoso antes de Aristóteles era muito escasso, assim, deve ser reconhecido que os estudos anatômicos pioneiros que ele realizou podem ser vistos como fundamentais, deixando solo firme para pesquisas futuras sobre anatomia.

Palavras-chave: Aristóteles, anatomia, sistema nervoso, cérebro, cerebelo, órgãos sensoriais

[1]Instituto de Neurologia Deolindo Couto and Instituto de Psiquiatria, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil

Conflict of interests: There are no competing interests to declare.
Funding: None.
Corresponding author address: eliasz@centroin.net.br

INTRODUCTION

One of the more distinguished sage ever, Aristoteles (384–322 BCE) (Figure 1), was born in the Macedonian region of Greece, in the small city of Stagira. He became philosopher and biologist, researcher, and writer, and left a great body of work, possibly as many as 200 treatises, from which approximately 31 survive, many as fragments resulting from excerpts or citations of later authors. Aristotle's intellectual range was vast, covering most of the sciences and many of the arts. His extant writings span a wide range of disciplines, from logic, metaphysics, and philosophy of mind, through ethics, political theory, aesthetics and rhetoric, and into such primarily non-philosophical fields as empirical biology, where he excelled at detailed plant and animal observation and description.[1,2,3,4]

Figure 1. Aristoteles at his writing-desk. Miniature in the manuscript Vienna, Österreichische Nationalbibliothek [1457] [unknown medieval author] [23-02-2023] https://commons.wikimedia.org/wiki/File:Aristotle,_Vienna,_Cod._Phil._gr._64.jpg

He left Stagira for Athens (367 BCE), at about the age of 17 years, where he remained for 20 years. There he studied in Platon's Academy, remaining associated as pupil and colleague until the master's death (347 BCE) (Figure 2). He left for Assos in Mysia, Asia Minor (present-day Turkey), where he continued the scholar activity he had begun in the Academy. There, in the city of Mytilene, on the island of Lesbos, he carried out extensive scientific research, particularly in zoology and marine biology. This work was summarized in a book later known as "On History of Animals", to which Aristotle added two short treatises, "On Parts of Animals" and "On Generation of Animals".[1,2,3,4,5]

Figure 2. The School of Athens by Raphael [1509–1510], fresco at the Apostolic Palace, Vatican City. [23-02-2023] https://upload.wikimedia.org/wikipedia/commons/4/49/%22The_School_of_Athens%22_by_Raffaello_Sanzio_da_Urbino.jpg

He was invited, at this time, by king Philip of Macedonia, to be the tutor of his 13-year-old son, Alexander, later the Great. He maintained this position until Philip's death (336 BCE), and the rise of his son to the throne, when he left the tutorship, and returned to Athens (355 BCE), where he proceeded with teaching, scientific research, and writing, backed by Alexander, with whom he maintained a strong attachment.[1,2,3,4,5]

He had a remote and indirect role in the founding of the great Museum of Alexandria (ca 280 BCE), which included the Library, where systematic human neuroanatomy began. The museum was founded at the end of the 3rd century BCE by Ptolemy I Soter, the first Greek ruler of Egypt, one of Alexander's generals. It was a vast state-supported institute for research, where more than a hundred professors lived communally. The museum included lecture and study rooms, an astronomical observatory, a zoo, a botanical garden, dissecting and operating rooms. There, Herophilus and then Erasistratus, began the systematic study of the structure of the human body, particularly of the nervous system.[2,3,6,7,8,9]

After Alexander's death, Aristoteles, due to political reasons, left for Chalcis of the island of Euboea, in Greece, where he died at the age of 63 years.[3,5]

In the century immediately after his death, Aristotle's works seem to have fallen out of circulation, reappearing in the 1st century BCE, and began to be disseminated, and came to form the backbone of about seven centuries of philosophy. Thereafter, from the 6th through the 12th centuries, although many of Aristotle's writings were lost to the West, they received extensive consideration in the East (Byzantine and Arabic authors),

which proved influential in the reception of the Aristotelian views into the Latin West in the 12th century.[1,2,4,5]

Here, Aristoteles' account on the nervous system, and closely related structures, as expressed mostly in two of his books, "On History of Animals" *(Peri Zoon Istorias [Περί Ζώων Ιστορίας]*) (*De Historia Animalium*) and "On Parts of Animals" (*Perí Zóon Morion [Περί Ζώων Μοριων]*) (*De Partibus Animalium*), and less in other works, will be summarized in the form of excerpts, and next analysed, with a look on the structural and functional aspects.

SKULL AND VERTEBRAL COLUMN

"...That part of the head [*kephalis* (*κεφαλής*)] [*caput*], which is covered with hair, is called skull (cranium) [*κρανιον (kranion)*] [*calvaria*], its anterior part is called 'sinciput' [*βρεγμά*] [*bregma*]...the hinder part is the 'occiput' [*οπίσθιον ινίον (opisthion inion)*] [*occiput*]...and between the occiput and sinciput is the 'crown' (vertex) [*κορυφή (koryfi)*] [*vertex*] of the head....The brain is placed beneath the sinciput, and...the back of the head is empty and hollow... The skull consists entirely of thin bone, rounded in shape, and contained within a covering of skin...The head is not composed of four bones, but of six, two of these are placed above the ears, and are small compared with the rest [occipital, parietals, temporals, and part of the frontal].... From the head the jaw-bones descend...The skull has sutures...the sutures of the skull are adapted to each other....the male has three [sutures], meeting at the top of the head, like a triangle...the part immediately beneath the sinciput and between the eyes is called the forehead... above the brain is the thinnest and weakest bone of the head, which is termed 'bregma' or 'sinciput'....The part immediately beneath the cranium is called the face [*πρόσωπο (prósopo)*], only in mankind..." [10,11,12,13,15]

"...The spinal column is made up of 'vertebrae' [*σπόνδυλος (spóndylos)*], and extends from the head to the hips...All the vertebrae are perforated...the upper part of the head is a bone joined to the last vertebra, and is called the skull, the saw-like part is the suture...." [11,15]

BRAIN AND SPINAL CORD

"...The brain (encephalon) [*egkephalos (εγκέφαλος)*] [*cerebrum*] is placed in the forepart of the head...In proportion to his size, man has the largest of all animals...the brain is split [double natured, twofold] [*διφυής (difyís)*] [*bipartitum*], and the cerebellum [*parenkephalis (παρεγκεφαλις)*] [*cerebellum*] is located posteriorly, being different from the brain both to the touch and in appearance...The brain is without blood, nor does it contain any veins [vessels], and it is naturally cold to the touch..." [10,11,12,13,16] "...There are many who think that the brain [encephalon] itself consists of 'marrow' [*myelon (μυελον)*] [*medulla*], and...the 'spinal marrow' [*spinal cord] [ραχίτην... μυελον (rachitin... myelon)*] [*dorsi medulla*] is continuous with the brain...[regarding] the spinal marrow... it is necessary that this shall be continuous and extend without break through the whole backbone, inasmuch as this bone consists of separate vertebrae.....In reality the two [brain and spinal marrow] may be said to be utterly opposite to each other in character...For of all the parts of the body there is none so cold as the brain, whereas the [spinal] marrow is of a hot nature, as is plainly shown by its fat and unctuous character...".[16] "...This brain is not residual matter...but it has a character peculiar to itself...that the brain is a compound of earth and water is shown by what occurs when it is boiled. For, when so treated, it turns hard and solid, inasmuch as the water is evaporated by the heat, and leaves the earthy part behind...."[16] "...The coldness of the brain is also manifest enough. For in the first place, it is cold even to the touch, and, secondly, of all the fluid parts of the body it is the driest and the one that has the least blood, for in fact it has no blood at all in its proper substance...".[16]

MENINGES, VENTRICLES AND CSF

"...[The brain] is surrounded by two membranes [meninges] [*μήνιγξ (minínx)*], one tougher adjacent to the bone of the skull, the other finer, which encloses it [the brain]...This latter [inner membrane] is vascular...consists in great part of a network of extremely numerous and very minute vessels.....[formed from] branches extending from each part near the ear [internal 'jugular vein' and 'carotid artery'] to the brain, where they divide into many small branches upon the membrane which surrounds the brain.....The viscera are enclosed each in a membrane....the stoutest and strongest invest the heart [pericardium], and the brain [dura mater]... For these are the parts which require most protection, seeing that they are the main governing powers of life..." [11,16]"...There is a small cavity (hole, hollow) [*koílon (κοίλόν)*] [*cauum*] in the centre [of the brain]...around which there is a membrane filled with veins [vessels], which is similar to the skin-like 'venous membrane' ['venous meninges' *(μήνιγξ φλεβώδης) (míninx flebodis)*] [*membrana venosa*], which encloses [intimately] the brain..." [10,11,12,13,16] "... the eye is the purest part of the liquidity about the brain drained off through the passages which are visible running from them to the membrane round the brain [separated by the ducts (*meatus*)] (see below).[14,16]

SENSORY ORGANS

"...The senses...are mostly five in number: seeing, hearing, smelling, taste, touch.....Under the forehead are two eyebrows...Beneath these are the eyes [*οφθαλμός (ofthalmós)*], which by nature are two in number...The part of the head by which we hear...is the ear [*ούς (oús*)] (organ of hearing)...inside there is structure similar to a 'cochlea' (trumpet-shell) [*στρομβός (stromvós)] [cochleis*], and a 'vein' extends from the brain to each ear...The eyes also are connected with the brain, and each eye is placed upon a

vein...In the middle of the face is the nose [*ρϊς (ris*)], the passage for the breath... The smell (organ of smelling) also resides in this part, this is the sense of odour [*οσμή (osmí)*]...The tongue is the organ of taste [*γεύση (géfsí)*]... [and] other sensations, as harshness, heat, and cold..... There is only one sense, that of touch [*επαφή (epafí)*], which is common to all animals...no exact name can be given to the part in which this sense resides... The sense of touch resides in the simple parts, as in the flesh and in similar places...The senses and the organs of sense, the eyes, nose, and tongue are in the same position, and in the anterior part of the body [head], but the hearing, and its organ, and the ears, are at the side, and upon the same circumference as the eyes...The sense of touch is the most accurate of the human senses, and next to this the taste..."[18,19] "...Each sense is confined to a single 'order of sensibles' [*sensibilium generum*], and its organ must be such as to admit the action of that kind or order... That it [brain] has no continuity with the organs of sense is plain from simple inspection, and is still more clearly shown by the fact, that, when it is touched, no sensation is produced...the heart...was in anatomical connexion, through the blood-vessels, with all the sense organs... As to the position of the sense-organs, they have been arranged by nature in the...well-ordered manner..."[16] "...Three passages (ducts) [*meatus*] [*πόροι (póroi)*] proceed from the eye to the encephalon, the largest and the middle-sized to the cerebellum, and the smallest to the brain itself..."[11]

FUNCTION OF THE BRAIN

"...The brain cannot be the cause of any of the sensations, seeing that it is itself as utterly without feeling as any one of the excretions..."[16] "...The purpose of its [brain] presence...is no less than the preservation of the whole body...The brain, then, tempers the heat and seething of the heart, combining in it the properties of earth and water [(plus earth and fire) classical elements, according to Empedocles] [...therefore causing it to be cold, for both earth and water are compounds of cold matter, the former with solid, the latter with fluid matter...].... In order, however, that it may not itself be absolutely without heat, but may have a moderate amount, branches run from both blood vessels, that is to say from the 'large vein' [*μεγάλης φλεβός (megális flevós)*] [*vena cauua*] [cava vein] and from what is called the 'aorta' [*αορτής (aortís)*] [aorta], and end in the 'membrane' [meninx – pia mater] which surrounds the brain..."[11,16] "...Nature has contrived the brain as a counterpoise to the region of the heart with its contained heat, and has given it to animals to moderate the latter..."[16] "...sleep occurs...when insensitive evaporation under the influence of heat, rises through the veins to the head.....The thinness and slender structure of the veins about the brain contribute to refrigeration [related to sleeping-wakening mechanisms]..."[17]

COMMENTS

Aristoteles, besides being viewed as one of the most influential theoretical philosophers and logicians, was also recognized as the founder of the science of Biology. He was probably the first anatomist in the modern sense of this term. He wrote on human anatomy, but he certainly did not perform dissections of human cadavers, relying only on the external aspects, and admitted that the lacking data on human anatomy, especially that of internal structures, were generalized from the knowledge obtained via the study of lower animals, through observation and dissection. He justified this procedure on the ground that there is a correspondence between human structures and its homologous of lower order vertebrates ("...while man is the animal with which we are all of us the most familiar...his internal organs are the least understood, and hence we must have recourse to examine the inner parts of other animals whose nature in any way resembles that of man..." .[5,15,18,19,24,25,27]

Aristoteles studied about 550 kinds of animals (mammals, birds, fish, reptiles, amphibians, molluscs, crustacea, insects, and shelled animals), and a number (around 49) of them were also investigated through dissection.[5,9,10,15,28] Thus, relatively few of this large number of different animals were dissected, and in general, the kind, and the time elapsed after the death were not mentioned. The latter item, if protracted, could lead to poor preservation of the corpses not treated by proper techniques, unknown at his epoch (e.g., use of fixatives), with putative variable rates of deterioration (decay) of the examined specimens, with resultant structural changes.[29,30,31,32,33,34] In spite of the possible hindrances, he revealed and named a large number of novel anatomical formations. However, the many inaccuracies were later criticized by many authors, who apparently did not recognize properly his pioneerism.

He described the bony structures that contains the central nervous system, beginning with the skull, and identifying some of its parts, as the presence of six bones (occipital, parietals, temporals, and part of the frontal).... [joined by] three sutures [in man] adapted to each other. Next, he described the vertebral column, formed by perforated vertebrae forming the spinal canal, extending from the head to the hip, the upper part being joined to the skull.[15,19]

Following, he gave an account on the encephalon, including its intracranial localization, its large size relative to the body, the bipartite form of the brain (hemispheres), and the presence of the cerebellum. He gave some characteristics of the brain, as its lack of blood, and of vessels, and recognized that the cerebellum is different in relation to the brain. Additionally, he acknowledged that the brain (encephalon), presented peculiar characteristics, and described that it consisted of 'marrow', observing that this kind of marrow being different from that found inside

bones ('bone marrow'). He also observed that the brain was formed by a solid part (earth) and a liquid one (water). He also noted that the marrow of the brain is in continuance with that of the spine (vertebral column) ('spinal marrow'), identifying thus the 'spinal cord'....underlining that this segment was continuous and extended without break through the whole vertebral column [not in humans], which consisted of separate vertebrae...He affirmed that brain marrow and the spinal marrow should be of 'opposite' [character], for the brain [marrow] is cold, whereas the [spinal] marrow is of a hot nature.[8,15,19] He described the coverings of the brain, comprising two membranes (meninges), an external tough one ('dura mater'), adjacent to the bone of the skull, and an inner delicate, enclosing directly the brain ('pia-arachnoid'). The inner membrane is related to vessels [in the not described subarachnoid space], and a network of small vessels ['pia mater'], derived from branches of the internal 'jugular vein' and 'carotid artery'. He also underlined, that the hardy membrane that invest the brain ('dura mater') is there as this structure [brain], as well as the heart (and its pericardium), require most protection, considering their importance ("...main governing powers of life..."). Regarding the presence of cavities, he found a small hole in the centre of the brain, which can probably be identified with an incipient description of the 'ventricular system'. Around the cavity, a membrane containing 'veins' (vessels) is described, which might be representing an initial description of the 'choroid plexus'. He mentioned a "...liquidity about the brain drained off through the passages which are visible running from them to the membrane round the brain..." [CSF?].[15,18,19] (Figure 3)

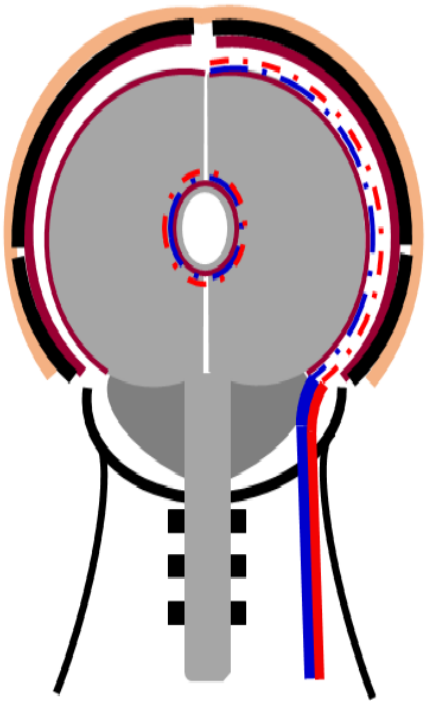

Figure 3. Drawing of the head, with scalp (orange), cranium [bones (black) and sutures (white)], meninges [inner and outer] (brown), vessels [meningeal and cervical (red and blue)], (represented only at the right side) nervous system (grey) [brain, cerebellum, spinal cord], cavity [ventricle] (white), and choroid plexus (brown, red, blue), according to Aristoteles' description in "On History of Animals" and "On Parts of Animals" (see text). [design by EE]

The functions of the brain were also considered, underlining that it was bloodless, lacked vessels, and was characteristically cold. He remarked that its cold nature represented a fundamental functional characteristic. It might give the impression, at first sight, that he regarded the brain as having a secondary function, the heart being the primary organ related to the senses (sensations), and faculties (superior nervous functions), and that the brain could not be the cause of any of the sensations, seeing that it was itself without feeling. However, Aristoteles perceived the brain as a device that tempers the heat and seething of the heart, functioning as a counterbalance to the heart with its contained heat, existing to moderate the heart. Moreover, the cooling property of the brain was also related to the sleeping-wakening mechanisms. Finally, he emphasized the importance of the brain, stating that its purpose is no less than the preservation of the whole body, and reinforced this view, mentioning its state of important ('governing') organ, considering its enclosing by a protective tough membrane, in the same manner as the heart.[15,19]

The senses, in number of five, are mentioned, comprising - sight, hearing, smell, gustation, and touch. They are related to organs of sense, respectively - eyes, ear, nose, tongue, and for the touch, no exact name of the part in which it resides was attributed. Then, he ponders that each sense was confined to a single 'order of sensible' ['sensory stimulus'], and its organ ['sensory receptor'] must be such as to admit the action of that kind of sensible. He denied that the brain has continuity with the organs of sense, instead, they are connected to the heart through the blood-vessels. However, he described connections of the eyes and the ears with the brain through a 'vein' [vessel? sinewy? nerve?), and also 'passages' (*meatus, póroi*) (ducts? nerves?] for the eyes, to the brain and cerebellum.[15,19]

It should be stressed that Aristoteles overlooked the existence of 'nerves' (as presently understood), and their relationship to the brain and spinal cord, using the term 'neura' [*νεύρα (névra)*] generically, for apparently comparable ill-identified structures (veins, ligaments, tendons, tubes, etc.).[5,15,19,21]

Aristoteles was a cardiocentrist, giving to the heart the location of the faculties of the soul, and the main ruling function of the body [as specified: "...it is in the front and centre of the body that the heart is situated, in which we say is the principle of life and the source of all motion and sensation...",[16] then "...the passages of all the sense-organs...run to the heart...",[22] and "...the motions of pain and pleasure, and generally of all sensation, plainly have their source in the heart, and find in it their ultimate termination..."], and apparently, giving to the brain a subordinate function.[16]

He was ridiculed by Galenus for having made the brain no more than a 'cooling device'.[23] However, in reality, he assigned to the brain a function scarcely less important than that he attached to the heart, considering that he represented the latter so directly dependent upon the

brain to accomplish its functions, heart and brain coming to be interdependent organs. Such view was reinforced by Aristoteles, when he stated: "...they [heart and brain] are the main governing powers of life..."[15,20,21,26]

CONCLUSION

More than twenty and three centuries have elapsed since Aristoteles began his biological investigation, and his work was and continues to be admired, despite the many inaccuracies that were pointed out by later authors, who analysed and criticized his descriptions.[5,10]

However, information on anatomy of the nervous system before Aristoteles was very scant, as his predecessors, mainly Alcmaeon of Croton, and Hippocrates of Kos (and the Corpus), left fragmentary and poor contribution to this subject.[18,35,36] Thus, it must be recognized that the pioneer anatomical studies performed by Aristoteles represent the foundations, and the firm ground he laid down for future research on anatomy, including of the nervous system, as well as on other disciplines in which he exceled.

REFERENCES

1. Amadio AH, Kenny AJP. Aristotle. Encyclopedia Britannica (2023, January 3). . [14-02-2023] https://www.britannica.com/biography/Aristotle
2. Diogenes Laertius. The lives and opinions of eminent philosophers. Yonge CD transl. London: H. G. Bohn, 1853. [23-02-2023]https://ia904506.us.archive.org/9/items/livesandopinions00dioguoft/livesandopinions00dioguoft.pdf
3. Grant A. Aristoteles. Borntraeger, 1878. [21-02-2023] https://books.googleusercontent.com/books/content?req=AKW5QacCOlt074HXKnwb36IRYFcYb_U2AXIkjnMTa7p9LPY10dqVbqwVFAVVPY3YUjMF6PCO1LVWjz_N7bakZnNIj_QIesBlydtFdE1_1UohKAqm9UN8EeVlhEcldRDavZQ205aLo0RqmEdGFFGhskl61QbVkHQOz6TMWRbNSrWHO5TNz7honQ9mFYDkvljxnucaxVkkrOnwIVEQla1vK0ATdkzKIuQNs8FuQ68HZmHEY3o8CaUaL26UFzDXH1Mjn0jUVNydeG1GUgRFr249fx9Yzahp5777Q
4. Shields C. Aristotle. The Stanford Encyclopedia of Philosophy, 2022. Edward N. Zalta ed. [14-02-2023] https://plato.stanford.edu/cgi-bin/encyclopedia/archinfo.cgi?entry=aristotle
5. Lewes GH. Aristotle: A chapter from the history of science, including analyses of Aristotle's scientific writings. London: Smith, Elder and Company, 1864. [21-02-2023] https://books.googleusercontent.com/books/content?req=AKW5QafTufwEaaN4oTAkZh147zBbpMKAmdBeqDom-cidYK6L3hUJ-yHBv-vFuRWmtXSel2iLoFQgq1Vk4xxRBqln4qY6_lyrQJ1oLKe6jDW2lIzvxCg0TlcgPaL8yFKGFaWDP0gJNCQlqx1r-DM1JiohbQov6fb2I-3lBTF7v74KOxDiVQvbjCyL-MA93glRsrj62kXtyv2R7WMXd9px6-LgZSDScGJrcCT-umM_9VNqQZTcpFLyFFA0nSNHoDFJrET5ZDfIXp1YkOpsYytFBMDL5IqJmbIoUg
6. Farrington B. Greek Science, vol. II. Theophrastus to Galen. Harmondsworth:Penguin Books, 1949. [17-02-2023] https://ia801709.us.archive.org/16/items/dli.ernet.1030/1030-Greek%20Science-ii%20%281949%29.pdf
7. Gross CG. Aristotle on the Brain. The Neuroscientist 1995;1:245-250. https://doi.org/10.1177/107385849500100408
8. Longrigg J. Anatomy in Alexandria in the third century B.C. British Journal for the History of Science 1988;21(71 Pt 4):455-488. https://doi.org/10.1017/s000708740002536x
9. Lloyd GER. Early Greek Science: Thales to Aristotle. New York: Norton & Company, 1970, p 116. [22-02-2023] https://archive.org/details/earlygreekscienc00gerl/page/116/mode/2up
10. Clarke E, Stannard J. Aristotle on the Anatomy of the Brain. Journal of the History of Medicine and Allied Sciences 1963;18(2):130-148. https://doi.org/10.1093/jhmas/XVIII.2.130
11. Aristoteles. History of Animals. In: The Complete Works of Aristotle. Barnes J edit. Oxford transl. Book I-III-IV. Princeton: Princeton University Press, 1991, 486a-497b, 509a-523a, 523a-538b [02-03-2023] https://cdchester.co.uk/wp-content/uploads/2018/05/Jonathan-Barnes-editor-The-Complete-Works-of-Aristotle_-The-Revised-Oxford-Translation-Vol.-1.-1-Princeton-University-Press-1991.pdf
12. Aristoteles. De animalibus historiae libri X. Tomus I.Schneider JG. Lipsiae: Hahn, 1811. [12-02-2023] https://download.digitale-sammlungen.de/pdf/16762272478888bsb10235015.pdf
13. Aristoteles. De animalibus historiae libri X. Tomus II.Schneider JG. Lipsiae: Hahn, 1811. [12-02-2023] https://download.digitale-sammlungen.de/pdf/16762244838888bsb10235016.pdf
14. Aristoteles. De Generatione Animalium. In: The Works of Aristoteles. Vol V. Book II. Platt A transl. Oxford: at the Clarendon Press, 1910 [1912], 731b-749b. [06-06-2022] https://archive.org/details/worksofaristotle12arisuoft
15. Lones TE. Aristotle's researches in natural Science. London, West, Newman & Co, 1912. [23-02-2023] https://ia600206.us.archive.org/19/items/aristotlesresear00lone/aristotlesresear00lone.pdf
16. Aristoteles. De Partibus Animalium. In: The Works of Aristoteles. Vol V. Book II-III. Ogle W transl. Oxford: at the Clarendon Press, 1911 [1912], 646a-661a, 661b-676a. [06-06-2022] https://archive.org/details/worksofaristotle12arisuoft
17. Aristoteles. On Sleep.In: The Complete Works of Aristotle. Barnes J edit. Oxford transl. Beare JJ transl. Princeton: Princeton University Press, 1991, 453b-458a. [02-03-2023] https://cdchester.co.uk/wp-content/uploads/2018/05/Jonathan-Barnes-editor-The-Complete-Works-of-Aristotle_-The-Revised-Oxford-Translation-Vol.-1.-1-Princeton-University-Press-1991.pdf
18. Crivellato E, Ribatti D. A portrait of Aristotle as an anatomist: Historical article. Clin Anat 2007;20:447-485. https://doi.org/10.1002/ca.20432
19. Geoffroy J. L'Anatomie et la Physiologie D'Aristote. Paris: Mulot et Vve F. Henry, 1878. [21-02-2023] https://ia600602.us.archive.org/27/items/39002086310597.med.yale.edu/39002086310597.med.yale.edu.pdf

20. Ogle W. Note 5. In: Aristoteles. De Partibus Animalium. In: The Works of Aristoteles. Vol V. Book II. Ogle W transl. Oxford: at the Clarendon Press, 1911 [1912], 653b [06-06-2022] https://archive.org/details/worksofaristotle12arisuoft
21. Landmann F. Die physiologischen Anschauungen des Aristoteles. Greifswald: Julius Abel, 1890. [21-02-2023] https://books.googleusercontent.com/books/content?req=AKW5QadplkcWxgb41odY900wFKuE5lQkcW2rEHcedUGuoluiI3SKRElL8RcxPG92i6X0MEI0LwKj8CS5RElbUYqDpfxI66qzktwdZdzdblelggBi1DUQ8q2eBDJdAZzW9-RcX56OT5w2Go-fCKRPaR5ks3EEZFUR0N5uZAGr3OBsKpb4KFUM_TLOLjCMLSGUHCtdxFX5QR0XmIbw7WqfbWFRM8lC7EzkMiDsOWDVxzbUewHpCOfhA3LpZj5lvaIvED_SgKoElzGx-92i1EQkDCchgkV8GjFMqvWLZg66T4w0ZKaKqM33Hk
22. Aristoteles. De Generatione Animalium. In: The Works of Aristoteles. Vol V. Book V. Platt A transl. Oxford: at the Clarendon Press, 1910 [1912], 781a. [06-06-2022] https://archive.org/details/worksofaristotle12arisuoft
23. Finger S. Minds Behind the Brain. Oxford: Oxford University Press, 2000.
24. Clarke E. Aristotelian Concepts of the Form and Function of the Brain. Bulletin of the History of Medicine 1963;37(1):1-14. http://www.jstor.org/stable/44446893
25. Rauber A. Lehrbuch der Anatomie des Menschen. 5te Aufl. 1. Band. Leipzig: A. Georgi, 1897. [21-02-2023] https://books.googleusercontent.com/books/content?req=AKW5QaeiG2uKAcRLchRnkbmuPf32COKRjaWkrXMURlCQseYKCmklsLKAFVe6PSnlAMvugYIeJ8cwR3prfnsLeyxNehG60ha1nO3WGBWjZAdjMicAkRCFGzFl9mWA2zP4X3k6UrUMmwe-MGg9fk2Vpg1otRwVlNvrGNZapEYO4VE-V2tmE5I_9FAAKghXXLTi5JuPV8jaO2uwoOFZd4tPDTtwVa3uFKZvaX2bfY1L4eWZ3wJVhp0ORqhv0YOEpuBeMzzqfZ8YSr40EzlsQM_i6Q_SPku0EE6KWfpZWxuElA8181ajWkRnNTY
26. Crivellato E, Ribatti D. Soul, mind, brain: Greek philosophy and the birth of neuroscience. Brain Research Bulletin 2007;71(4):327-336. doi: 10.1016/j.brainresbull.2006.09.020
27. Rábano A. Aristotle's "mistake": the structure and function of the brain in the treatises on biology. Neurosciences and History 2018; 6(4):138-143.
28. Meyer MF. Aristotelian Biology. A Synopsis. Peitho. Examina Antiqua 2020;11(1):83-120. https://doi.org/10.14746/pea.2020.1.4
29. Carlos AF, Poloni TE, Medici V, Chikhladze M, Guaita A, Ceroni M. From brain collections to modern brain banks: A historical perspective. Alzheimers Dement (N Y). 2019 Feb 5;5:52-60. doi: 10.1016/j.trci.2018.12.002.
30. Clark MA, Worrell MB, Pless JE. Postmortem Changes in Soft Tissues. In: Haglund WD and Sorg MH eds. Forensic Taphonomy: The Postmortem Fate of Human Remains. Boca Raton: CRC Press LLC, 1997, pp 156-164.
31. Javan GT, Finley SJ, Tuomisto S, Hall A, Benbow ME, Mills D. An interdisciplinary review of the thanatomicrobiome in human decomposition. Forensic Science, Medicine, and Pathology 2019;15(1):75-83. https://doi.org/10.1007/s12024-018-0061-0
32. Mann G. Physiological histology. Method and Theory. Oxford: Clarendon Press, 1902. [16-10-2022] https://ia800201.us.archive.org/35/items/physiologicalhi00manngoog/physiologicalhi00manngoog.pdf
33. Shrestha R, Kanchan T, Krishan K. Methods of Estimation of Time Since Death. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing, 2022. [25-02-2023] https://www.ncbi.nlm.nih.gov/books/NBK549867/
34. Shedge R, Krishan K, Warrier V, Kanchan T. Postmortem Changes. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022. [25-02-2023] https://www.ncbi.nlm.nih.gov/books/NBK539741/?report=printable
35. Blits KC. Aristotle: Form, function, and comparative anatomy. The Anatomical Record (New Anat) 1999;257:58-63. https://doi.org/10.1002/(SICI)1097-0185(19990415)257:2<58::AID-AR6>3.0.CO;2-I
36. Lauth T. Histoire de l'Anatomie. Thome 1. Strasbourg: Levrault, 1815.[26-12-2022] https://download.digitale-sammlungen.de/pdf/16720974378888bsb10330990.pdf