

# Galen's understanding of the digestive system in the context of the commensurability of medical knowledge in different periods

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## Abstract

The foundations of ancient rational medicine were laid by Hippocrates, but the credit for rethinking medicine as a comprehensive system of protoscientific knowledge belongs to Galen. Before him, medicine had no unified system of thought on the basic principles of the structure of living things, and no systemic approach to clinical practice, based on the apodictic method. In this article, I examine Galen's teachings on the digestive system (one of the key aspects of his system) in terms of the "commensurability" of the ideas of ancient medicine and modern science. An analysis of the information in Galen's works indicates that his system of theory and practice is substantially commensurable with the principles of modern medicine: many aspects of modern theory and practice represent a development of Galen's ideas.

A comparative analysis of Galen's reconstructed views and those found in modern medicine calls for the use of tools from philosophy and the history of science to enable a correct interpretation of the historical medical texts. Such fundamental concepts include "type of rationality" and "scientific worldview". This research is based on extant texts by Galen, primarily his two treatises *On the Natural Faculties* and *On the Usefulness of the Parts of the Body*, which may be regarded as fundamental to reconstructing Galen's views on physiology and anatomy. Galen constructs a comprehensive system rather than simply listing individual facts he knows. The treatises in question underline the comprehensive and systemic nature of the great Roman physician's arguments, which were to a large extent supported by experiment.

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## Keywords

history of medicine, ancient medicine, Galen, digestive system, stomach, oesophagus, intestine, bowel

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This article analyses Galen's teachings on the digestive system in terms of the "commensurability" of the ideas of ancient medicine and modern science. To start with, it is worth recalling the division of the history of medicine as a science into periods, according to which Galen's works are seen as the starting point for the protoscientific period (Balalykin 2016). Before Galen, medicine had no universal, unified system of thought on the basic principles of the structure of living things, no integrated system of anatomy and physiology, and no systemic approach to clinical practice, based on the apodictic method. These approaches had been outlined by Hippocrates, but the credit for rethinking medicine as a comprehensive system of protoscientific knowledge

undoubtedly belongs to Galen (Balalykin and Shok 2016).

A second important feature of my proposed methodology is that it examines the views of scholars in antiquity on specific aspects of anatomy and physiology in terms of the "commensurability" of the scientific knowledge of medicine in different periods, which I consider an important practical solution to the general challenge of analysing historical events from a contextualist position.

My proposed method of analysing and comparing medical knowledge in different periods represents a development of the ideas of Thomas Kuhn (Kuhn 2014). The prominent historian of science, who developed a

theory of scientific revolutions, proposed using the term “incommensurability” to describe the differences in the language of science in different periods. Kuhn used this concept in analysing paradigms in physics from the time of Aristotle until the mid-twentieth century.<sup>1</sup>

It is worth noting that Galen’s medicine is not as fundamentally different from modern medicine as the physical theories of antiquity are from modern physics. There is a considerable level of commensurability between Galen’s system of theory and practice and the principles of modern medicine: while one cannot argue with the views of Kuhn and Karl Popper that, for example, twentieth-century physics and the basic concepts of Aristotle’s physics are not commensurable, the correlation between Galen’s views and the ideas of modern medicine makes it possible to argue that they are.

When comparing Galen’s views to the methods of inquiry used in scientific medicine today, we also need to use certain tools from philosophy and the history of science: the concepts of “type of rationality”, “scientific worldview”<sup>2</sup> and others needed to interpret his texts correctly. We need to bear in mind Galen’s attempt to establish a universal and consistent comprehensive system of medical knowledge (Balalykin 2015).

The main sources used in this study are Galen’s two treatises *On the Natural Faculties* (Galen 2018a)<sup>3</sup> and *On the Usefulness of the Parts of the Body* (Galen 1971).<sup>4</sup> With regard to their significance, two factors need to be borne in mind. First, they are essential to getting a full picture of Galen’s views on the physiology (*On the Natural Faculties*) and anatomy (*On the Usefulness of the Parts of the Body*) of humans and the most advanced animals. Second, they have been unjustifiably neglected in the historiography. *On the Natural Faculties* has long since been translated into English (Brock 1916), but no commentator as yet has provided a comprehensive analysis of it within the general context of the history of physiology. I attempted to do this during the preparation of its translation into Russian (Galen 2018a), which was published in 2018. *On the Usefulness of the Parts of the Body* is much more familiar to Russian speakers than to English speakers: a complete translation of it into Russian was published in 1971, and it was for a long time the only work by Galen available in the language (Galen 2018a). This was edited by Vasilii Ternovskiy, a prominent scholar and anatomist in his day,

ensuring that the highly complex anatomical material was rendered into good Russian. Ternovskiy, however, did not provide a comprehensive analysis of the text, merely writing a brief introductory article. Here, he suggested in particular that Galen had performed numerous dissections of the most advanced animals because he did not have the opportunity to dissect human cadavers. This, according to Ternovskiy, explains a number of Galen’s misunderstandings of the structure of the human body. It was even suggested that a special term be used to describe Galen’s “approximate” knowledge: “descriptive anatomy”, as opposed to “scientific anatomy”, which began with the works of Andreas Vesalius. I have repeatedly criticised this view as unfounded, but it is widespread among anatomists and historians of medicine.<sup>5</sup>

It seemed to me that a comprehensive analysis of these two fundamental texts by Galen would produce good results. Galen does not simply list individual facts known to him: he sets out a comprehensive system of anatomy and physiology. Thus, the comprehensive and systemic nature of the great Roman physician’s arguments, which were to a large extent supported by experiment, becomes clear.

## The structure and functions of the oesophagus and the stomach

Galen regards the oesophagus as merely the instrument by which food is delivered to the stomach. His understanding of the functional purpose of the oesophagus is very close to ours: he sees it as the part of the body responsible for transporting food previously ground down in the mouth to the stomach. He points out the similar structure of the muscles of the walls of oesophagus and the cardiac portion of the stomach, emphasising that food does not undergo any changes in the oesophagus. Galen also notes that the oesophagus has relatively few blood vessels compared to the stomach. He believes this to be because the oesophagus receives exactly the amount of blood it needs to provide nutrition to the muscles of its own coat. Their job is to ensure only the motor activity, and, thereby, the delivery of food from the oral cavity to the stomach.

Galen presents the stomach as the true organ of digestion, in which food undergoes both mechanical and qualitative changes. The great Roman physician clearly refers to the existence of a mechanism by which nutriment is acquired from food: it is absorbed through the walls of the stomach and the intestines to the veins. Matter useful to the body is absorbed, while matter that is not passes down through the digestive system and is excreted: “For just as workmen skilled in preparing wheat cleanse it of any earth, stones, or foreign seeds

<sup>1</sup> For more details on this, see (Balalykin 2015).

<sup>2</sup> For more on these terms, see (Stepin 2015).

<sup>3</sup> A complete translation of *On the Natural Faculties* from the Greek into Russian appears in Volume V of *The Works of Galen* (Galen 2018a). The English translations used here are taken from *Galen: On the Natural Faculties*, translated by A.J. Brock, Loeb Classical Library, 1916 (Brock 1916).

<sup>4</sup> The English translations used here are taken from *Galen: On the Usefulness of the Parts of the Body*, translated by Margaret Tallmadge May, vol. I, Cornell University Press, 1968.

<sup>5</sup> See (Balalykin 2014).

mixed with it that would be harmful to the body, so the faculty of the stomach thrusts downward anything of that sort, but makes all the rest of the material, that is naturally good, still better and distributes it to the veins extending to the stomach and intestines” (Galen 1971).

Galen's ideas on the diversity and importance of the physiological processes occurring in the stomach may be correctly understood only by comparing what he has to say on its physiology and anatomy with his description of the workings of the other digestive organs.

### Galen's understanding of the physiology of digestion in the stomach

The complexity of the processes involved in the processing of all kinds of foods in a person's body reflects the fact that some of them are absorbed, while others, unsuitable for absorption, or surplus to requirements, are excreted from the body. Accordingly, the organs too must be highly complex in structure: their job is to remove the superfluities and deliver the useful matter to the parts of the body that need it. Nutrition, writes Galen, is “*an assimilation of that which nourishes to that which receives nourishment*. And in order that this may come about, we must assume a preliminary process of *adhesion*, and for that, again, one of *presentation*. For whenever the juice which is destined to nourish any of the parts of the animal is emitted from the vessels, it is in the first place dispersed all through this part, next it is presented, and next, it adheres, and becomes completely assimilated” (Brock 1916, p. 39).

According to Galen, the function of “assimilation” (a necessary transformation of nutriment taking place in the digestive system) comes first, followed by the functional processes of “adhesion” and “presentation”. At the end of this chain of interrelated and interdependent functions comes a process that Galen again calls “assimilation”, but here the meaning is different. The first, initial, “assimilation” is the transformation of food, which is foreign in nature and enters the body from outside, into certain substances suitable for the body to absorb. This process takes place mainly in the stomach, and partly in the small intestine. The second is the final absorption by the parts of the body of the nutriment once it has been processed into a fundamentally different state. These processes take place after blood imbued with the necessary nutriment has reached the parts of the body. Galen, justifiably, clarifies this: “Strictly speaking, then, *nutriment* is that which is actually nourishing, while the *quasi-nutriment* which is not yet nourishing (*e.g.* matter which is undergoing adhesion or presentation) is not, strictly speaking, nutriment, but is so called only by an equivocation. Also, that which is still contained in the veins, and still more, that which is in the stomach, from the fact that it is destined to nourish if properly elaborated, has been called ‘nutriment’” (Brock 1916, p. 41, 43). Galen posited the existence of

highly complex biochemical mechanisms for processing nutriment so that it can be further absorbed. The ‘destined nutriment’ in the stomach is food, but cannot directly strengthen the worn-out homoiomeres of the muscles, which are built into them as an appropriate specific combination of primary elements. Food has to be processed in the stomach, and then in the liver, where, according to Galen, venous blood is synthesised from the substances that have entered the body.

However, even this is not enough: Galen suggests that the substances flowing from the blood to the tissues must be further processed, and only then do they become the building material for the homoiomeric parts of the body. He emphasises that he agrees with his great predecessor: “This was also what Hippocrates said, viz., ‘Nutriment is what is engaged in nourishing, as also is quasi-nutriment, and what is destined to be nutriment’. For to that which is already being assimilated he gave the name of *nutriment*; to the similar material which is being presented or becoming adherent, the name of *quasi-nutriment*; and to everything else – that is, contained in the stomach and veins – the name of *destined nutriment*” (Brock 1916, p. 43). A brilliant insight on the part of Hippocrates and Galen was their understanding that the nutriment entering the body from outside had to take on a substantial similarity with the homoiomeres making up the parts of the body nourished by them.<sup>6</sup>

Galen's understanding of the physiology of living beings is based on a hypothesis that the parts of the body, being different in structure, attract different constituents of the matter entering the body as food.

In physiological terms, Galen sees the work of the stomach as a combination of the functions of “retention” and “expulsion”. The great physician constantly illustrates his arguments regarding aspects of theory with specific examples from clinical or experimental practice. For example, he observes that many physicians, not without justification, regard “gurgling” in the stomach as a sign of gastric disease. This process does not depend on the amount of food: Galen notes that if the stomach is in a healthy condition, “even if its contents be very small, it grasps the whole of them and does not leave any empty space” (Brock 1916, p. 237). According to him, disruption to the normal function of this organ leads to disruption of both processes – both retention and expulsion. In a state of illness, retention is impaired, the food is not grasped tightly, and empty spaces appear – and it is in these, according to Galen, that the sounds in question arise. Disruption to the digestive mechanism affects both liquids and solid food.

*On the Natural Faculties* allows us substantially to reconsider our views on the history of physiological studies of the gastrointestinal tract, and indicates that the first experimental studies of digestion in the history of

<sup>6</sup> See *On the Natural Faculties* (Brock 1916, p. 39, 41, 43).

medicine were performed by Galen. The great physician refers directly to the existence of a physiological norm for the amount of time it takes for the stomach to digest food. The experimental procedure as a result of which Galen draws his conclusions is extremely interesting. Galen conceptualises in advance the goal of an experiment performed on animals, repeats it multiple times, and clearly explains: “Suppose you fill any animal whatsoever with liquid food – an experiment I have often carried out in pigs, to whom I give a sort of a mess of wheaten flour and water, thereafter cutting them open after three or four hours; if you will do this yourself, you will find the food still in the stomach. For it is not *chylification* which determines the length of its stay here – since this can also be effected outside the stomach; the determining factor is *digestion* which is a different thing from chylification, as are blood-production and nutrition. For, just as it has been shown that these two processes depend upon a *change of qualities*, similarly also the digestion of food in the stomach involves a transmutation of it into the quality proper to that which is receiving nourishment.

Then, when it is completely digested, the lower outlet opens and the food is quickly ejected through it, even if there should be amongst it abundance of stones, bones, grape-pips, or other things which cannot be reduced to chyle. And you may observe this yourself in an animal, if you will try to hit upon the time at which the descent of food from the stomach takes place. But even if you should fail to discover the time, and nothing was yet passing down, and the food was still undergoing digestion in the stomach, still even then you would find dissection not without its uses. You will observe, as we have just said, that the pylorus is accurately closed, and that the whole stomach is in a state of contraction upon the food very much as the womb contracts upon the foetus” (Brock 1916, p. 241, 243).

Galen realises that gastric disorders often happen when the stomach “is irritated by acidity” (Brock 1916, p. 247). This assertion suggests that the chronology generally agreed in the literature with regard to the study of ulcers of the stomach and duodenum might need revising (Balalykin 2008, Balalykin 2005, Balalykin 2017a): Galen’s remarks on gastric diseases and stomach disorders resulting from excess acidity are the oldest evidence we currently have of such a pathogenetic view of such conditions. This is yet further confirmation of the exceptional value of Galen’s works as a source.

Galen had a deep understanding of issues relating to gastric health and disease. He describes dysphagia, expressly linking the status of the disease in terms of its symptoms with the presence (or lack) of an appetite in the patient: “This may often be clearly observed in those who are disinclined for food; when obliged to eat, they have not the strength to swallow, and, even if they force themselves to do so, they cannot retain the food, but at once vomit it up. And those especially who have

a dislike to some particular kind of food, sometimes take it under compulsion, and then promptly bring it up; or, if they force themselves to keep it down, they are nauseated and feel their stomach turned up, and endeavouring to relieve itself of its discomfort” (Brock 1916, p. 247).

In describing the process of the “attraction” of the substances the body needs, and to which it has an inclination, and the rejection and “elimination” of “foreign” substances, Galen uses the word “benefit”. By “some benefit”, which for the body means a healthy stomach here, he has in mind the teleological principle. Specialists today would be more likely to use the phrase “physiological purpose” or “physiological benefit”. However, this does not alter the gist of the matter: Galen’s ideas on diseases of the stomach remind us once again that the teleological principle is fundamental to his theory. Galen believes that the human body was created by the Creator as a well-defined, balanced complex, all parts of which were interconnected. Nothing in it is superfluous, and if the purpose of any its parts or the meaning of a physiological process is unclear to a doctor, this is a cause for further research. There is nothing useless or unnecessary in the body of a living being, and there cannot be – such is the essence of one of Galen’s fundamental disagreements with Erasistratus and his followers (Balalykin 2018a, Balalykin 2018b, Balalykin 2018c).

Galen sees the work of the stomach not just as the physical digestion of food, but also as sorting it, as a kind of filter. The components of the food in the stomach that are useful to the body are extracted and absorbed. The useless, “foreign”, elements are separated from the useful ones, and the gastrointestinal tract, when “sufficiently full”, “puts away from it, as one might something troublesome, the rest of the food” (Brock 1916, p. 251). At the same time, Galen sees the physiological process of digestion in the stomach as the interaction of ‘two bodies’ that need each other. In other words, the stomach affects the food, but the food also affects the stomach.

The process of digestion, according to the great Roman physician, starts in the mouth, where the food undergoes not only mechanical processing, but also certain other “alterations”.

Galen realised that at the different stages of digestion food was altered not only mechanically, but also in substance: “We must, therefore, observe to what extent [*the stomach*] does alter [*food*]. The alteration is more than that which occurs in the mouth, but less than that in the liver and veins. For the latter alteration changes the nutriment into the *substance* of blood, whereas that in the mouth obviously changes it into a new *form*, but certainly does not completely transmute it. This you may discover in the food which is left in the intervals between the teeth, and which remains there all night; the bread is not exactly bread, nor the meat, for they

have a smell similar to that of the animal's mouth, and have been disintegrated and dissolved, and have had the qualities of the animal's flesh impressed upon them. And you may observe the extent of the alteration which occurs to food in the mouth if you will chew some corn and then apply it to an unripe [undigested] boil: you will see it rapidly transmuting – in fact entirely digesting – the boil, though it cannot do anything of the kind if you mix it with water. And do not let this surprise you; this phlegm [saliva] in the mouth is also a cure for *lichens*; it even rapidly destroys scorpions; while, as regards the animals which emit venom, some it kills at once, and others after an interval; to all of them in any case it does great damage” (Brock 1916, p. 251, 253). Galen puts forward a hypothesis that would be confirmed in the twentieth century by the discovery of enzymes and the protective properties of saliva.

The great physician analyses the process by which food is digested in the stomach, stating that it is at this stage that it undergoes its greatest alteration (compared to the previous stage, in the oral cavity, and the next, in the intestines). Galen is right to say that the food processed in the stomach changes not just mechanically but also in quality and substance. “How,” he asks, “could it easily become blood if it were not previously prepared by means of a change of this kind?” (Brock 1916, p. 255). In his view, the remaining food that is not required by the body undergoes less profound (compared to those in the stomach), but still serious alterations in the intestines. Unlike many of his contemporaries, Galen believed that faeces were not formed in the small intestine, to which he assigned the role of a digestive organ.

The idea that food does not change qualitatively in the stomach but acquires the form of faeces in the small intestine, which was commonplace among physicians in his day, seems absurd to Galen, precisely because of his views on the physiological processes. His teachings on the qualitative (what doctors today would call “chemical”) alterations of food in digestion are eminently rational: “For what possible reason, then, will objectors have it that bread may often remain a whole night in the stomach and still preserve its original qualities, whereas when once it is projected into the intestines, it straightway becomes ordure? For, if such a long period of time is incapable of altering it, neither will the short period be sufficient, or, if the latter is enough, surely the longer time will be much more so! Well, then, can it be that, while the nutriment does undergo an alteration in the stomach, this is a different kind of alteration and one which is not dependent on the nature of the organ which alters it? Or if it be an alteration of this latter kind, yet one perhaps which is not proper to the body of the animal? This is still more impossible. Digestion was shown to be nothing else than an alteration to the quality proper to that which is receiving nourishment. Since, then, this is what digestion means and since the

nutriment has been shown to take on in the stomach a quality appropriate to the animal which is about to be nourished by it, it has been demonstrated adequately that nutriment does undergo digestion in the stomach” (Brock 1916, p. 255, 257).

### The anatomy of the stomach: Galen's teleological approach

The great Roman physician states that the stomach has three coats. Two of these are muscular – an inner and an outer, with the latter being “of a more fleshy nature in the gullet” (Brock 1916, p. 261, 263). With the teleological principle in mind, Galen is interested in why the organ has its particular structure. Galen is always asking himself what the functional purpose of this organ is: “The inner coat has its fibres straight, since it exists for the purpose of traction. The outer coat has its fibres transverse, for the purpose of peristalsis. In fact, the movements of each of the *mobile* organs of the body depend on the setting of the fibres. Now please test this assertion first in the muscles themselves; in these the fibres are most distinct, and their movements visible owing to their vigour. And after the muscles, pass to the *physical* organs, and you will see that they all move in correspondence with their fibres. This is why the fibres throughout the intestines are circular in both coats – they only contract peristaltically, they do not exercise traction. The stomach, again, has some of its fibres longitudinal for the purpose of traction and the others transverse for the purpose of peristalsis. For just as the movements in the muscles take place when each of the fibres becomes tightened and drawn towards its origin, such also is what happens in the stomach” (Brock 1916, p. 263).

Galen states that the contraction of the longitudinal muscle fibres is just as important as that of the transverse ones: peristalsis involves a combination of the contraction of the two.

It is thanks to the consistent work of the longitudinal muscles of the stomach that food is drawn from the oesophagus to the stomach and onwards, which Galen sees as a physiological mechanism supporting the function of “traction”, which he discusses in the treatise. He links the sense of appetite with how strongly this function is expressed. “Thus the actual process of swallowing occurs very quickly in those who have a good appetite for such foods as are proper to the stomach; this organ obviously draws them in and down before they are masticated; whereas in the case of those who are forced to take a medicinal draught or who take food as medicine, the swallowing of these articles is accomplished with distress and difficulty” (Brock 1916, p. 269).

In Galen's system of thought, based on the teleological principle, the functional purpose of a part of the body, and its relationship to the function of the adjacent

parts, which are specifically connected with it within the overall system, is of huge importance (Balalykin 2017b). Galen identifies three coats in the stomach: two muscular ones, which are, as it were, a continuation of the oesophagus and perform the function of supporting gastric motility. The third coat covers the stomach on the outside. Nature, according to the great physician, has created this “as a covering and protection for the second, fleshy coat” and “has made *[it]* into a ligament to bind the entire stomach to the parts at the spine” (Galen 1971).

Galen attempts to analyse in detail the functional purpose of the two components of the muscular coats of the oesophagus and stomach. He is clearly very interested in what the functional relationship between these two organs is. Naturally, this important anatomical and physiological question needed to be answered with the help of experiments, which Galen indeed performed: “Take an animal, then; lay bare the structures surrounding the gullet, without severing any of the nerves, arteries, or veins which are there situated; next divide with vertical incisions, from the lower jaw to the thorax, the outer coat of the oesophagus (that containing transverse fibres); then give the animal food and you will see that it still swallows although the peristaltic function has been abolished. If, again, in another animal, you cut through both coats with transverse incisions, you will observe that this animal also swallows although the inner coat is no longer functioning. From this it is clear that the animal can also swallow by either of the two coats, although not so well as by both. For the following also, in addition to other points, may be distinctly observed in the dissection which I have described – that during deglutition the gullet becomes slightly filled with air which is swallowed along with the food, and that, when the outer coat is contracting, this air is easily forced with the food into the stomach, but that, when there only exists an inner coat, the air impedes the conveyance of food, by distending this coat and hindering its action” (Brock 1916, p. 273–275).

Galen writes of “a pair of nerves of considerable size” (Galen 1971) that descend to the stomach, and, each branching in its own direction, cover the stomach as far as its lower end. Clearly, he is talking about the vagus nerve, some branches of which are found in the walls of the lower part of the stomach. Galen, of course, could not have observed these. The stomach, Galen believes, is round and elongated so that it can be as capacious as possible. Its lower end is broader than its mouth, because it is directed downwards when it is filled. Its constriction when food is transferred to the intestines is particularly significant: the purpose of this anatomical detail is to prevent “anything large or hard” from getting into the intestines (Galen 1971). The stomach’s inner coat is “somewhat membranous”, as Galen describes the mucosal fold,

emphasising that the muscular coat has straight fibres. These features assist in peristalsis. Galen’s view of the purpose of the omentum, which covers part of the stomach, is as follows: “Hence to serve this same purpose, namely, to warm the stomach, Nature has not hesitated to form at the front, covering it completely, a certain body that is dense but at the same time light and warm. It is dense in order to keep in the innate heat, light in order to give heat without painful pressure, and warm – well, we need give no reason why it is warm, because anything formed for heating must have this quality” (Galen 1971). As such, Galen believes, anatomical structures help to preserve the innate heat, providing energy to biological processes. As empirical confirmation for this theory, the great physician reminds his readers of the experience of patients who have had their omentum removed as a consequence of operations to treat penetrative wounds of the abdominal organs. He recalls: “I myself once removed nearly the whole omentum from a gladiator who had been wounded in this way. The man recovered promptly, but he was so sensitive to external cold and so easily harmed by it that he could not bear to have his abdomen uncovered and kept himself wrapped in wool. His whole body, however, was naturally thin, particularly in the region of the stomach, and I have thought that this was the reason why he was easily chilled” (Galen 1971).

The stomach “is subject to very great distension due to food and drink” (Galen 1971), so it is supported by a strong ligament structure. In addition, this, the main organ of digestion in Galen’s system, is abundantly supplied with blood vessels. When one recalls the function of the veins carrying the nutriment absorbed from the food from the stomach to the liver, it becomes clear why Galen pays so much attention to these anatomical structures.

The intestines, notes Galen, also contract upon their contents. This stage of digestion also involves an integral physiological process, combining manifestations of the retentive and expulsive faculties. Interestingly, Galen reaches this conclusion via an experiment rather than speculation: “Now I have personally, on countless occasions, divided the peritoneum of a still living animal and have always found all *the intestines* contracting peristaltically upon their contents. The condition of the *stomach*, however, is found less simple; as regards the substances freshly swallowed, it had grasped these accurately both above and below, in fact at every point, and was as devoid of movement as though it had grown round and become united with the food. At the same time I found the pylorus persistently closed and accurately shut, like the os uteri on the foetus.

In the cases, however, where digestion had been completed the pylorus had Opened, and the stomach was undergoing peristaltic movements, similar to those of the intestines” (Brock 1916, p. 245).

## Galen's views on the physiological significance of the liver

The useful matter acquired by the body dissolves in the venous contents and is carried to the liver. There is a reason that I am using the expression “venous contents” rather than “blood”. According to Galen, blood itself is formed in the liver from the useful matter taken by the body from food. In *On the Usefulness of the Parts of the Body*, he does not say exactly which particular fluid fills the veins running from the stomach and intestines to the liver. To him, it is clear that actual blood fills the veins flowing from the liver to the parts of the body, and this blood is formed in the liver from the constituents of food that are absorbed into the veins of the stomach and intestines through their walls: “When the liver has received the nutriment already prepared by its servants and having the crude outline, as it were, and indistinct semblance of blood, it provides the final elaboration itself so that the nutriment becomes actual blood” (Galen 1971).

Describing the portal veins, Galen writes: “Just as city porters carry the wheat cleaned in the storehouse to some public bakery of the city where it will be baked and made fit for nourishment, so these veins carry the nutriment already elaborated in the stomach up to a place for concoction common to the whole animal, a place which we call the liver” (Galen 1971). Galen compares to their contents to “a fluid or humor, pre-concocted and already elaborated, but still needing its concoction to be completed” (Galen 1971). Later in *On the Usefulness of the Parts of the Body*, Galen makes extensive use of metaphors from winemaking to illustrate his ideas on the specific “chyle” filling the portal veins. This is cleansed of the unnecessary impurities, which form faecal matter as they pass further down the coils of the intestines. However, it also contains unnecessary “residues”, which have to be rendered harmless and processed in the liver.

The blood formed in the liver is sent via the superior and inferior venae cavae to the upper and the lower parts of the body. Galen believes that this blood is “charged in abundance with a thin, watery fluid” (Galen 1971), noting that Hippocrates shared this view. I think this remark is important: it reminds us that in the medicine of Hippocrates and Galen the “blood” that is one of the four humours is not the same as the “blood” running through a particular blood vessel. As Galen sees it, the vessels do not contain just blood: the arteries contain blood and pneuma, while the veins may contain blood mixed with phlegm or bile (the latter being a feature of serious disease). This is a reason to take a detailed look at humoral theory, the basis of the views of Hippocrates and Galen, in terms of the concept of “commensurability”. Studying the historiography, I have been unable to find any (!) textbook or guides on ancient medicine that talks about

the so-called four humours of the human body in professional, medical language: where exactly, and under what conditions, are these humours contained? Some interpretations of the ideas of Hippocrates and Galen by modern historians give the impression that the ancient physicians saw the human body as a kind of barrel with a mixture of these four humours (or juices) sloshing around in it.

There is not enough space in this article to discuss this issue, so I will merely give one example from general pathology: in Galen's system, black bile is a factor in carcinogenesis. A cancerous tumour does not form without an excess of black bile. We know that such tumours arise in various parts of the body, and there is only one way for black bile to end up in any of them: with the blood circulating in the vessels. In fact, modern medical theory also understands that cancer metastasizes via a circulating fluid. The only difference is that today we know that metastasis can be lymphatic as well as haematogenous.

According to Galen, veins may contain not blood, but a nutritive chyle – i.e. water containing a thick suspension of the nutriment extracted from food in gastric digestion. In addition, the blood in the veins may vary in consistency (containing more or less fluid): For example, the blood in the venae cavae has a higher fluid content. This may be understood not only as a view on possible differences in the qualitative composition of the blood, but also as a reference to the presence in the veins of the other basic humours as well – not just blood, but also phlegm and both types of bile. Such a combination is possible in a state of health, whereas the presence of an increased concentration of black bile in the blood is associated with the development of a pathological process.

There may be little water in the veins, or there may be enough for the parts of body to perform their functions. There may also be an excess of water with impurities dissolved in it (Galen calls these mixtures “thin fluids”), which is expelled through the kidneys: “This is the purpose for which the kidneys have been formed, hollow instruments that attract this thin, watery residue through one set of canals and expel it through another” (Galen 1971). Galen thus classes the kidneys as part of the digestive system.

In assessing Galen's views on the anatomy and physiology of the liver, we need to bear in mind that he assigns a significant role to the lowest, “desiderative”, part of the soul, located in the liver. The vegetative pneuma (or “vegetative spirit”), according to Galen, is the main mediator of this level of physiological processes. The lowest part of the soul is substantively similar to the tissue of the liver and dies at the same time as this organ. In general, I have already written in some detail on the physiological importance of the vegetative pneuma and the activities of the lowest part of the soul (Balalykin 2015).

## Galen on other digestive organs

Galen discusses the part of the small intestine, which emerges directly from the stomach “between the jejunum and the lower part of the stomach” and “is customarily called ‘the outgrowth into the intestine’ by anatomists” (Galen 1971). He points out the anatomical features distinguishing it from the other parts of the small intestine: it does not form coils and runs along the spine as a continuation of the stomach. Galen writes: “Here, then, is the list of the instruments which, after the stomach, receive the nutriment: 1. Outgrowth; 2. Jejunum; 3. Thin intestine; 4. Caecum; 5. Colon; 6. Rectum. At the end of the rectum are the sphincter muscles that confine the residues” (Galen 1971).

The importance of the duodenum, according to Galen, is due to the fact that the bile duct leads into it. Galen points out the functional purpose of this, illustrating the importance of bile to digestion. The presence of bile<sup>7</sup> in the stomach disturbs gastric digestion right up to the total disruption of the organ’s function. However, the food processed in the stomach has “viscous”, “thick” and “phlegmatic” components, which bile helps to process. Consequently, the mechanism of involving bile in the processing of food immediately after its digestion in the stomach, without the bile entering the stomach, is the ideal structure of the digestive system from a teleological point of view. It is through this mechanism, brilliantly created by Nature, believes Galen, that the bile duct enters the duodenum. In addition, Galen, in detailing the anatomy of the gallbladder, rightly assesses its function as a reservoir for bile, excesses of which it expels to the duodenum when required.

Galen mentions the pancreas more than once in *On the Usefulness of the Parts of the Body*, such as when describing the omentum, which, he believes, Nature has attached to the spleen and the pancreas. The only thing Galen says expressly about the pancreas is that its soft glandular tissue protects and safeguards the blood vessels, which are abundant in the region of the liver, pancreas and duodenum, in order “to protect the branching vessels distributed there” (Galen 1971). Galen states: “Nature, realizing this, created a glandular body called the pancreas and spread it beneath all the vessels, surrounding them with it and filling the places where they divide. As a result, no one of them is unsupported and easily torn asunder, but all are at all times kept from being bruised, crushed, or broken, because they rest on a soft, moderately yielding substance, and if they are moved with some violence, they strike against objects which are not hard and resistant but which receive them gently and gradually deaden the force of the motion”

(Galen 1971). However, Galen does not believe that the pancreas plays a significant role in digestion: he barely mentions the organ in *On the Natural Faculties*. This should not surprise us: the significance of the pancreas to the body’s vital processes did not become evident until the final quarter of the nineteenth century and the significant development of chemistry and physiology (the experiments of Rudolf Heidenhain and Ivan Pavlov). Given the technical possibilities available to physicians in the second century, it is hard to imagine that anyone then could have described the significance of the pancreas more accurately than Galen himself!

Galen attached great importance to the pressure of the muscles of the abdominal wall and the diaphragm in ensuring intra-abdominal pressure as a factor in supporting the peristaltic activity of the gastrointestinal tract. He considers the peritoneum, which envelops all the digestive organs with its folds, to be the instrument of this pressure. Galen regards it as a huge ligament that regulates the anatomical position and physiological functions of the abdominal organs: “first, it serves to protect all the parts lying beneath it, the stomach, intestines, and [other] viscera below the diaphragm; second, it separates these same viscera from the outer muscles resting upon them; third, it helps the residues of the dry nutriment to descend more quickly; its fourth use is to guard against flatulence in the stomach and intestines; and its fifth to bind together all the parts below the diaphragm and furnish each of them with its own special covering as with a skin... This covering known as the peritoneum is useful in another way: it is drawn close around all the inner parts (this is the reason for its name), and at its upper extremities near the sternum and false ribs it meets the diaphragm stretching obliquely downward and aids to some extent the peristaltic movement of the stomach and intestines by which I have said the residues of the nutriment are moved downward. For the parts held between the peritoneum and diaphragm as if by two hands joined above and separated below compress and push downward the residues of the nutriment” (Galen 1971).

The functional purpose of the small intestine, according to Galen, lies in the fact that “the nutriment is still undergoing concoction while it passes through [the intestines]” (Galen 1971). In the small intestine, the nutriment is absorbed through the same mechanism as in the stomach: the necessary matter enters the venous blood through the intestinal wall and is then distributed throughout the whole body. “The substance of the intestines differs only slightly from that of the stomach” (Galen 1971). The bowel, according to Galen, is first and foremost an organ for distributing the useful elements of food, and secondly an organ for digestion and the removal of faeces (the food residues that are not needed) from the body.

Galen sees this process as follows: in the stomach, a certain juice, now suited for absorption into the ve-

<sup>7</sup> The bile from the duodenum should not be identified with the black and yellow bile that feature among the four basic fluids of the human body.

nous blood, is formed from food. In other words, food does not go from the stomach to the bowel unprocessed: “Actually, the coils of the intestines, having countless veins from the liver inserted into them, send up all the juices concocted in the stomach. With the other arrangement, however, only a little of the chyli-fied nutriment would be accommodated at one time in the mouths of the few veins, and *anadosis* would become a slow, time-consuming process; But as it is, the narrowness of the passage, by reducing the nutriment to small particles, forces almost all of it to come into close contact with the tunic of the intestines where the mouths of the veins open and so also with the mouths of the vessels. If any nutriment escapes contact in its passage through the first coil, it is caught in the second, and if it escapes in the second, then it is caught in the third, fourth, fifth, or one of those farther on; for there are very many of them. Certainly every particle of the nutriment is forced to encounter the mouth of a vessel at some point in this canal that is so long and narrow and has so many coils. In fact, the whole curved surface of the intestine is pierced by innumerable openings that extend to the inside and seize upon the useful part of the nutriment as it is going by. As a result, no juice useful for nourishment escapes and passes out of the animal, at least when the parts of the body are given by Nature’s law” (Galen 1971).

Galen describes the large intestine as consisting of the following parts: the caecum (located at the junction of the small and large intestines), the colon (part of which rises up from the caecum), and the rectum. The functional purpose of the large intestine in humans and the most advanced animals, apart from the formation and expulsion of faecal matter, is “to prevent elimination from being a continuous process” (Galen 1971). Here, Galen observes that some animals “incessantly eliminate” (Galen 1971), but the more advanced the animal is, the more complex the structure of its large intestine. Furthermore, the combination of straight and transverse fibres makes it possible to ensure the strength required to expel the faeces. The rectal part of the large intestine has the highest number of straight fibres, reflecting its physiological purpose.

With regard to the commensurability or incommensurability of Galen’s views on anatomy and physiology with the ideas of modern medicine, we should also recognise his mistakes. These include his interpretation of the function of the kidneys, which he classes as part of the digestive system. Galen regards urine as a “thin and watery residue” (Galen 1971) that needs to be removed from the blood; the main connecting point between the digestive and circulatory systems is the liver and its surrounding vessels. This, Galen believes, is why Nature placed the kidneys near the liver. The function of the ureters – “long, strong canals connecting the kidneys and bladder” – is to ensure “convenience in excreting [the urine]” (Galen 1971): Nature “created first the

bladder, a receptacle like a cistern, and then at the lower end of the bladder a muscle to prevent the untimely expulsion of the residues” (Galen 1971).

Galen wonders whether there exists a physiological mechanism through which the kidneys “attract” urine and then expels it through the urinary tract. Galen considers an explanation of this process similar to the modern one: the kidneys filter the blood, extracting from it the parts not needed by the body. However, he rejects this explanation, having little understanding of the true role of arterial blood. Galen knows that it contains the vital spirit – and this is enough for him. The great physician believed that venous blood was fundamentally important and performed a nutritive function. Galen argues as follows: if the kidneys filtered the blood, and urine was formed as a result of this filtration, all the blood would have to pass through the kidneys. However, the latter, unlike the liver, lie on the periphery of the venous circulatory system on either side of the inferior vena cava. In Galen’s system, there is no closed circulatory system, and no concept of a finite volume of circulating blood. For this reason, there is no logical explanation in his arguments for the interesting hypothesis that urine is the filtered residue of blood, and Galen ultimately rejects it.

This leaves the idea that the kidneys attract the fluid from which urine is formed, which he illustrates by drawing an analogy with a magnet attracting iron.

Even in Galen’s time, however, a theory rejecting the concept of attraction, as proposed by Hippocrates and developed by Galen himself, was emerging. This was put forward by a physician called Lycus, from Macedonia,<sup>8</sup> with whom Galen had many arguments.<sup>9</sup>

From the viewpoint of modern medicine, Lycus’s theory has to be regarded as sound: according to it, urine comprises residues expelled from the body in the process of alimentation. Galen, by contrast, believes that all the fluid taken in by a person turns into urine, a hypothesis that is incorrect from the viewpoint of modern physiology.

Galen recognises that “all parts which are undergoing nutrition produce a certain amount of residue, but it is neither agreed nor is it likely, that the kidneys alone, small bodies as they are, could hold four whole *congi*, and sometimes even more, of residual matter. For this surplus must necessarily be greater in quantity in each of the larger viscera” (Brock 1916, p. 111). He disagrees with Lycus, and it must be said that his arguments are unconvincing and extremely vague and number-heavy: “For, if the kidneys produce in drinkers

<sup>8</sup> Galen calls him “Lycus of Macedonia” in *On the Natural Faculties* (Brock 1916, p. 109) and “the Macedonian” in *On the Usefulness of the Parts of the Body* (Galen 1971).

<sup>9</sup> Galen devotes an entire work (*Against Lycus*, a translation into Russian of which appears in Volume V of *The Works of Galen*) to his arguments with Lycus (Galen 2018b). See also (Balalykin 2018d).

three and sometimes four *congi* of superfluous matter, that of each of the other viscera will be much more, and thus an enormous barrel will be needed to contain the waste products of them all. Yet one often urinates practically the same quantity as one has drunk, which would show that the whole of what one drinks goes to the kidneys” (Brock 1916, p. 111, 113).

Galen talks unambiguously about the innervation of the internal organs – including, of course, the regulation by the nerves of the work of the digestive organs. Pointing to the teleological purpose of the anatomy of this innervation, Galen writes: “Now Nature had three ends in view when she distributed the nerves, to provide first sensitiveness for the instruments of sense perception, second, motion for the instruments of motion, and third, for all the others, recognition of what will cause them pain” (Galen 1971). The stomach, like the tongue, eyes and ears, is supplied with large nerves: here, Galen states that it, and the inner sides of the hands, having an unambiguous physiological purpose, are, in addition to this, also “to a certain degree instruments of perception”. It is with the activity of the two large nerves (I repeat: it is quite clear that the great physician is describing the vagus nerve) that Galen links the onset of the feeling of hunger. None of other digestive organs is “an instrument of sensation or motion”, so they are innervated with small nerves, the purpose of which is “conferring perception of what will cause pain” (Galen 1971). Galen states: “For if the instruments had no such perception and were insensible of the injuries inflicted on them, nothing would prevent animals from perishing in a very short time. But as it is, when we feel gripping pain in the intestines, we hasten at once to get rid of what is causing it. If they were completely without sensation, they would all, I think, be easily ulcerated, eaten away, and putrefied by the daily supply of residues flowing into them” (Galen 1971).

## Mechanisms of regulating the work of the digestive system

Galen not only suggests that the digestive organs are supplied with nerves, but also unambiguously recognises the existence of mechanisms by which nerves regulate the activities of all parts of the human body, the digestive organs being no exception. The great physician believes that the nerves possess sensitivity and the capacity to effect the function of movement, by conveying the relevant impulses to the parts of the body. Clearly, the division of the nerves into those of motion and those of sensation that later became established in physiology represents a natural development of Galen’s ideas. He had a particularly clear understanding the performance of the mechanism of voluntary motions, such as those of the limbs. The highest, immortal, part of the soul, which is located in the brain and governs reason (the

function of thought and human self-consciousness), communicates the motor impulse to the relevant part of the body. This command is transmitted via the movement along the nerve of the psychic pneuma (the animal spirit), which is synthesised in the brain, with the fourth, “cerebellar” ventricle playing a particular role here. The psychic pneuma in Galen’s system acts as a mediator of both excitation and sensitivity: the great physician identifies the capacity to recognise causes of pain to the body as a separate function of the nerves. Naturally, in the context of the teleological principle, the functions of the nerves are also defined as the “three ends” followed by Nature in organising them, of which two relate to sensitiveness (“to provide... sensitiveness for the instrument of sense perception” and “recognition of what will cause [*the parts of the body pain*]” and one to motion (to provide “motion for the instruments of motion”).

It seems obvious to me that these ideas about the functioning of the nervous system are commensurable with modern ones. At the same time, they cannot be compared by drawing parallels, as sometimes happens when ancient medicine is described in historiography influenced by presentism: compare how much people knew in the nineteenth century with how little Galen knew! They need to be evaluated from the viewpoint of an analysis of the continuity and further development of theory and practice, which will make everything fall into place. It is becoming clear that the division of the nerves into those of motion and those of sensation, established experimentally in the second half of the nineteenth century, represents a development of the previously established understanding of the main purposes of the function of the nervous system.

Naturally, Galen, in analysing the anatomy and physiology of the digestive organs, always mentions the nature of their innervation: in the main, he draws attention to the size of the nerves with which a particular organ is supplied, their number and the nature of the innervated muscles. The fact is that Galen was well aware of the existence of what would later be called the neuromuscular reflex. In *On the Doctrines of Hippocrates and Plato*, he describes a neuromuscular junction as a functional lever, the structure of which potentiates the relevant impulse.

In describing the anatomy of the stomach, he draws attention to the innervation of its upper part with the powerful, branching vagus nerve. This, he believes, reflects the complexity and importance of the functions of the stomach, and is complemented by the appropriate structure of this organ’s muscular coat. Furthermore, diseases of the stomach and a feeling of hunger are crucial states, information on which, in the form of a relevant sensory impulse, needs to be conveyed to the brain promptly and in full. In full, since experienced physicians know how varied a patient’s subjective perceptions of the different diseases of the stomach can

be. Nature, Galen believes, justly allocates the nerves among the organs: "For whenever instruments are of the same kind, as sensory instruments are similar to other sensory instruments, or muscles to other muscles, she considers the mass of their bodies, the importance of their actions, the weakness or strength of their motions, and the frequency or infrequency of their activity, and, estimating the exact worth in each case, she assigns to one part a larger nerve and to another a smaller one, each receiving a nerve of the size which is just its due" (Galen 1971).

Galen has a brilliant understanding of the purpose and diversity of the functions, and innervation is not a measure of an organ's importance in his system. First, all organs are important, each in its own way; second, an important function may not require a significant neural structure. For example, Galen points that the liver has few nerves. In his view, "the nerve which Nature has assigned to the liver is a very small one" (Galen 1971), since the functional purpose of the liver is to effect qualitative transformations but does not include "any movement or sensation".

The liver is the most important organ in the human body, where, under the influence of the lower, vegetative, part of the soul the blood is synthesised. Meeting this task requires the liver to be connected by the blood vessels with all the parts of body. In *On the Usefulness of the Parts of the Body*, Galen devotes a lot of attention to showing that this teleological prerequisite is achieved by Nature: the liver is abundantly provided with large and small blood vessels. Some bring dissolved, partially processed nutriment to it from the stomach and (to a lesser extent) the small intestine. Others, running from it, distribute blood imbued with nutriment to the parts of the body in line with their needs.

Accordingly, the level of innervation of a part of the body, Galen believes, depends on the complexity of its motor action, on its muscular function and on its degree of mobility. The extent to which an organ is vascularised depends on the intensity of the metabolic processes or qualitative changes in substrates taking place in it. The stomach has two large nerves with many branches, and the liver one small one. The stomach is supplied with enough blood to support the processes of absorption; the liver is supplied with an abundance of incoming and outgoing vessels, from very large to small, so that the function of haematopoiesis and the task of supplying all the parts of the body with blood are performed in full.

It should be noted that Galen addresses activities relating to the regulation the work of every organ and system, and the digestive tract is no exception. One recalls that, for example, according to Galen the muscles of the rib cage play a crucial role in respiratory excursion. This is an example of the "voluntary movements" that are ensured by a nerve impulse from the brain, as a manifestation of the activity of the highest, immortal, part of the soul. Much of *On the Doctrines of Hippo-*

*crates and Plato* is devoted to explaining how they are performed and demonstrating their very existence.

It is no accident that Galen is particularly successful in analysing the activities of the digestive organs, where the "voluntary functions" controlling the muscles are concerned. For example, he discusses a person's capacity to control the excretion of faeces, pointing to mental activities that distinguish humans from the most advanced animals. In modern terms, his theory of the structure and function of the human soul allows him to understand correctly the nature of the neuromuscular reflex with regard to the striated muscles.

Galen regards innate heat as the chief mechanism ensuring energy for the human body's vital processes. The ideas about this in Galen's system are essentially equivalent to the concept of "life". In his *Commentary on Hippocrates' Aphorisms*,<sup>10</sup> Galen devotes a lot of attention to showing that there is more innate heat in a baby's body than in that of an adult or elderly person. The greater the amount of innate heat, the more vital energy there is, and the more rapidly the body grows and develops. *Against Lycus* helps us to get an idea of the importance of the slightest nuances in the interpretation of these ideas about innate heat. I have written elsewhere on the essence of Galen's theory of innate heat and how it draws on the ideas of Plato and Aristotle,<sup>11</sup> and the issue has also been addressed by various other authors (Longrigg 1993, Nutton 1995, Nutton 2013). I do not see the need to analyse it again in this article, but I do think it worthwhile to mention the importance of innate heat for a general analysis of Galen's views on the mechanisms of the body's vital functions.

To conclude, I would like to examine several key aspects of the methodology.

Even scholars taking a presentist view of ancient medicine have deigned to praise the works of Galen, admitting that he correctly understood many aspects of anatomy and physiology.<sup>12</sup> If we consider anatomical and physiological science in the nineteenth century in terms of its overall historical development, we see that it was not distinct from Galen's system of theory and practice, but a continuation of it.

The prominent French physiologist Claude Bernard, one of the leading figures of the scientific revolution of the nineteenth century, paid tribute to Galen, whom he regarded as his predecessor in the search for the principles underlying the acquisition of accurate

<sup>10</sup> See "ΙΠΠΟΚΡΑΤΟΥΣ ΑΦΟΡΙΣΜΟΙ ΚΑΙ ΓΑΛΗΝΟΥ ΕΙΣ ΑΥΤΟΥΣ ΥΠΟΜΝΗΜΑΤΑ". *Claudii Galeni opera omnia*, vols. 17.2 & 18.1. Ed. Kühn C.G. Leipzig: Knobloch, 1829, Repr. 1965.

<sup>11</sup> See, for example, the section "Plato and Aristotle in the history of medicine" in the introductory article to Volume II of *The Works of Galen* (Balalykin 2015, p. 34–60).

<sup>12</sup> A good example of this is the introductory articles by Boris Petrov and Vasily Ternovskiy to the Russian translation of Galen's *On the Usefulness of the Parts of the Body* (Galen 1971).

knowledge of the physiology of living beings. Although medicine would seem to have been developing under completely different conditions in his time, Bernard compares his practice to Galen's ideas: "Experiment... implies, on the contrary, the idea of a variation or disturbance that an investigation brings into the conditions of natural phenomena. This definition corresponds, in fact, to a large group of experiments made in physiology, which might be called experiments by destruction. This form of experimenting, which goes back to Galen, is the simplest; it should suggest itself to the minds of anatomists wishing to learn, in the living subject, the use of parts that they have isolated by dissection in the cadaver. To do this, we suppress an organ in the living subject, by a section or ablation; and from the disturbance produced in the whole organism or in a special function, we deduce the function of the missing organ. This essentially analytic, experimental method is put in practice every day in physiology" (Bernard 2010).<sup>13</sup>

Galen was well aware of the need to employ a method making it possible to discern truth from falsehood, and to strive for truth in addressing specific medical objectives. In addition, he believes that the method should be used in order not only to gain knowledge, but

also to be able to use it. This, of course, explains why Bernard refers so often to the history of the emergence of the experimental method in medicine, which he associates with Galen: "By following the same analytic path, physiologists should succeed in reducing all the vital manifestations of a complex organism to the play of certain organs, and the action of these organs to the properties of well-defined tissues or organic units. Anatomico-physiological experimental analysis, which dates from Galen, has just this meaning, and histology, in pursuing the same problem to-day, is naturally coming closer and closer to the goal" (Bernard 2010).

Of course, the discipline of Galen's experiments cannot be compared to that of experimental medicine at the end of the nineteenth century, familiar to researchers today: The technical possibilities available to Galen or Herophilos cannot be compared to those available to Bernard or François Magendie. Nor should the information available from other disciplines – physics, chemistry and mathematics – to researchers in the age of scientific revolution be forgotten. This information had a significant influence on the development of their worldviews, determining their capacity to set goals and objectives for their experiments. However, I believe, Galen's ideas about the anatomy and physiology of digestion analysed in this article show that it is justified to speak of the "commensurability" of medical knowledge in different periods.

<sup>13</sup> The English translations used here are taken from: Bernard C. *An Introduction to the Study of Experimental Medicine*.

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