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REVIEW ARTICLE

Knowledge of the anatomy and physiology of the spleen throughout Antiquity and the Early Middle Ages

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Abstract The evolution of knowledge regarding the anatomy and physiology of the spleen throughout Antiquity and the Early Middle Ages is described, and general perceptions about this organ during different eras along this time line are presented. The original words of great physicians from the period of time stretching from Ancient Egypt to the Avicennan era are quoted and discussed to demonstrate how knowledge of the spleen has evolved and to present the theories that dominated each era. Furthermore, theories about illnesses relating to the spleen are reported, which show how this organ was perceived —in terms of its function and anatomy—during each era.

Keywords Anatomy · Antiquity · Early Middle Ages · Physiology · Spleen

In this paper, we review how knowledge of the anatomy and physiology of the spleen evolved during the period from Antiquity (particularly Ancient Egypt) to the Avicennan era. The original words of great physicians from this period are quoted, in order to give the reader a feel for not only the state of knowledge about the spleen during each era but also the style of each of these physicians and the way that each deployed and processed their scientific opinions.

This review is dedicated by all authors to the memory of Nikolaos K. Koutsouflianiotis, general surgeon in "Papageorgiou Hospital", who initiated and advised us for writing this study.

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We first consider the etymology of the word "spleen." This word derives from the Greek "σπλήν" In the *Etymologicum Magnum*, it states "*σπλήν· παρά τό ἐπισπᾶσθαι εἰς ἑαυτόν τά φαυλισθέντα τῶν ὑγρῶν*" which means "spleen; from the one which breaks through to itself the remedies of the liquid" (Gaisford 1848). Furthermore, the term "spleen" is related to the Greek word "σπλάγχνα" which corresponds to the viscera. Specifically, it was mentioned that "*ὁ σπλήν παράγει τά σπλάγχνα κατά τούς παλαιούς*" (Van der Valk 1971), which means "from the word spleen is derived the word splachn-splachnic according to the olders."

Little knowledge of the spleen can be gleaned from the Ebers Papyrus, an Egyptian medical papyrus dating back to 1550 B.C. that is proposed to include the most important medical information to Ancient Egyptians: "There are four vessels to the intestines and to the spleen which likewise convey moisture and air." The Ebers Papyrus provides more anatomical data on the liver: "Four vessels lead to the liver, supplying it with air and water, and, being overfilled with blood, influence the occurrence of all sorts of illness" (Bryan 1930). That report presumably corresponds to either the two branches of the proper hepatic artery and the two branches of the portal vein, or to the inferior vena cava and the portal triad (i.e., the bile duct, the proper hepatic artery, and the portal vein). Ayurveda—a traditional Indian system of medical practice based on the concept of "humors"—describes the spleen as "the root of the ducts which transport the blood" (see Fig. 1) (Wujastyk 1998).

The Talmud, which includes the Mishna (oral law) and the Gemara (commentary) and defines the manners and morals of the Jewish people, provides much information on anatomy and physiology as well as surgery and pathology. Physicians consider the knowledge provided by Hippocrates, Aristotle, and Galen to be extremely important;

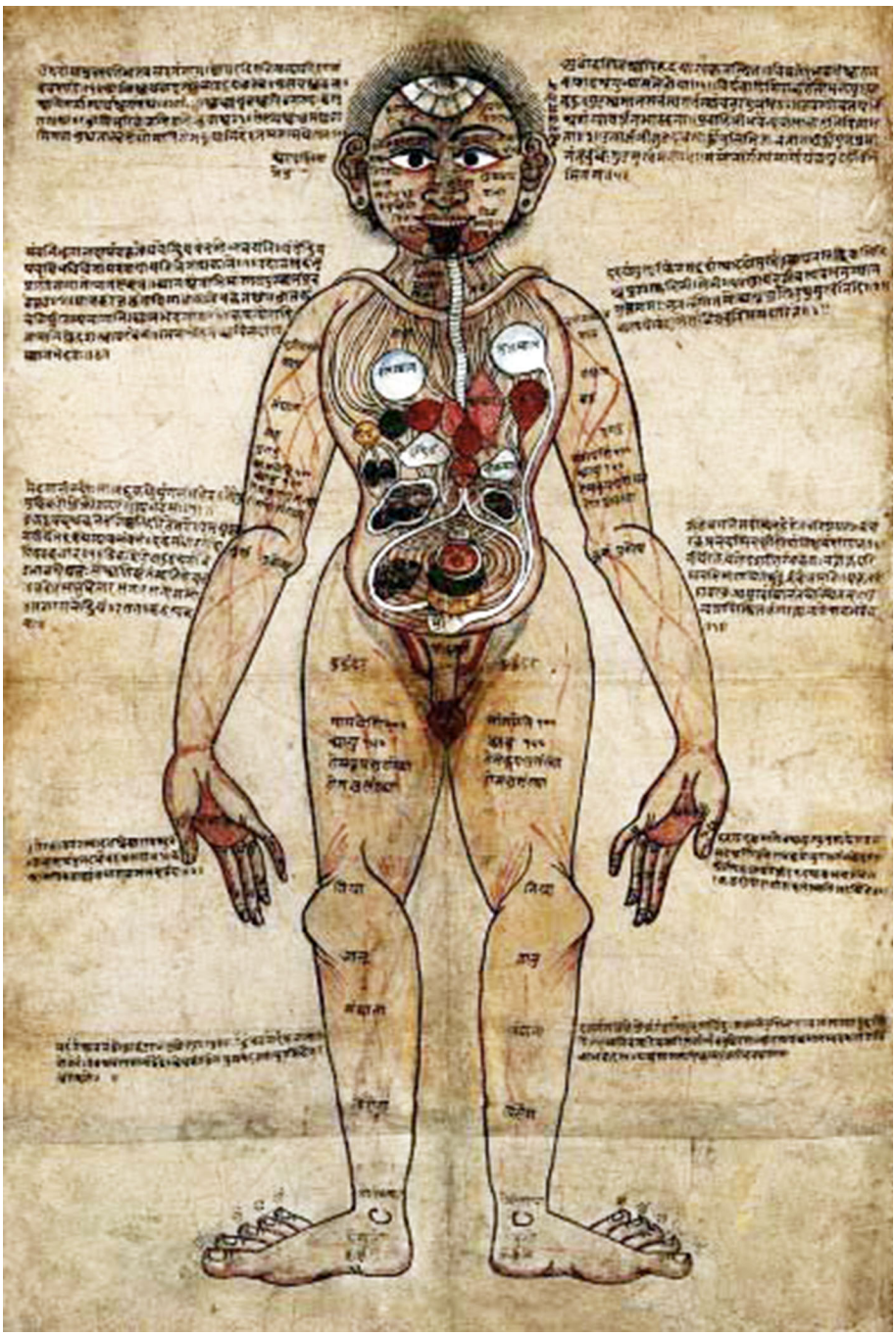


Fig. 1 *Ayurvedic Man* (18th century). Anatomical study of a man standing, with Nepalese and Sanskrit texts showing the ayurvedic understanding of the human anatomy. (Public domain image provided courtesy of the Wellcome Library, London)

yet the Talmud contains medical information that cannot be found in the combined works of these three great philosophers (Cohen 1900). However, the Talmud presents only very limited knowledge of the spleen, and this organ is not mentioned at all in the Bible. The spleen is called *tichäl* ("techol") in Arabic; its convex side is the "breast (*dad* = mamma) of the spleen;" the fat capsule is termed *qerum*, its "skin;" and the vessels of the hilum are *chutin*, its "threads." Although the spleen looks like blood, it is not. It is a fat-like substance, "schumna," and can therefore be eaten. In contrast, enjoyment of the blood that flows from the veins of the organ is forbidden under penalty of flagellation. According to the Mishnah, which implements the microcosm theory in detail, the spleen is within the human body, what the laws are in the world, the regulator (Preuss 1923). Post-Talmudic literature sought to explain the opinion expressed in the Talmud that the spleen causes laughter. Judah Halevy, the great Jewish philosopher, stated that "the spleen is called laughing because it is its nature to cleanse both blood and spirit from unclean and

obscuring matter. If they are pure, cheerfulness and laughter arise" (Rosner 1995).

The practitioners of traditional Chinese medicine utilized the theory of five elements to explain and comprehend the physiology and the interactions of the *zang–fu* organs. Earth, one of the five elements, was associated with the spleen (Yang and Jia 2013). The five *zang* organs are the heart, lungs, spleen, liver, and kidneys (Bing and Hongcai 2010). The mother of all things was considered to be the earth, which can disintegrate everything and from which everything derives. In the same way, the spleen—through digestion—stores essence in order to produce *qi*, and thus the energy and blood that nourishes the body. Furthermore, just as the flora on the earth is nourished, the spleen distributes essence through the body and into the five channels. Moreover, the amount of water on the earth is controlled by the rivers, the sea, and the lakes such that the earth always contains an appropriate amount of moisture. Correspondingly, the spleen regulates the blood and protects the body from illnesses that derive from a surplus of liquids (Yang and Jia 2013). The physiological functions of the spleen can be summarized as follows.

In the theory of the five elements, the spleen is the source of *qi* and blood. Furthermore, the spleen contributes significantly to the storage of food. In the work *Plain Questions*, the following is stated: "After food and drink enter the stomach, they are digested and transformed into food essence, and then transmitted upward to the spleen, which disperses the essence upward to the lungs and the lungs regulate water pathways downward to the bladder. And by doing so body fluid is finally disseminated to all parts of the body along all the meridians and collaterals. The opening of the spleen is the mouth and its outer display, the lips. The spleen is related to thinking, and saliva is the natural fluid of the spleen. It prevails in muscles and limbs and it is affiliated externally and internally with the stomach" (Bing and Hongcai 2010).

Hippocrates of Cos was born in 460 B.C., but he spent only part of his life on Cos, the island of his birth. He later moved to continental Greece; more specifically to Thessaly, the mythic cradle of the family of Asclepiads, where he died. Hippocrates has been considered the father of medicine for more than 2000 years. His pronouncements on health, disease, and prognosis went unchallenged in the Western world until scientific advances in the nineteenth and twentieth centuries made many of his ideas obsolete (Jouanna 2001). Hippocrates wrote about the macroscopic and microscopic anatomy of the spleen as well as the veins associated with viscera. He provides us with data on the topography of this organ in his work *Anatomy*: "Out of the side by the false ribs—I mean on the left—the spleen has its origin; it spreads out symmetrical with a foot print" (Littre 1853a, b, c; Potter 2010). In *Fleshes*, he states that "The spleen was formed as follows. With what was moist and gluey was kindled very much heat, and very little cold, just the right amount to condense the gluey material itself, which constitutes the fibers that are in the spleen; it is because of these fibers that the spleen is soft and stringy" (Littre 1853a, b, c; Potter 1995). In his work *The Nature of Man*, Hippocrates mentions, "There are four pairs of veins in the body… The third pair of veins passes from the temples through the neck under the shoulder-blades, then they meet in the lungs and reach, the one on the right the left side, and the one on the left the right. The right one reaches from the lungs under the breast both to the spleen and to the kidneys, and the left one to the right from the lungs under the breast both to the liver and to the kidneys, both of them ending at the anus" (Littre 1853a, b, c; Jones 1931). It is likely that he is referring to the azygos venous system here. However, while this venous system is known to connect to the perinephric venous plexus, it does not reach the spleen or terminate into the anal venous system (see Fig. 2).

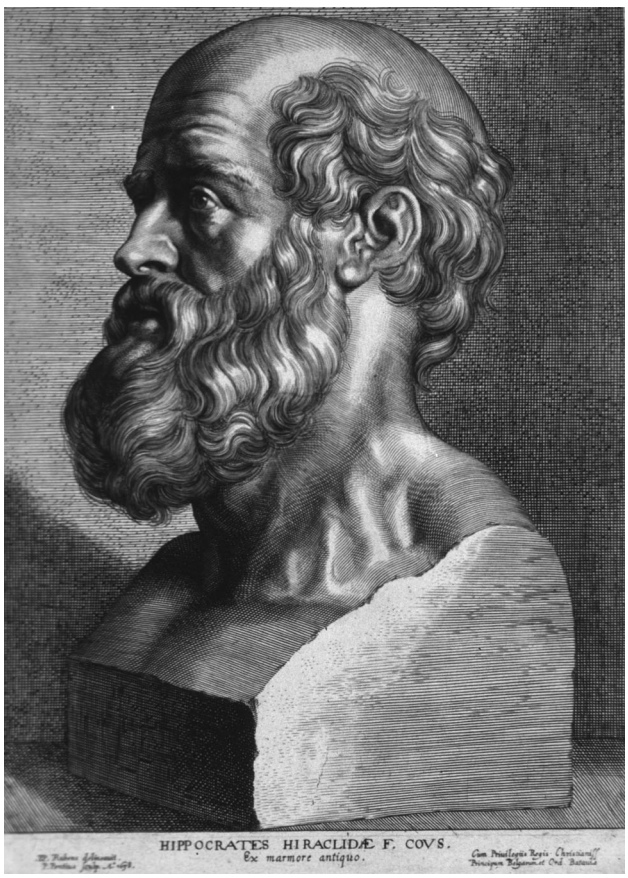


Fig. 2 Engraving (from 1638) by Peter Paul Rubens of Hippocrates. (Public domain image provided courtesy of the National Library of Medicine)

In his work *Diseases*, Hippocrates directly links the physiology of the spleen to the functions of the four humors of the organism: "I would like first to show how too much or too little bile, blood, water, and phlegm arise from foods and drinks: when the cavity is full, it is a spring supplying all things to the body, but when it is empty, it draws moisture out the body, and the body melts away. There are also four other springs, which can each pour one kind of these (sc. moistures) into the body, after they have acquired them from the cavity: when they are empty, these springs draw moisture out of the body, and the body then attracts moisture from the cavity, as long as it has anything in it. The spring for blood is the heart, for phlegm the head, for water the spleen, and for bile the locus on the liver. These four are springs for these moistures, independent of the cavity: of these, the hollowest are the head and the spleen, for they have the emptiest space" (Littre 1851; Potter 2012). Moreover, in his work *Ancient Medicine*, Hippocrates submits his opinion on the way the spleen absorbs the liquids which increase in the abdomen and gave a pathophysiological perspective on the physiology of the organ. He states, "Spongy, porous parts, like the spleen, lungs and breasts, will drink up readily what is in contact with them, and these parts especially harden and enlarge on the addition of fluid… but when one of these parts drinks up the fluid and takes it to itself, the porous hollows, even the small ones, are everywhere filled, and the soft, porous part becomes hard and close, and neither digests nor discharges" (Littre 1839; Jones 1923a, b).

Furthermore, Hippocrates linked the spleen to illnesses and symptoms, such as spots that appear on the skin due to a poorly functioning liver and spleen. He offered data that could aid the differential diagnosis; for instance, in the text of *Epidemics II*, he says, "Colors, like those of Polychares: <yellowish, greenish,> dead white are to be observed, since everything of this kind comes from the liver. Thence come hepatic diseases and among them are the jaundices from the liver that tend to whiteness, and dropsical diseases and leucophlegmatic ones. Jaundices from the spleen are darker" (Littre 1846; Smith 1994). Hippocrates also described types of individuals who suffer from spleen diseases; for instance, in his work *Affections*: "Persons that have a large spleen: those who are bilious take on a poor color, suffer from malignant ulcers, smell foully from the mouth, and become thin; their spleen is hard and always about the same size; foods do not pass off below. Those who are phlegmatic suffer these things less, and their spleen sometimes increases in size, sometimes decreases" (Littre 1849; Potter 1988). In addition, Hippocrates provided information about the body type of people with a spleen disorder. In his work *Airs, Waters, and Places*, he specifies, "… the fact is that their flesh dissolves to feed the spleen, so that they are lean. With such a constitution they eat and drink heavily…" (Littre 1840; Jones 1923a, b).

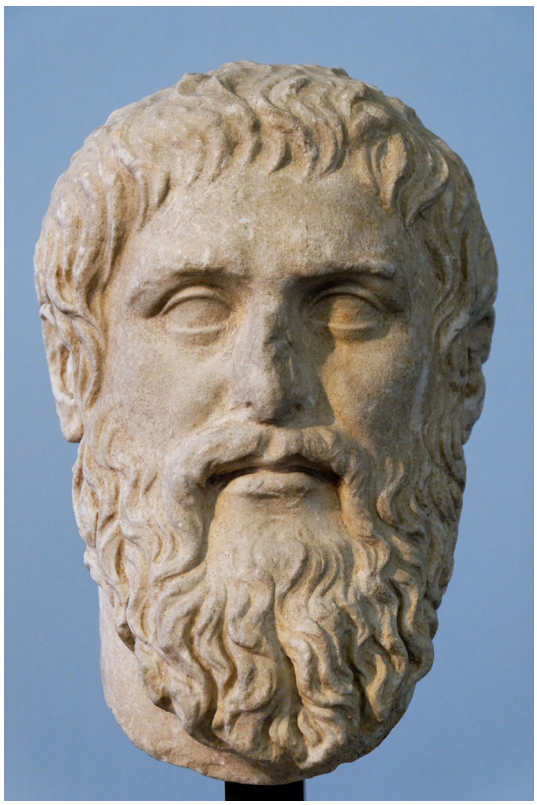


Fig. 3 A copy, made from Luni marble, of a portrait of Plato created by Silanion in ca. 370 B.C. for the Academia in Athens. (Public domain image)

Plato (see Fig. 3), a native Athenian, was born in 427 B.C. and died at the age of 81 in 347 B.C. At some point in his late teens or early twenties, he began to frequent the circle around Socrates, the Athenian philosopher. After the death of Socrates, he spent a considerable period of time in Greek-settled southern Italy, where he appears to have met philosophers and scientists belonging to the indigenous Pythagorean school. At some point, Plato opened a school of higher education in the sacred grove of Academus, teaching mathematics, philosophy, and political studies (Cooper and Hutchinson 1997). In his work *Timaeus*, Plato vaguely refers to the spleen and its physiological functions ("cleans the liver as a napkin does to the mirror"): "The neighboring organ (to the liver) (the spleen) is situated on the left-hand side, and is constructed with a view of keeping the liver bright and pure—like a napkin, always ready prepared and at hand to clean the mirror. And hence, when any impurities arise in the region of the liver by reason of disorders of the body, the loose nature of the spleen, which is composed of a hollow and bloodless tissue, receives them all and clears them away, and when filled with the unclean matter, swells and festers, but,

Fig. 4 Bust of Aristotle. Roman copy in marble of a Greek bronze original by Lysippos (330 B.C.); the alabaster mantle is a modern addition. (Public domain image)

again, when the body is purged, settles down into the same place as before, and is humbled" (Jowett 1999). Plato later defines the spleen as a soft organ but incorrectly states that this organ is composed of bloodless tissue (Fig. 4).

Aristotle of Stagira was born in Stagirus in 384 B.C. and died in Chalcis in 322 B.C. Building on Plato's dialogic approach, Aristotle developed what is known as the scientific method. In addition, he founded the Lyceum, a university-type institution, which—with its vast collections of biological specimens and manuscripts—housed the first research library (Magill 1998a, b, c). In his work *On the Parts of Animals*, he describes his theory on the symmetry of the viscera, which regards the heart as a single organ and the kidneys as a double organ, while the liver and spleen are neither single nor double organs but halfway between these types: "Of the viscera some appear to be single, as the heart and lung; others to be double, as the kidneys; while of a third kind it is doubtful in which class they should be reckoned. For the liver and the spleen would seem to lie half-way between the single and the double organs. For they may be regarded either as constituting each a single organ, or as a pair of organs resembling each other in character. In reality, however, all the organs are double. The reason for this is that the body itself is double, consisting of two halves, which are however combined together under one supreme center. For there is an upper and a lower half, a front and a rear, a right side and a left" (Ogle 2014).

He furthermore extended this theory to discuss the use of the spleen and to characterize it in comparison with the liver. In some cases, such as in animals that require a spleen, he considered it a "bastard liver," whereas in other animals that present a spleen but do not necessarily require it, he found the liver to consist of two parts, with the larger part tending to lie on the right side and the smaller on the left. "…But when we come to the liver and the spleen, any one might fairly be in doubt. The reason of this is, that, in animals that necessarily have a spleen, this organ is such that it might be taken for a kind of bastard liver; while in those in which a spleen is not an actual necessity but is merely present, as it were, by way of token, in an extremely minute form, the liver plainly consists of two parts; of which the larger tends to lie on the right side and the smaller on the left…" (Ogle 2014). Aristotle is apparently referring to the (larger) right and (smaller) left lobes of the liver here. Moreover, he described the anatomy of the vessels that nourish the spleen and liver. Specifically, in his work *On the Parts of Animals*, we can find information about the circulation in this region: "Those viscera which lie below the diaphragm exist one and all on account of the blood-vessels; serving as a bond, by which these vessels, while floating freely, are yet held in connection with the body. For the vessels give off branches which run to the body through the outstretched structures, like so many anchorlines thrown out from a ship. The great vessel sends such branches to the liver and the spleen; and these viscera —the liver and spleen on either side with the kidneys behind—attach the great vessel to the body with the firmness of nails. The aorta sends similar branches to each kidney, but none to the liver or spleen" (Ogle 2014). Aristotle accurately stated that the (abdominal) aorta gives rise to the renal arteries, but he failed to describe the celiac trunk and branches of it to the spleen, liver, and stomach as branches of the aorta; indeed, he instead indicated that these arteries constitute branches of the so-called "great vessel" (presumably the inferior vena cava).

Aristotle did not end his theory about the spleen with his description of the anatomy of the organ. He proposed a possible function of it which also included the liver: "These viscera, then, contribute in this manner to the compactness of the animal body. The liver and spleen assist, moreover, in the concoction of the food; for both are of a hot character, owing to the blood which they contain… The spleen, on the other hand, (in contrast to the heart and the liver) is not invariably present; and, in those animals that have it, is only present of necessity in the same sense as the

excretions of the belly and of the bladder are necessary, in the sense, that is, of being an inevitable concomitant. Therefore it is that in some animals the spleen is but scantily developed as regards size… For the spleen attracts the residual humors from the stomach, and owing to its bloodlike character is enabled to assist in their concoction…" (Ogle 2014). Thus, Aristotle correctly reported the well-known "bloodlike character" of the spleen. He related illnesses to the function of the spleen: abundant residual fluid or a diseased spleen could lead to disorders. "… Should, however, this residual fluid be too abundant, or the heat of the spleen be too scanty, the body becomes sickly from over-repletion with nutriment. Often, too, when the spleen is affected by disease, the belly becomes hard owing to the reflux into it of the fluid; just as happens to those who form too much urine, for they also are liable to a similar diversion of the fluids into the belly…" (Ogle 2014). We should also mention the connection that Aristotle made between the spleen and the state of melancholy (depression) here. In his work *Problems* (particularly the chapter "Of the gall and the spleen"), he reports that the spleen causes laughter because it draws much melancholy (one of the four humors) to itself (Coker 2010).

Erasistratus (see Fig. 5), born around 330 B.C., was exposed to the teachings of Aristotle and the school of Cnidus through his master Metrodorus (Libby 1922). But he does not appear to have agreed with Hippocrates and Plato about the function of the spleen, as reported by Galen: "For among the numerous physiological teachings regarding the genesis and the destruction of animals, their health, their diseases and the method of treating these, there will be found one only which is common to Erasistratus and the Peripatetics, namely the view that Nature does everything for some purpose and nothing in vain. Erasistratus makes havoc of it a thousand times over. For, according to him, (Erasistratus) the spleen was made for no purpose as also the omentum" (Brock 1916a, b, c, d, e). "Thus he (Erasistratus) ought not to have said anything about the spleen, nor have stultified himself by holding that an artistic Nature would have prepared so large an organ for no purpose. As a matter of fact Hippocrates and Plato say that this viscus also is one of those that cleanse the blood, but there are thousands of ancient physicians and philosophers who are in agreement with them" (Brock 1916a, b, c, d, e).

Rufus of Ephesus (1st–2nd century A.D.; see Fig. 6), a Greek physician and anatomist who was educated at Alexandria, was respected greatly by Galen, and his high reputation lived on for many centuries after his death (Gersh 2012a, b, c). In his work *On the Names of the Parts of the Body*, where he discusses the terminology used for anatomical structures, he provides information on the anatomy of the spleen and the circulation around this organ, even though he believed that this viscus served no purpose: "The spleen is located to the left of the stomach. The thick and highest part of it is called the head." Rufus claimed the following regarding the veins of the spleen: "But unlike the liver, the spleen has no offshoots on the

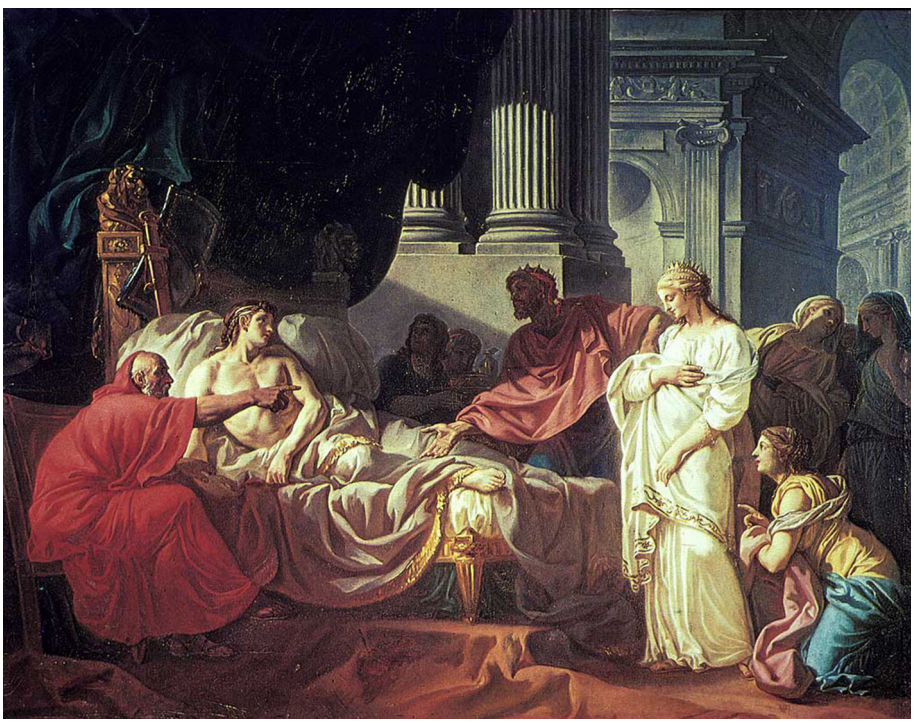


Fig. 5 Erasistratus discovers the cause of Antiochus' illness. Painting by Jacques-Louis David (1774). (Public domain image)

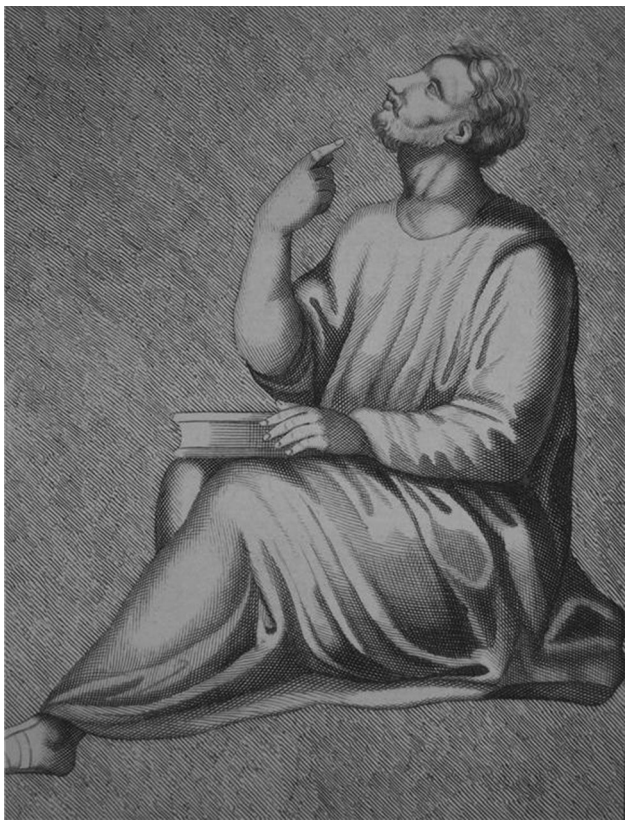


Fig. 6 Color gravure (17th century A.D.) of Rufus of Ephesus. (Image obtained from www.mystockphoto.com)

left, extending either upwards or downwards. Those who make this claim are incorrect. The veins which extend to the spleen are narrow and, in fact, end at the spleen" (Gersh 2012a, b, c). Rufus properly stated that the splenic vein terminates at the hilum of the spleen: "On each side of the torso, under the cartilage of the chest, are the spleen and the liver. …The spleen is located opposite the bladder; it is stretched-out and long, resembling the footprint of a man. On its upper portion, it is round and sturdy; on its lower portion, tight and thin; and on its middle portions, narrow as well. Its color is that of wine. Its structure is loose and porous, since it is a network of vessels. It is idle and serves no purpose" (Gersh 2012a, b, c). Rufus provided an excellent and accurate description of the spleen's morphology, describing its upper and lower poles, its size, its color, and its texture. Moreover, he noted that it is located under the left costal arch, opposite the gallbladder. Nevertheless, he failed to propose the functional significance of the spleen.

The Greek physician Galen (born 129–130 A.D., died 199–201 A.D.) was the most famous physician of antiquity after Hippocrates (see Fig. 7). His name came from *galenos*, which means "calm" in Greek. He was born in Pergamum, an important center of Hellenistic culture in Asia Minor, where he carried out his initial studies in medicine. He learned anatomy from Satyrus in 147 A.D. and anatomy at Smyrna under the Dogmatist Pelops in 151 A.D. In 152 A.D., he studied anatomy under Numisianus, initially at Corinth and later in Alexandria. In 162 A.D. he reached Rome, where he attained a brilliant reputation as both a practitioner and a public demonstrator of anatomy (Singer 1956a, b; Brock 1916a, b, c, d, e). Galen's empirical approach based on original animal experimentation had an enormous influence on Western medicine for almost 1500 years during the Middle Ages and Renaissance (Singer 1956a, b; Fullerton and Silverman 2009). Galen provided anatomical information on the spleen in his works *On the Usefulness of the Parts of the Body* and *On Anatomical Procedures*. In the latter work, he discusses differences between animals and also describes the dissection method that he utilized, marking him out as a true anatomist: "On the concave side are the intersections of the arteries and veins and the connection with the omentum (gastrosplenic ligament): on the convex side where it draws away from the false ribs and the flanks, no vessel is inserted but certain fibrous connections (phrenocolic and splenorenal ligaments) are found in that region which attaches it to other parts in the vicinity. The tunic surrounding the spleen is not only a ligament, but, as its name implies, a tunic as well, covering and clothing the viscus on all sides" (Kuhn 1822; May 1968). "The spleen lies on the left, having its concavity towards the right. From the liver there goes to it a vein [splenic], a branch of which goes on to the stomach. After sending branches to all the parts of the spleen, part of the vein continues to the convex part of the stomach [he presumably meant the short gastric veins] and the rest to the left region of the omentum [he is likely referring to the left gastroepiploic artery here]. These features are common to all the red-blooded animals, but not so with either the size of the spleen or its color" (Kuhn 1821a, b; Singer 1956a, b). Galen also commented on the physiology of the spleen. He stated his opinion with reference to great physicians and philosophers such as Hippocrates, Plato, and Erasistratus; in particular, he strongly disagreed with Erasistratus and his theory that the spleen had no purpose.

In the following passage, Galen describes the Hippocratic theory for the function of the spleen, which he adopted and can be observed in the manuscripts of many subsequent physicians throughout Antiquity: "Hippocrates, indeed, says that the spleen is wasted in those people in whom the body is in good condition, and all of those physicians also who base themselves on experience agree with this. Again in those cases, in which the spleen is large and is increasing from internal suppuration, it destroys the body and fills it with evil humors; this again is agreed on not only by Hippocrates but also by Plato and many others including the Empiric physicians. And the jaundice that

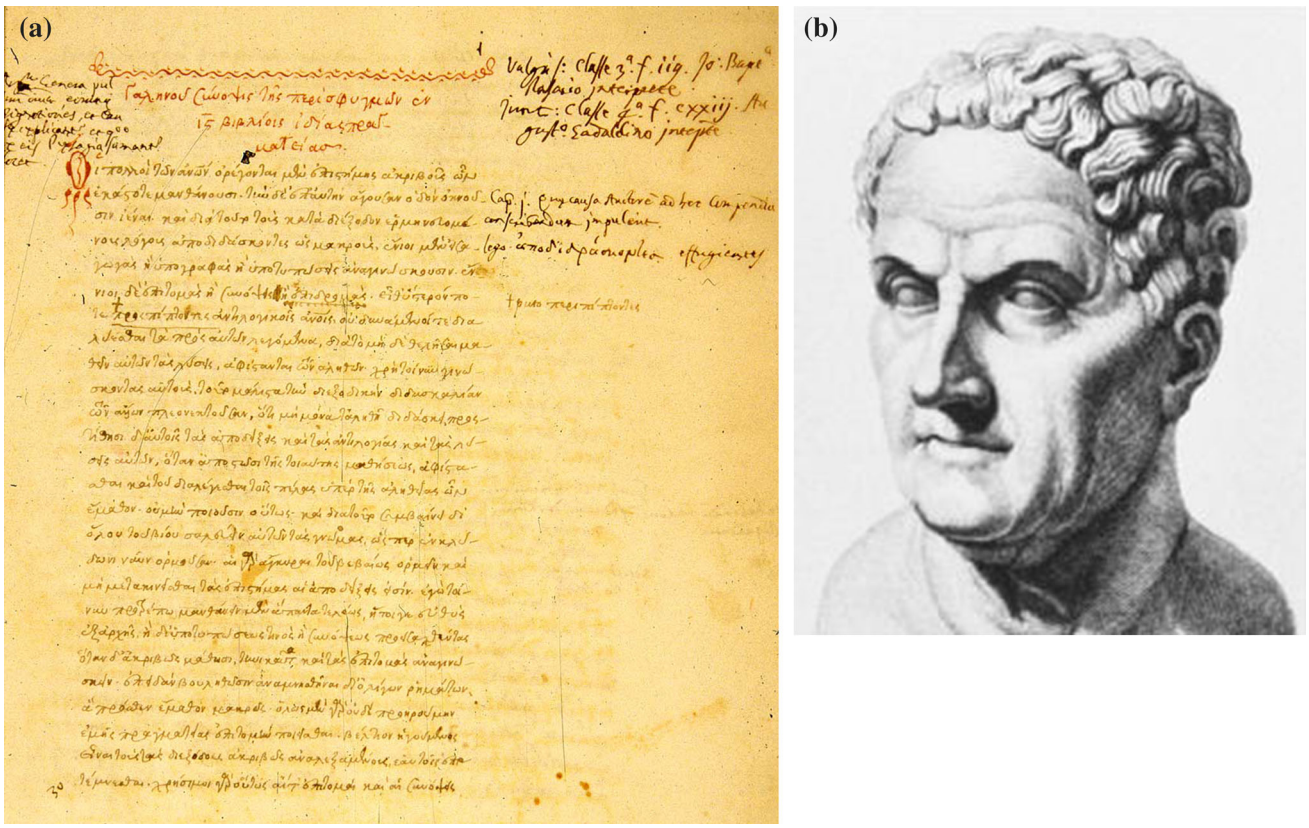


Fig. 7 **a** Manuscript (Venice, ca. 1550) of *De Pulsibus* by Galen. This Greek manuscript of Galen's treatise on the pulse is interleaved with a Latin translation. (Public domain image.) **b** Galen. (Image provided courtesy of the Library of Congress at http://www.notablebiographies.com/)

occurs when the spleen is out of order is darker in color, and the cicatrices of ulcers are dark. For generally speaking, when the spleen is drawing the atrabiliary humor into itself to a less degree than is proper, the blood is unpurified, and the whole body takes on a bad color. And when does it draw this into a less degree than it is proper? Obviously when it (the spleen) is in bad condition" (Kuhn 1821a, b; Brock 1916a, b, c, d, e).

Aulus Cornelius Celsus was born c. 25 B.C., possibly near Narbonne on the Mediterranean coast of France, and was a Roman aristocrat and author. He died c. 50 A.D., probably in Rome. Celsus' most famous work, *De Medicina*, was the first complete history of medicine and comprehensive account of medical and surgical procedures to be written in Latin—before Celsus, notable Greco-Roman physicians wrote in Greek (Magill 1998a, b, c). Celsus provided information on the anatomy of the spleen as well as the symptoms of and possible treatments for diseases associated with the spleen. In particular, he stated, "But below the heart and lungs there is a transverse septum formed of a strong membrane, separating the abdomen from the praecordia, being of a tendinous structure, and having a number of vessels dispersed on it: it separates not only the intestines, but the liver and spleen from the upper parts. These viscera are in proximity with it, but have their position below, on the right and left…. but the spleen on the left, being connected with the intestines, and not with the same septum, is of a soft and exceeding porous structure, and of a moderate length and thickness; and emerging slightly from beyond the margin of the ribs into the abdominal cavity, is principally buried under them: and these three organs are joined" (Collier 1831a, b). Celsus provided an accurate description of the macroscopic anatomy and histological nature of the spleen, but improperly claimed that the phrenosplenic ligament does not exist. Moreover, he accurately described the topography of the spleen in the region of the left hypochondrium, but wrongly stated that the spleen extends beyond the left costal arch under normal circumstances. However, it should be noted that splenomegaly caused by malaria and other infections was common in Antiquity (Oren et al. 1998). Celsus also states the following: "But when the spleen is affected, it swells, as does likewise the left side; and this last is hard and renitent: the bowels are tense: there is also some tumidity in the legs: the ulcers either do not heal at all, or certainly cicatrize with difficulty: in active walking and running there is a pain, with some sense of uneasiness" (Collier 1831a, b).

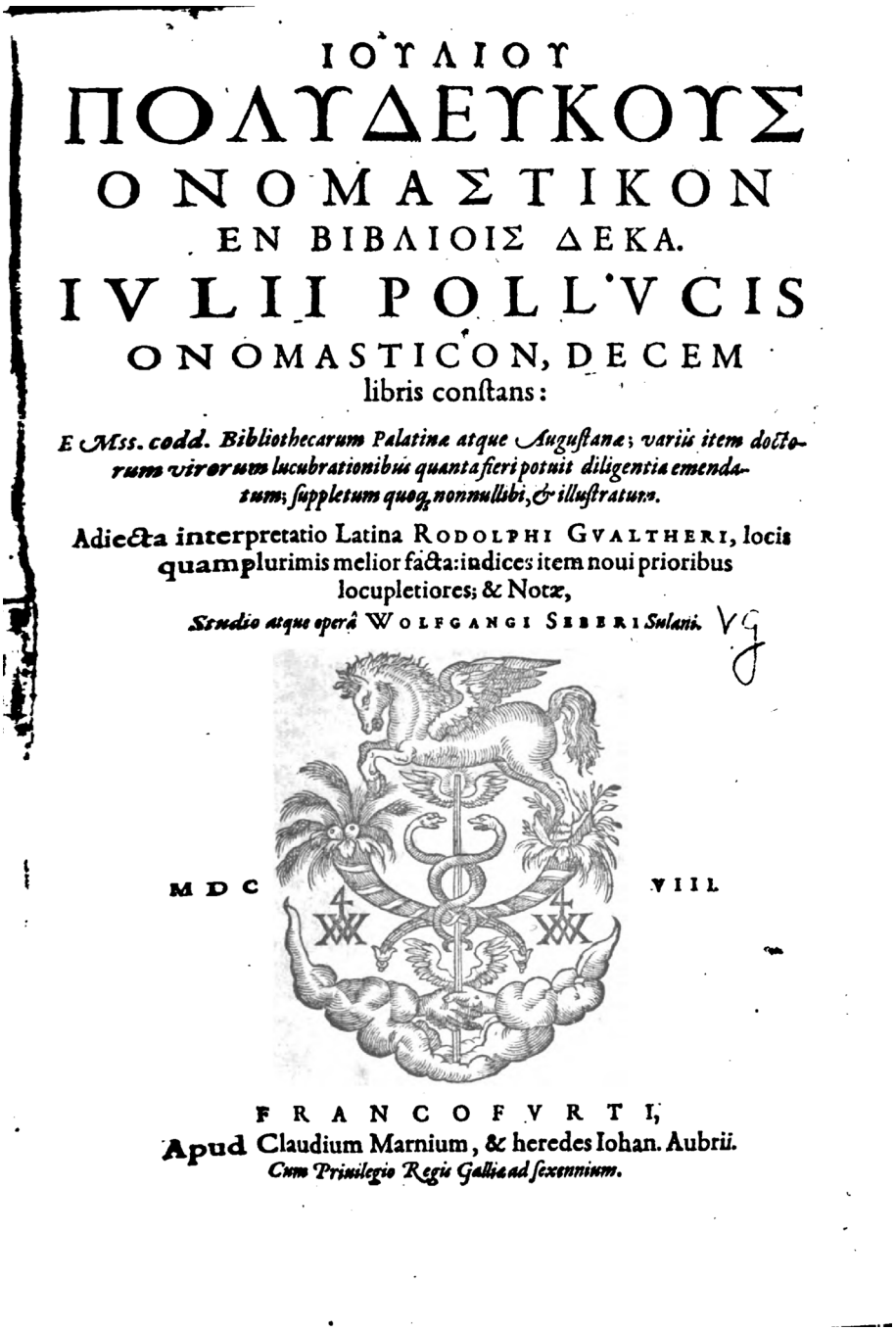
Fig. 8 Aretaeus the Cappadocian. (Image provided by the US National Library of Medicine, History of Medicine Division: http://ihm.nlm.nih.gov/)

Aretaeus of Cappadocia (2nd century A.D.) is considered by many to be the greatest physician of the ancient world after Hippocrates (see Fig. 8). He wrote the best and most accurate descriptions of many diseases and made crucial studies of diabetes and neurological and mental disorders. He probably studied in Egypt at Alexandria and it is believed that he practiced medicine in Rome (Magill 1998a, 1998b, 1998c). Information provided by Aretaeus on the spleen focused largely on its function. Indeed, he usually referred to the spleen indirectly when discussing the pathophysiological mechanisms of certain diseases, such as jaundice. He was clearly influenced by Galen as well as earlier physicians who had inspired Galen. "If jaundice make its appearance in connection with the spleen, it is dark-green, for its nutriment is black, because the spleen is the strainer of the black blood, the impurities of which it does not receive nor elaborate when diseased, but they are carried all over the body with the blood. Hence patients are dark-green from icterus in connection with the spleen; but the color is darker than usual in the customary discharges from the bowels, for the superfluity of the nutriment of the spleen becomes recrement from the bowels" (Adams 1856). Thus, Aretaeus incorrectly described icterus as a hematological disorder and gave an explanation for the illness that was based on scientific method but also the usual beliefs about the function of the spleen associated with his era.

Julius Pollux was a great rhetorician and teacher as well as a lexicographer who lived in the 2nd century A.D. He was born in Naucratis (in Egypt) and studied rhetoric in Athens. He taught Emperor Commodus and, with his assistance, Julius was appointed a chair of rhetoric in Athens. He wrote many treatises, but the only one that has survived is the *Onomasticon*, which contains details about many aspects of daily life in the ancient world (see Fig. 9) (Chatzopoulos 2004). This treatise provides insight into perceptions about the spleen during this era; for instance, "In respect to the abdomen on the left of the diaphragm the spleen happens to exist and Plato used to say that it has become effigy of the liver. Because it doesn't ensure no other need. The head of the organ is the most thick side. But it is called also splenion" (Pollux 1846). Thus, Pollux offers a precise description of the spleen's topography, but his opinion that the head of the organ (presumably the superior pole) is the thickest side is inaccurate.

Oribasius (see Fig. 10), who was born (like Galen) in Pergamum in the early 320s A.D. and died in the late 390s A.D., was personal physician to the Emperor Julian. His excellent *Synopsis*, which comprises more than 70 books, was written in order to make the huge body of Galenic works available to the ordinary practitioner (Brock 1916a, b, c, d, e). In his work *Collectiones Medicae*, Oribasius provides an authentically scientific anatomy based on the work of Galen. This treatise is considered to be the first well-organized anatomy textbook with a structure similar to modern anatomical works after Galen's *On Anatomical Procedures*. He provides information that was mentioned by Galen in reference to the physiology and gross anatomy of the spleen as well as its histological nature and topography. In particular, he mentions that "The spleen is a cleansing organ receiving the melancholic, thick and silty humors that are secreted by the liver. Thus, the spleen transmits the humors via a small vein into the stomach (presumably through the short gastric vessels). It is located deep in the abdomen, and remodels the humors transferred to it from the adjacent abdominal organs…..furthermore the spleen through an additional small vein takes the useless components of the food and that is a function not insignificant. The body of the spleen is called parenchyma and its histological nature is loose and spongy… the spleen is located on the left side of the abdomen with its concave surface facing the liver and the stomach and the convex surface being on the opposite side" (Oribasius 1556; translated by the present authors). Thus, Oribasius accurately described the morphology, topography, and structure of the spleen, but—as expected—failed to elucidate its physiology.

Paul of Aegina, also known as "the obstetrician," was a famous 7th-century physician who was an expert in woman's diseases (see Fig. 11). He lived in Alexandria, and his medical studies drew largely on the works of Hippocrates and Galen (Pormann 2004). While Paul of Aegina did not contribute any new information on the anatomy of the spleen, he did comment on illnesses of the


ΙΟΥΛΙΟΥ
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ΟΝΟΜΑΣΤΙΚΟΝ
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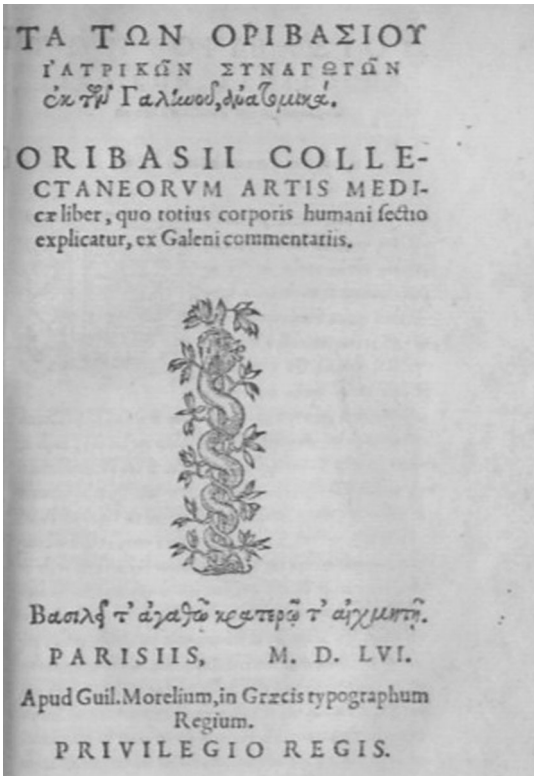
IVLII POLLVCIS
ONOMASTICON, DECEM
libris conſtans:
E Mss. codd. Bibliothecarum Palatinæ atque Auguſtanæ; variis item doctorum virorum lucubrationibus quanta fieri potuit diligentia emendatum; ſuppletum quoq; nonnullibi, & illuſtratum.
Adiecta interpretatio Latina RODOLPHI GVALTHERI, locis quamplurimis melior facta: indices item noui prioribus locupletiores; & Notæ,
Studio atque operâ WOLFGANGI SEBERI Sulani.
MDC VIII
FRANCOFVRTI,
Apud Claudium Marnium, & heredes Iohan. Aubrii.
Cum Priuilegio Regis Galliæ ad ſexennium.

Fig. 9 Cover page of the *Onomasticon* (1608) written by Julius Pollux. (Public domain image)

organ, basing his theories on the doctrine of the humors. In addition, he implied that the function of the spleen is relevant to appetite: "The use of the spleen being to attract from the liver the melancholic humor, which is, as it were, the lees of the blood, if its attractive power be weakened, or the passage obstructed by which this was formerly attracted, the black jaundice is formed, blood in an unpurified state being distributed over the whole body; and if there be weight and distension about the spleen, or if there be also pain, obstruction is indicated; but if there be none of these, it is weakness of the attractive power. But vomiting of black bile taking place without fever, or any other symptom of malignity, indicates a weakness of the retentive faculty of the spleen" (Adams 1844).

Meletius the Monk, who lived in the 8th century A.D., wrote the following on the spleen in his treatise *Nature of Man*: "The spleen cleans the liver from the purulent and turbid humors that are rejected from the liver, to familiar food. Therefore the term spleen is derived from the word ἐπισπαίσθαι which means breakthrough the incoming


ΤΑ ΤΩΝ ΟΡΙΒΑΣΙΟΥ
ΙΑΤΡΙΚΩΝ ΣΥΝΑΓΩΓΩΝ
ἐκ τῶν Γαλήνου, βιβλία κε'.

ORIBASII COLLE-
CTANEORVM ARTIS MEDI-
cæ liber, quo totius corporis humani sectio
explicatur, ex Galeni commentariis.

Βασιλεῦ τ' ἀγαθῷ καὶ περιφῶ τ' αἰχμητῇ.

PARISIIS, M. D. LVI.

Apud Guil. Morelium, in Græcis typographum Regium.

PRIVILEGIO REGIS.

Fig. 10 Cover of the *Collectiones Medicae* (1556) by Oribasius. (Early European Books, copyright 2011. Images reproduced courtesy of The Wellcome Trust, London. 393/A/1)

Fig. 11 Paul of Aegina, as pictured in a 16th-century woodcut. (Public domain image)

Fig. 12 Cropped portrait of Avicenna from a Tadjik banknote. (Licensed by http://creativecommons.org/publicdomain/zero/1.0/deed.en)

humors" (Migne 1857). In addition, we should mention the work *Introduction to Anatomy*, written by an anonymous author and based on the writings of Aristotle. The author of this text is unknown but was thought to be a Byzantine physician (Pournaropoulos 1973). In a discussion of the spleen, the anonymous author notes, "Above is the diaphragm, on the left, the spleen naturally exists. Attached to the abdomen on the omentum. The look of the human spleen is narrow and long. As it is necessary, the nature of the spleen is such that the spleen is not much in all the animals. Many of them have no spleen or they have a small and a solid one. And the liver and the spleen contribute in the digestion of the food. And it looks that the liver and the spleen are amphoteric. Also as single or twofold organs they have the similar nature. The cause of which is that those who necessarily have spleen, the spleen seems to be a bastard liver. Through the spleen comes the vein, from the great vein, the so-called gate. And from which trends vein into the spleen" (Kouzis 1909). This anonymous author therefore succeeds in accurately describing the spleen's topography and morphology as well as the splenic vein, which drains into the "great vein" (likely to be the portal vein). Nevertheless, the author does not consider the physiology of the spleen.

Finally, Avicenna (see Fig. 12) was born in 980 A.D. in Bukhara, Persia (present-day Uzbekistan) during a unique time in the Middle East. The relatively new religion of Islam was spreading into North Africa, Europe, and the rest of Asia. Muslim Arabs were exchanging goods and ideas

with a wide variety of cultures. It was in this dynamic and intellectual world that Avicenna grew to prominence (Khan 2006). He possessed an unusually high ability to comprehend the sciences, and also studied medicine. Avicenna was influenced by Aristotle, and his work in turn influenced medieval Europe. Although his anatomical observations of the spleen, as described in the *Canon*, added nothing new to this field of study, he managed to describe the physiology and utility of this viscus in a wider context, always in reference to the other organs. This work was, of course, based on the doctrine of the humors, which dominated for many centuries; for example, "The portion (of atrabilious humor) which passes to the spleen is such as is of no longer any use to the blood. Its primary use as regards the body as a whole is that it clears the body of so much effete matter. Its use in regard to one special organ is that it supplies nourishment to the spleen. The part of atrabilious humor which goes to the spleen is such as is no longer needed by the blood and that part that emerges from the spleen is no longer needed by the spleen" (Book 1, Thesis IV, Paragraphs 88–89; Gruner 1929a, b). Avicenna believed that weakness of the spleen was one of the circumstances that could lead to excess atrabilious humor. Furthermore, he provided an explanation for visceral pain in the spleen and other viscera due to inflammation or tumors: "Due to membranes which impart sensation to members which are themselves insensitive by providing a sensitive covering, they enable the member to be aware of anything befalling it. For example, lung, liver, spleen, kidneys. A flatulent distension or an inflammatory deposit in the organ is felt by us only because the enclosing membrane, being stretched, feels it; or in the case of an inflammatory mass is aware of the weight" (Book 1, Thesis V, Paragraph 116) (Gruner 1929a, b).

Conclusion

It is clear that, as Galen states, the spleen is an organ "full of mystery." Much of the research into this viscus that took place over many centuries from Antiquity to the Early Middle Ages was characterized by the doctrine of the humors and strongly influenced by the works of Hippocrates and Galen. Generally speaking, those works reported macroscopic observations of the spleen (usually based on studies of animals) as well as arbitrary hypotheses concerning the spleen's physiology. Therefore, descriptions of the spleen's gross anatomy were usually relatively accurate, whereas accounts of the spleen's physiology were usually incomplete and inaccurate. Such perspectives on the anatomy and function of the spleen dominated this field until the Renaissance, and guided physicians to appropriate therapies.

Compliance with ethical standards

Conflict of interest The content has not been published or submitted for publication elsewhere. All authors have contributed significantly, and all authors are in agreement with the content of the manuscript. The authors declare that they have not received any funding support and they do not have any conflict of interest.

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