

Hippocrates and the anatomy of the nervous system

Hipócrates e a anatomia do sistema nervoso

Elias Engelhardt¹ [<https://orcid.org/0000-0003-4168-1992>]

ABSTRACT

Hippocrates was one of the greatest physicians ever, and merited unquestionably, the title of 'Father of Medicine'. He, together with other authors, formed an assemble of texts known as 'Hippocratic Collection' (or 'Hippocratic Corpus'). There, the ample and brilliant medical experience remained documented, and left as a legacy. Even after almost two and a half millennia, these medical writings continue to be admired, and regarded as a lasting fount of inspiration. However, regarding anatomy, including that of the nervous system, and related structures, the texts are poor. About the nervous system, he mentioned the brain and its two hemispheres, the spinal cord, and the sensory organs. The related structures are also cited, comprising the meninges, the cerebrospinal fluid, and the blood vessels, as well as the skull, and the vertebral column. The functions of the brain were partly explained, and he ascribed to the brain the main ruling function of the body, a mark of encephalocentric position. Thus, counterposed to his ample medical accomplishments was his poor anatomical contribution. However, it must be recognized that the incipient contribution on anatomy that was legated, represented an important starting point for upcoming scholars and further studies on the subject.

Keywords: Hippocrates, anatomy, nervous system, brain, sensory organs

RESUMO

Hipócrates foi um dos maiores médicos de todos os tempos, merecendo, de modo inquestionável, o título de 'Pai da Medicina'. Ele, juntamente com outros autores, constituiu um conjunto de textos conhecido como 'Coleção Hipocrática' (ou 'Corpo Hipocrático'). Lá, a ampla e brilhante experiência médica permaneceu documentada e deixada como um legado. Mesmo após quase dois e meio milênios, estes escritos médicos continuam a ser admirados e vistos como uma fonte duradoura de inspiração. Entretanto, considerando a anatomia, os textos são pobres, inclusive os sobre o sistema nervoso e estruturas relacionadas. Quanto ao sistema nervosa, ele mencionou o cérebro e seus dois hemisférios, a medula, e os órgãos sensoriais. As estruturas relacionadas também são mencionadas, compreendendo as meninges, o líquido cefalorraquidiano, e os vasos sanguíneos, assim como o crânio e a coluna vertebral. As funções cerebrais foram explicadas em parte e ele atribuiu ao cérebro a principal função de controle do corpo, uma marca de sua posição encefalocêntrica. Assim, contraposto às suas amplas realizações médicas foi sua contribuição anatômica pobre. Entretanto, deve ser reconhecido que a contribuição incipiente sobre anatomia que foi legada representou um ponto de partida importante para os estudiosos porvindouros e os estudos que prosseguiram sobre o assunto.

Palavras-chave: Hipócrates, anatomia, sistema nervoso, cérebro, órgãos sensoriais

¹Instituto 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

The Greek physician of the Classical Period, considered one of the most outstanding figures in the history of Medicine, was Hippocrates (ca 460 - ca 370 BCE) (also known as Hippocrates II), born on the Greek island of Kos. His origins are traced to Asclepios, so he pertained to the Asclepiades family. He was taught medicine by his father and grandfather (Hippocrates I), and probably was trained at the Asklepeion of Kos. His further instruction comprised literature and philosophy, provided by two outstanding personalities, Gorgias of Leontini, philosopher and rhetorician, and Democritus of Abdera, philosopher, and atomist. He left his home island for a pilgrimage at his 20's, as the custom of the time, practicing medicine in the Aegean regions, and probably in north Africa, including Egypt, according to his writings. He died, most likely in Larissa, in Thessaly, his age being variously stated as 85, 90, 104 and 109 years.^{1,2,3,4,5,6} (Figure 1)



Figure 1. Hippocrates. Line engraving, 1584. [13-04-2023] https://commons.wikimedia.org/wiki/File:Hippocrates_Line_engraving,_1584_Wellcome_V0002784.jpg [This file is licensed under the Creative Commons Attribution 4.0 International license.]

There is meagre register of the poorly known early Greek medicine, which can be referred as pre-Hippocratic phase. It is possible to see this time, as divided in a very ancient one, comprising the Minoan and Mycenaean civilisations (2,000 - 1,100 years BCE), a period of stagnation (1,125-800 years BCE), followed by the strict pre-Hippocratic or Homeric era (800-700 years BCE), then a post-Homeric phase, and finally the Hippocratic era.^{7,8,9}

The Minoan and Mycenaean civilisations

The Minoan and Mycenaean civilisations can be seen as eras probably precursors of the pre-Hippocratic phase. The medicine of the Minoan civilisation (2,000-1,375 years BCE), flourished in the island of Crete. There were links with Egyptian and Cretan medicine, some therapies being used in an interchangeable manner. Next, came the Mycenaean civilisation (1,400-1,100 years BCE), developed in the mainland of the present days Greece, and Aegean neighbouring regions, which probably was stimulated by contact with Crete. The medical practice was run by physicians (or healers), and priest-healers, possibly combining religion with practical experience. There was probably medical interaction with Egypt, including the possible access to medical papyri (Ebers, Edwin Smith, and others), which could have circulated for a time before their entombment.^{7,8,10,11}

The extant medical knowledge from the Aegean civilisations can be seen as restricted, considering that their influence probably relied on oral interactions, as written text were not found, and possibly on Egyptian papyri, which may have been accessible to the Greeks for a time. Regarding the legacy on anatomy, the situation appears even worse.^{8,10,11}

The strict pre-Hippocratic, or Homeric era

After the Aegean civilisations came a stagnation period of Greek culture and medicine (1,125-800 years BCE), lasting more than three centuries. This phase was followed by the pre-Hippocratic or Homeric era of Archaic Greece (800-700 years BCE), when the renovation of the Greek literature by Homer and Hesiod occurred. The Homeric era also marked the beginning of Greek medical literature, and the Homero's epics, mainly the Iliad, revealed that medical practice was based on religious concepts. The legacy of these writings may be seen as very poor, as he mentioned, mainly in the Iliad combats, some restricted medical and anatomical aspects. So, regarding anatomy, there are only the naming of structures, with a nomenclature that was probably popular, as he mentioned only that "the brain was inside the cranium", and "the spinal cord inside the spinal column," and always invoking the gods.^{5,9}

The post-Homeric phase, and the medical schools

The three centuries between the Homeric writings and the Hippocratic era showed a progressive change in the medical activity. Although part of the population continued to view medicine as having a religious base, a rise towards hypotheses built on natural science appeared. Such process was initiated by a number of philosophers-physicians, who emphasized philosophy. The training of apprentices occurred mainly in certain recognised centres of medical excellence, often referred to as 'medical schools'. Probably the oldest of these was localized in Croton (Italy)

(founded by Pythagoras) (6th century BCE), followed by Cyrene (North Africa [Lybia]), Knidos (Asia Minor [Turkey]) (5th century BCE), Kos (that became famous as the home of Hippocrates) (5th century BCE). These philosophers-physicians were not a homogeneous group and their hypotheses differed quite widely, and among them can be cited Pythagoras, Alcmaeon, Parmenides of Elea, Empedocles, Philistion, Anaxagoras, Heraclitus of Ephesus, Leucippus, Diogenes of Apollonia, Democritus of Abdera. Their medical-related works (except for fragments from Alcmaeon) have been lost, remaining only quotations from later authors like Hippocrates, Aristoteles, Platon, Diogenes Laërtius, Celsus, Galenus, and Aëtius.^{5,8,9,12,13,14,15,16}

The Hippocratic era

As seen, there is no significant post-Homeric literature on Greek medicine (and anatomy) prior to Hippocrates. Thus, the writings of Hippocrates and of the Hippocratic Corpus, radiating from Kos and Knidos, have come to represent the birth of empirical medicine, separated from philosophy, as we know it today. The Hippocratic Corpus was built on what the physicians of Kos and Knidos, at the end of the 5th century BCE, saw as most acceptable, incorporating a secular heritage of mostly orally transmitted knowledge of philosophers exploring the dominion of natural medical science, devoid of magic and religion.^{5,12,13,14}

Similarly, the knowledge on anatomy at the time of Hippocrates, and the Corpus, who gave precedence to medical practice, was restricted, in view of the lacking heritage, and apparent reduced interest on the issue. Anyway, historically speaking, the study of anatomy in the Western world was first developed in structured terms in ancient Greece, and Hippocrates, and the Corpus, played a basic role.^{8,10,11} (Figure 2)

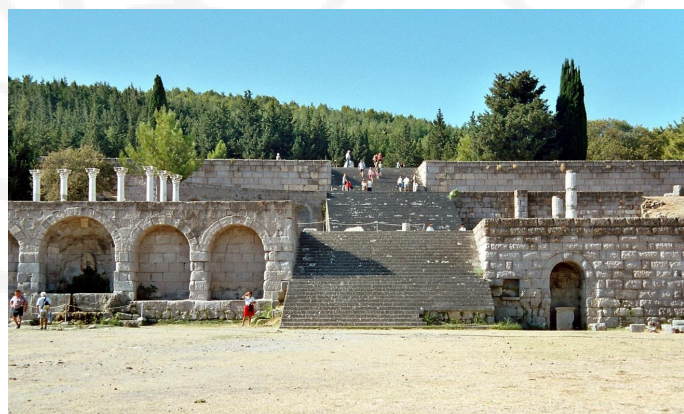


Figure 2. Kos Asklepeion [13-04-2023] [photographer: Heiko Gorski - Date: May 2003] https://commons.wikimedia.org/wiki/File:Kos_Asklepeion.jpg [File licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license.] [Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version]

Hippocrates and his disciples produced a large number of medical texts, but most of this writings were lost. The surviving ones were published under the label of 'Hippocratic Corpus', or 'Hippocratic Collection'. The more

significant writings, that form the core of the Collection, were produced between 420-350 years BCE. Most of these texts were not written by Hippocrates himself, considering their heterogeneity, including the variety of subjects, peculiarities of styles, presence of anachronisms, and divergent opinions. Thus, part only can be accepted as genuine, while many of the remaining writings include texts that antedate, contemporaneous, and posterior to his time, the latter produced by his sons Thessalus and Dracon, his son-in-law Polybus, as well as other students and followers. Such Collection form an assembly of a variable number of treatises (up to 87 according to authors), a heterogeneous collection of medical manuals, speeches, notes, fragments, and books, which can be seen as genuine and non-genuine.^{1,5,6,17,18,19}

THE ANATOMY OF THE NERVOUS SYSTEM- EXCERPTS

Here, the few mentions on the nervous system, and closely related structures, as expressed in the Hippocrates' works, genuine or not, will be summarized in the form of excerpts, and analysed in order to extract the reported structural and functional aspects.

SKULL and VERTEBRAL COLUMN

Some components of the structure of the skull are described.

- "...Men's heads (*κεφαλῖς* [*kefalís*]) are not alike, nor are the sutures (*ραφαί* [*rafai*]) of the head disposed the same way in all...The bones (*οστέον* [*osteon*]) are double [tables] along the middle of the head, and the hardest and most dense part of it is disposed both uppermost where the smooth surface of the skull [cranium] comes under the scalp [external table], and lowest [internal table] where the smooth surface below is towards the [underlying] membrane (*μήνινγι* [*miningi*]) [meninx]. Passing from the uppermost and lowest layers, the hardest and most dense parts, the bone is softer, less dense, and more cavernous right into the diploe (*διπλόην* [*diplóin*]). The diploe is very cavernous and soft and particularly porous... There are also rather thin hollow vessels full of blood contained within the bone." [On Injuries of the Head – I]^{1, 20,21}
- "...The head [skull] has sutures, sometimes three, sometimes four. In those with four sutures, there is one suture in the region of the ears, on each side, another at the front, and other behind... The skull with three sutures has them by the ears and at the front." [On the Places in Man – VI]^{20,21}
- "...the bone is thinnest and weakest at the bregma...and there is most underlying brain at this part of the head..." [On Injuries of the Head – II]^{22,23}
- "...[there are] eight [bones] at the cranium, including those of the orbit ..." [On the Nature of Bones – V]^{22,23}

The account on the vertebral column is as follows.

- "One should first get a knowledge of the structure of the spine (*ράχιος* [*rachios*])...Now on the side turned towards the body cavity, the vertebrae (*σπόνδυλοι* [*spóndyloi*]) are fitted evenly to one another and bound together by a mucous and ligamentous connection ([or]...pulpy and nervous band of connexion...) [intervertebral disk] extending from the cartilages right to the spinal marrow [spinal cord]...Posteriorly, the vertebrae are connected with one another by hinge-like joints...From the sacrum to the great vertebra [L5], near which the origin of the legs is inserted, all this is curved outwards... From this to the great vertebra [C7] over the shoulder-blades..." [On Articulations - XLV]^{24,25}
- "...The spine, after the sacrum until this vertebra, is curved to lodge there the bladder, the genital parts, and part of the rectum. Then the spine bends till near where the diaphragm is fixed ...Next the spine curves until the large vertebra, localized above the shoulder blade [C7]..." [On the Nature of Bones - II]^{22,23}
- "The vertebrae of the dorsum...all are articulated by synarthrosis by means of thick cartilages and ligaments that penetrate backwards until the spinal cord (*τον νωτιαίον* [*ton notiaion*])..." [On the Nature of Bones - III]^{22,23}
- "...seven vertebrae at the neck, the first articulates to the skull...a similar number as the ribs, meaning twelve...five lumbar, which ends the dorsal spine..." [On the Nature of Bones - V]^{22,23}

BRAIN and SPINAL CORD

The brain is described succinctly.

- "...The brain [encephalon] (*εγκέφαλος* [*enkefalós*]) of man, like that of all animals, is double (paired) (*διπλός* [*diplos*]), being parted down its centre by a thin membrane... ([or]...a thin membrane divides it through the middle...)..." [On the Sacred Disease - VI]^{25,27}
- "...the bone is thinnest and weakest at the bregma...and the largest proportion of brain is situated in that region of the head..." [On Injuries of the Head - II]^{22,23}
- "...The brain (encephalon) is like a gland, for the brain is white and friable just like glands..." [On Glands - X]²¹
- "... The brain is the metropolis (source, matrix) of the cold and the 'glue matter' (*κολλώδης* [*kollódeos*]), and heat the metropolis of the fatty, since the first thing of all to melt, on being heated, becomes fat. Thus, the brain, having the least fat but the most gluey material, cannot be burnt up by heat..." [On Fleshes - IV]²¹

The spinal cord is only cited, with few anatomical details.

- "...The marrow (*μυελός* [*myelós*]) called spinal (*νωτιαίος* [*notiaíos*]) [spinal cord] extends down from the brain, and it, just like the brain, has little fat [or gluey material]. Thus, it does not rightly bear the name marrow, since it is not like the other marrow in the

bones, it alone having a membrane (*μήνιγγας* [*miningas*]) [meninx], and they none..." [On Fleshes - IV]²¹

- "... when the vessels in his head are heated by the brain, and those along the spine are heated by the spine, the spine was heated by the spinal marrow [spinal cord] (*τον νωτιαίον μυελόν* [*ton notiaion myelon*]), and the spinal marrow by the brain out of which it grows..." [Diseases II - V]²⁶
- "...extending from the cartilages right to the spinal cord ([or] spinal marrow) (*τον νωτιαίον* [*ton notiaion*])..." (On Articulations - XLV)^{24,25}

MENINGES, CSF and VESSELS

The meninges are briefly described.

- "...The brain of man...is double...a thin membrane ... (*μήνιγξ λεπτή* [*mininx leptí*]) [thin meninx] divides it through the middle...[falx]" [On the Sacred Disease - VI]²⁵
- "...The [bones] of the skull are double along the middle of the head... [the] uppermost... comes under the scalp, and [the] lowest...is towards the membrane (*μήνιγγι* [*miningi*]) [meninx]..." [On Injuries of the Head - I]¹
- "...There are two meninges that envelop the brain (encephalon), one outer, thicker [dura mater], the other thinner, touching the encephalon [pia mater]..." [On the Places in Man - II]²⁰
- "... The same principle applies to the membrane which covers the brain: for when, by sawing the bone, and removing it from the meninx..." [On Injuries of the Head - XV]¹
- "... also the spinal cord itself with its coverings [meninges] ([or]...sort of sheaths the spinal cord is enclosed...)..." [On Articulations - XLV]^{25,27}

There are mentions of the presence of liquids that could be interpreted as CSF.

- "...The brain is unnaturally moist, and flooded with phlegm, so that not only do fluxes occur more frequently but the phlegm can no longer separate, nor the brain be dried, being on the contrary soaked and moist. The truth of this is best shown by the cattle that are attacked by this disease [sacred disease], especially by the goats... If you cut open the head you will find the brain moist, very full of dropsy (It is well known that this is also the case with sheep, and that they are subject to the disease called the sturdy, which is indisputably a sort of epilepsy. Many shepherds...have perforated the skull so as to evacuate the water in the brain.)...So it is also with man...when the disease has become chronic it then proves incurable, for the brain is corroded by phlegm and melts, and the part which melts becomes water, surrounding the brain externally and flooding it..." [On the Sacred Disease - XIV]^{25,27}
- "If fluid (*ύδωρ* [*ídor*]) [water] forms on the brain [encephalon], violent pain is present between the bregma and the temples...and then incise the head at

the bregma, bore (*τρυπήσαι* [*tripísai*]) [get pierced] right through to the brain [encephalon] ..." [On Diseases II – XV]^{25,28}

The vessels that supply the brain are described as follows.

- "...and veins (*φλέβες* [*phlebes*] [vessels] (...difference between veins and arteries was not known in the author's time...) run towards it from all parts of the body, many of which are small, but two are thick, the one from the liver (*ήπατος* [*ípatos*]) [hepatic], and the other from the spleen (*σπληνός* [*splinós*]) [splenic]. The vein from the liver has the following distribution -a part of it stretches downwards through the parts on the right side....called the 'hollow vein' (*κοίλη φλέψη* [*koili phlépsi*]) [cava vein]...other part stretches upwards... divides into branches...[the] remaining part of it rises upwards across the clavicle to the right side of the neck...near the ear it is concealed, and there it divides, its thickest, largest, and most hollow part ending in the brain (*ἐγκέφαλον* [*enkéfalon*]) [encephalon], another small vein goes to the right ear, another to the right eye, and the last to the nostril. ...The vein from the spleen is distributed on the left side, upwards and downwards, it is similar to the one from the liver, but thinner and feebler...." [On the Sacred Disease – VI]^{25,27}

SENSORY ORGANS

Some aspects of the sensory organs are described in the following way.

- "...Through seven figures [the seven vowels] come sensations for a man - there is hearing for sounds, sight for the visible, nostril for smell, tongue for pleasant or unpleasant tastes...body for touch, passages outwards and inwards for hot or cold breath. Through these comes knowledge or lack of it..." [On Regimen I – XXIII]²⁹
- "... the other things that give us knowledge, [are known] by the eyes, ears, nose, hand..." [Epidemics 4 – XLIII]³⁰
- "...First there is an opening through which we hear...it is the only opening that exists at the meninges extended to the encephalon. As for the nostrils, there is not an opening, but there is something that is soft as a sponge, which permits to perceive at a large distance what ones smells...Regarding the eyes, the fine venules course from the encephalon to the pupil through the enveloping meninges, these venules nourish the pupil by the more pure humidity that comes from the encephalon. There are three membranes that protect the eyes, one external is the thickest, the middle one is somewhat thinner, and the thinnest third one contains the humor (liquid)..." [On the Places in Man – II]^{20,31}
- "...[The] eyes, ears, tongue, hands, and feet act in accordance with the discernment of the brain. In fact, the whole body participates in intelligence in

proportion to its participation in air..." [The Sacred Disease – XIX]^{25,27}

- "... the senses of the soul that act through sight or hearing are quick, while those that act through touch are slower, and produce a deeper impression. Accordingly, persons of this kind perceive as well as others the sensations of cold, hot, and so on, but they cannot perceive sensations of sight or hearing unless they are already familiar with them." [On Regimen I – XXXV]²⁹

Hippocrates overlooked the existence of 'nerves', as presently understood, and when the term 'neuron' (*νεῦρον* [*neuron*]) is found in his writings, it is to designate indistinctly varied different fibrous structures (ligaments, tendons, aponeurosis, nerves proper, and other whitish tissues).^{5,22}

FUNCTION of the BRAIN, and SPINAL CORD

There is a description of some functions of the brain, and others can be assumed from loss of function due to lesions.

- "...from the brain, and from the brain only, arise our pleasures, joys, laughter, and jests, as well as our sorrows, pains, griefs, and tears. Through it, in particular, we think, see, hear, and distinguish the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant, in some cases using custom as a test, in others perceiving them from their utility..." [On the Sacred Disease – XVII]²⁵
- "In these ways I hold that the brain is the most powerful organ of the human body, for when it is healthy it is an interpreter to us of the phenomena caused by the air, as it is the air that gives it intelligence. [The] eyes, ears, tongue, hands, and feet act in accordance with the discernment of the brain; in fact, the whole body participates in intelligence in proportion to its participation in air. To consciousness the brain is the messenger. For when a man draws breath into himself, the air first reaches the brain, and so is dispersed through the rest of the body, though it leaves in the brain its quintessence, and all that it has of intelligence and sense..." [On the Sacred Disease – XIX]^{25,27}
- "Wherefore I assert that the brain is the interpreter of consciousness... ([or]... Wherefore, I say, that it is the brain which interprets the understanding...)." [On the Sacred Disease – XX]^{25,27}
- "...some are paralyzed: if the wound is on the right side [of the skull] paralysis on the left, if on the left, the right..." [Epidemics 7 – XXXV]³⁰
- "...Most cases have spasm of the parts on one side of the body. If the patient has the lesion on the left side of the head, spasm seizes the right side of the body, [while] if he has the lesion on the right side of the head, spasm seizes the left side of the body..." [On Injuries of the Head – XIX]³²

- "... If the brain (*ἐγκέφαλος*) is shaken and suffers damage as the result of a blow, the patient immediately loses his speech, sight, and hearing. If the brain is wounded...the patient becomes paralysed in some part of his body..." [Diseases I – IV]²⁶
- "In cases of concussion of the brain from any cause, the patients of necessity lose at once the power of speech (*ἀφώνους* [*afónous*]) [speechless]." [Aphorisms – VII – LVIII]³³
- "As for sleep (*ὕπνου* [*ýpnou*]), the patient ought to follow the natural custom of being awake during the day and asleep during the night..." [Prognostic – X]²⁶
- "... When sleep (*ὕπνος* [*ýpnos*]) comes upon the body the blood is chilled, as it is of the nature of sleep to cause chill. When the blood is chilled its passages become more sluggish. This is evident, the body grows heavy and sinks...the eyes close, the intelligence alters, and certain other fancies (envisions) linger, which are called dreams..." [Breaths – XIV]^{26,27}
- "...But when the body is at rest, the soul (*ψυχή* [*psichē*]), being set in motion and awake, administers (controls) her household (interior), and performs all the acts of the body. For the body when asleep has no perception. But the soul when awake has cognizance of all things - sees what is visible, hears what is audible, walks, touches, feels pain, ponders. In a word, all the functions of body and of soul are performed by the soul during sleep..." [Dreams – LXXXVI]³³

There is no description of functions of the spinal cord, but some can be inferred from loss of function due to affection of the vertebral column.

- "...The spinal cord...would suffer...and the displaced vertebra would compress the spinal cord (spinal marrow), even if it did not break it, and being compressed and squeezed, would produce insensibility [paralysis] (*ἀπὸνάρκωσιν* [*aponarkosin*]) of many large and important parts..." [On Articulations – XLVI]^{24,25}
- "In cases where the vertebrae are curved inwards from a fall or the impact of some heavy weight...if there is great displacement of one or more, it brings death. But... this dislocation also is in the form of a curve and not angular. ...In such cases, then, retention of urine and faeces is more frequent than in outward curvatures. The feet and lower limbs as a whole more usually lose heat...if they survive, they are more liable to incontinence of urine, and have more weakness and torpor of the legs, while if the incurvation occurs higher up, they have loss of power and complete torpor of the whole body..." [On Articulations – XLVIII]²⁵
- "...If the spinal marrow [cord] (*νωτιαίος μυελός* [*notiaíos myelós*]) suffers...the individual loses the use [motion] of the legs [inferior limbs], so that he cannot perceive [feel] them when touched [loss of sensibility], and even the belly and the bladder, so that in the first days he does not pass neither stool nor urine, unless with effort. But, after a time, he passes stool and urine

without noticing [incontinence]..." [Prorrhethics II – XVI]^{26,34}

COMMENTS

Hippocrates is seen as the most admirable physician of the antiquity, and, since Medieval times, is often referred as the 'Father of Medicine', in recognition of his outstanding contributions to the field.^{11,35} His large scientific production was mostly lost. However, the relatively extensive extant works demonstrate the greatness of his (including the Hippocratic Corpus) contribution in the field of Medicine, approaching a large and variable spectrum of themes. The main focus of his practice and his writings, as a physician, was diagnosis, treatment, and mainly prognosis.^{5,12}

So, his main focus was medical, and despite the implicit need of knowledge of anatomy, even the basics to perform the described medical interventions, it was not privileged in most of his writings.^{9,12}

Regarding the source of his findings (as well that of the Hippocratic Corpus) on anatomy, except for external (surface) inspection and of the examination of bones, there is no evidence of examination of human internal structures being performed, as at the time, autopsies were not allowed. It is probable that he relied on observation of persons (gladiators, soldiers, and civilians) who sustained wounds that exposed their bones and internal organs. Among the texts there are incidental mentions on the likeness of the human organs with that of animals. So, he might have watched men butchering animals, domestic or hunted, and possibly by dissection of varied animals, although contested by authors.^{13,17,22}

However, despite Hippocrates has recommended the study of the human body, and stated that such study should be the starting point of medicine (e.g., "One should first get a knowledge of the structure of the spine..." [in On Articulations]), the Hippocratic physicians practically ignored human anatomy.^{5,17,22}

So, apparently, he regarded anatomy as important, even not being privileged in the Hippocratic texts. However, relying on his medical interventions, and reading between the lines of his writings, it is possible to perceive that his knowledge on anatomy was not negligible. Thus, many of the not described anatomic structures can be assumed through his detailed clinical descriptions.

He described the bones, based on human skeletons to which he probably had access, and on cases of traumatic injuries of the head and the spine. According to him, the cranium comprised eight bones, including those of the orbit. The structural characteristics of the bones were described, considering that they were double, with an external (upper) and internal (lower) table, with a space between the tables containing a cavernous, soft, and porous structure, with thin vessels full of blood contained

inside - the diploe. The bones are joined by three or four sutures, forming diverse configurations.

The spinal (vertebral) column was described, detailing the anatomy of the vertebrae, their mucous (intervertebral discs) and ligamentous connection, and fibrous bindings, their number in each level (cervical, thoracic, lumbar, and additionally the sacrum [described apart]), as well as the curvatures of the spine. There was no mention of the vertebral (spinal) canal, which can be inferred by the inside located spinal cord, apparently viewed as making part of the structure of the spine.

He gave a very succinct account on the brain (encephalon) anatomy, comprising its bipartite form (hemispheres), the large size, and its intracranial localization. Some characteristics of the brain were given, as its gland-like structure, and its gluey formation.

The spinal cord (spinal marrow) is poorly described, and its function can only be inferred through the clinical symptoms resultant from lesions suffered by the spine, as motion and sensory loss, as well as urinary and faecal continence disorders.

The coverings of the brain were described, comprising two membranes (meninges), an external thicker ('dura mater'), adjacent to the bone of the skull, which apparently projected a septum between the two hemispheres ('falx cerebri'), and an internal thinner, directly touching the brain ('pia mater'). There is also a mention of coverings (meninges) of the spinal cord.

He mentioned, in several instances, the presence of a liquid related to the brain surface (CSF). There was no description of cavities inside the brain. Regarding the vascular supply, he described branches originating from the hepatic and splenic vessels, one on each side, ending in the brain, without further details (Figure 3)

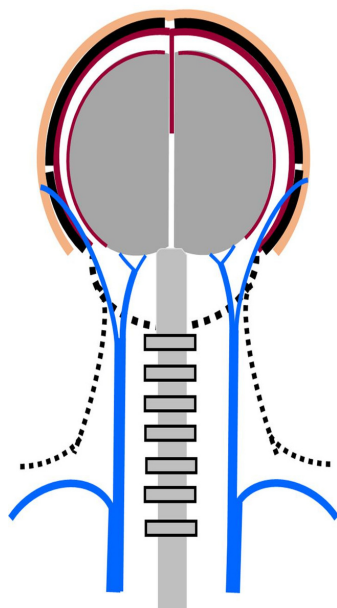


Figure 3. Drawing of the head, with scalp (orange), cranium [bones (black) and sutures (white)], meninges [inner (pia), outer (dura), and between the hemispheres] (brown), vessels (veins) - branches to the head and to the arm (right side from the hepatic vein, and left side from the splenic vein), nervous system (grey) [brain, spinal cord], according to Hippocrates' description (see text). [design by EE]

The senses, in number of five, were mentioned, comprising sight, hearing, smell, gustation, and touch, related to organs of sense, eyes, ears, nose, tongue, and body, respectively. He mentioned some connection of the eyes and ears with the brain, in an ill-defined manner. However, he advances that there is a functional link between the brain and the organs of sense.

It should be stressed that Hippocrates ignored the existence of 'nerves' (in the present sense), and their relationship to the brain and spinal cord, using the term for varied structures (ligaments, tendons, tubes, nerves proper, etc.).

The functions of the brain were also considered.

He stated clearly and emphatically the prominence of the brain in affective, and cognitive functions. Additionally, brain motor control was deduced from the objectively described resultant symptoms of injuries to the head (cranium) (and to the brain), as seizures, and paralysis, indicating a crossed motor control. Sensory and language functions of the brain may also be deduced in the same way, through the loss consequent to disorders. Finally, the excerpts above permit to understand the relation of the brain to sleep and dreaming.⁵ As seen, when sleep comes upon the body the blood is chilled, its passage becomes more sluggish, the body grows heavy and sinks, the eyes close, the intelligence alters, allowing the emergence of dreams, also a production of brain functioning.

Lastly, as Hippocrates and his followers defended the encephalocentric concept, he ascribed to the brain the main ruling function of the body,¹⁷ expressing this understanding emphatically, as already seen, and here repeated: "...In these ways I hold that the brain is the most powerful organ of the human body, for when it is healthy it is an interpreter to us of the phenomena caused by the air, as it is the air that gives it intelligence. [The] eyes, ears, tongue, hands, and feet act in accordance with the discernment of the brain. ...To consciousness the brain is the messenger..."²⁵

CONCLUSION

Hippocrates was indubitably one of the greatest physicians ever, and has received the title of 'Father of Medicine' for his accomplishments. He produced a number of texts, which together with those of other authors, formed an assemble known as Hippocratic Collection or Hippocratic Corpus, many of which survived as a legacy. It should be underlined that he has received only a few fragmentary written information from the pre-Hippocratic philosophers-physicians, and practically nothing from the archaic civilizations that flourished and faded in the region. Even after almost two and a half millennia, his writings (and of the Corpus) continue to be admired, and regarded as a never-ending fount of medical knowledge and inspiration.

His inspired medical accomplishments stand in contrast to the poor anatomical contribution. However, it must be recognized that the incipient information on anatomy, including those on the nervous system, legated by Hippocrates and the Corpus, represented a starting point for the upcoming personalities for the steps to be taken for further studies on the subject.

REFERENCES

1. The genuine works of Hippocrates. Vol I. Adams F transl. London: Sydenham Society, 1849. [25-03-2023] <https://ia902802.us.archive.org/19/items/genuineworksofhi01hippuoft/genuineworksofhi01hippuoft.pdf>
2. Hippocratis Coi Medicorum Omnium longe principis, opera quae apud nos extant omnia. Per Ianum Cornarium interprete. Basileae: Froben, 1546, pp 11-12. [05-05-2023] <https://services.biusante.parisdescartes.fr/medicapdf/main.php?key=cGFydGlhbHwzMDAxOXwxMXwxMg>
3. Hippocrates. Oeuvres complètes. Vol 1. Littré, Émile trad. Paris: J-B Baillièrre, 1839, pp 20-43. [09-05-2023] <https://services.biusante.parisdescartes.fr/medica-pdf/main.php?key=cGFydGlhbHwzNDg1OXgwMXwyMHw2MA>
4. Ribeiro Jr WA. Hipócrates de Cós. In: Textos hipocráticos: o doente, o médico e a doença. Cairus HF, Wilson WA eds. Rio de Janeiro: Editora FIOCRUZ, 2005, pp 11-24. [06-05-2023] <https://static.scielo.org/scielobooks/9n2wg/pdf/cairus-9788575413753.pdf>
5. Souques AA. Étapes de la Neurologie dans l'Antiquité Grecque: d'Homère à Galien. Paris: Masson, 1936. [27-05-2023] <https://services.biusante.parisdescartes.fr/medica-pdf/main.php?key=ZnVsbHwzNDA0OTR8fA>
6. Tuke JB. Hippocrates. In: Chisholm, Hugh. Encyclopaedia Britannica. Vol 13. 11th ed. Cambridge: Cambridge University Press, 1910, pp. 517-519. [09-03-2023] <https://archive.org/details/encyclopaediabrit13chisrich/page/516/mode/2up>
7. Arnott R. Healing and medicine in the Aegean Bronze Age. Journal of the Royal Society of Medicine 1996;89(5):265-270. <https://doi.org/10.1177/014107689608900508>
8. Arnott R. Minoan and Mycenaean Medicine and its Near Eastern contacts. In: Magic and Rationality in Ancient Near Eastern and Graeco-Roman Medicine. Horstmanshoff HFJ, Stol M, Van Tilburg CR eds. London: Brill Academic Publishers, 2004.
9. Karenberg A. The Greco-Roman world. In: Handbook of Clinical Neurology, Vol. 95 (3rd series). History of Neurology. S. Finger, F. Boller, K.L. Tyler, Editors. Elsevier 2010, pp 49-59. [17-03-2023] <https://reader.elsevier.com/reader/sd/pii/S0072975208021052?token=3E2B717CBB6752FDE00925899BA7A21C1CE2947A00E3D279FE904F519C59C9F6F41F95263288B68823B1408E90BCECE4&originRegion=us-east-1&originCreation=20230318201129>
10. Breasted JH. The Edwin Smith Surgical Papyrus. Vol I. Chicago: University Chicago Press, 1930. [10-03-2023] https://ia801407.us.archive.org/31/items/oip3_20220624/oip3.pdf
11. Conti AA, Paternostro F. Anatomical study in the Western world before the Middle Ages: historical evidence. Acta bio-medica: Atenei Parmensis 2019;90(4):523-525. <https://doi.org/10.23750/abm.v90i4.8738>
12. Houdart M-S. Histoire de la médecine Grecque depuis Esculape jusqu'à Hippocrate exclusivement. Paris: J-B Baillièrre, 1856. [18-04-2023] <https://www.biusante.parisdescartes.fr/histoire/medica/resultats/index.php?do=pdf&cote=46528>
13. Lloyd GER. Magic, reason and experience. London: Cambridge University Press, 1979.
14. Longrigg J. Greek medicine from the Heroic to the Hellenistic age. New York: Routledge, 1998.
15. Penfield W. The Asclepiad Physicians of Cnidus and Cos with a Note on the Probable Site of the Triopion Temple of Apollo. Proc Am Philosoph Soc 1957; 101(5):393-400. <http://www.jstor.org/stable/985193>
16. Retief F, Cilliers L. Pre-Hippocratic Greek medicine and its influence on the Hippocratic Corpus. Acta Academica, 2007;39(1):79-92. <https://hdl.handle.net/10520/EJC15372>
17. Finger S. Minds Behind the Brain: A history of the pioneers and their discoveries. Oxford: Oxford University Press, 2000, pp 7-20, 21-38.
18. Cairus HF. O Corpus Hippocraticum. In: Textos hipocráticos: o doente, o médico e a doença. Cairus HF, Wilson WA eds. Rio de Janeiro: Editora FIOCRUZ, 2005, pp 25-38. [06-05-2023] <https://static.scielo.org/scielobooks/9n2wg/pdf/cairus-9788575413753.pdf>
19. Hippocrates. Volume I. Jones WHS transl. London: Heinemann, 1957. [09-03-2023] <https://ia802708.us.archive.org/8/items/hippocrates01hippuoft/hippocrates01hippuoft.pdf>
20. Hippocrates. Oeuvres complètes. Vol 7. Littré E. Paris : J.-B. Baillièrre, 1849. [24-04-2023] <https://www.biusante.parisdescartes.fr/histoire/medica/resultats/index.php?do=pdf&cote=34859x06>
21. Hippocrates. Vol VIII. Potter P transl. London: Harvard University Press, 1995. [12-04-2023] <https://ia600909.us.archive.org/15/items/hippocrateswith08hippuoft/hippocrateswith08hippuoft.pdf>
22. Oeuvres d'Hippocrate. Tome I. Mercy FCF éd. Paris: Béchét Jeune, 1831. [03-04-2023] <https://services.biusante.parisdescartes.fr/medica-pdf/main.php?key=ZnVsbHwzMzI3MngwMXx8>
23. Hippocrates. Oeuvres complètes. Vol 9. Littré E trad. Paris : J.-B. Baillièrre, 1861. [09-04-2023] <https://services.biusante.parisdescartes.fr/medica-pdf/main.php?key=cGFydGlhbHwzNDg1OXgwOXw1fDgw>
24. Hippocrates. Vol III. Withington ET transl. London: Heinemann, 1959. [07-03-2023] <https://ia802708.us.archive.org/3/items/hippocrates03hippuoft/hippocrates03hippuoft.pdf>
25. The genuine works of Hippocrates. Vol II. Adams F transl. London: Sydenham Society, 1849. [25-03-2023] <https://ia800701.us.archive.org/20/items/genuineworksofhi02hippuoft/genuineworksofhi02hippuoft.pdf>
26. Hippocrates. Vol 5. Potter P transl. London : Heinemann, 1923. [04-04-2023] <https://ia800906.us.archive.org/11/items/hippocrateswith05hippuoft/hippocrateswith05hippuoft.pdf>

27. Hippocrates. Vol II. Jones WHS transl. London: Heinemann, 1959. [07-03-2023] <https://ia802704.us.archive.org/26/items/hippocrates02hippuoft/hippocrates02hippuoft.pdf>
28. Hippocrates. Oeuvres completes. Vol 7. Littré E. Paris : J.-B. Baillière, 1851. [24-04-2023] https://ia601008.us.archive.org/20/items/BIUSante_34859x07/BIUSante_34859x07.pdf
29. Hippocrates. Vol IV. Jones WHS transl. London: Heinemann, 1959. [08-03-2023] <https://ia601609.us.archive.org/20/items/hippocrates04hippuoft/hippocrates04hippuoft.pdf>
30. Hippocrates. Vol VII. Smith WD transl. Cambridge: Harvard University Press, 1994. [04-04-2023] <https://ia903009.us.archive.org/25/items/L477HippocratesVII.EpidemicsLoebClassicalLibrary/L477-Hippocrates%20VII.%20Epidemics%20%28Loeb%20Classical%20Library%29.pdf>
31. Lascaratos J, Marketos S. Ophthalmological lore in the Corpus Hippocraticum. *Doc Ophthalmol* 1988;68:35-45. <https://doi.org/10.1007/BF00153586>
32. Hippocrates. Vol III. Withington ET transl. London: Heinemann, 1959. [07-03-2023] <https://ia802708.us.archive.org/3/items/hippocrates03hippuoft/hippocrates03hippuoft.pdf>
33. Hippocrates. Vol IV. Jones WHS transl. London: Heinemann, 1959. [08-03-2023] <https://ia601609.us.archive.org/20/items/hippocrates04hippuoft/hippocrates04hippuoft.pdf>
34. Hippocrates. Magni Hippocratis Opera Omnia. Tomus I. Kühn KG éd. Leipzig: Car. Cnoblochii, 1825. [09-04-2023] <https://services.biusante.parisdescartes.fr/medica-pdf/main.php?key=cGFydGlhbHxoaXBwb2t1aG54MDF8NDEyfDQ2MQ>
35. von Klein CH. The medical features of the Papyrus Ebers. Chicago, American Medical Association, 1905. [18-03-2023] <https://ia800202.us.archive.org/9/items/cu31924000900849/cu31924000900849.pdf>