



History

The Ancient Greek discovery of the nervous system: Alcmaeon, Praxagoras and Herophilus

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ABSTRACT

The aim of this historical overview is to show that the theories of Alcmaeon of Croton formed an important part of a developing conception of the brain and the nervous system. The vital contributions of Praxagoras of Kos, who suggested the existence of what we now call “neurons”, and Herophilus of Chalcedon, who distinguished between sensory and motor nerves and demonstrated the existence of the nervous system by dissection, also established the foundation principles of neuroscience, but their importance is sometimes forgotten. We trace the discovery of the nervous system through an investigation of these three thinkers. Combining astounding philosophical concepts with sharp observation, they conceived and demonstrated the existence of a nervous system by the third century BCE. This discovery is central not only to neuroscience, but also to all of medicine and to our concept of the human organism: it articulated the connection between the mind, the brain, and the body.

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1. Introduction

Medicine began with inquiry into the structure, composition, and form of the body [1]. Like the Egyptians and Babylonians, whose medical tradition was also based on a combination of traditional magical and religious methods, some philosophers in Greece sought to develop a detailed anatomical understanding of the body [2]. Regarding the connection between magic and medicine, the most important points to acknowledge are (i) that Greek medicine was “rational” but not in the modern sense of the term: the “rational” included magic, gods, and spirits; (ii) that the gods were part of nature to the Greeks, and therefore the investigation of the soul and evil spirits was considered an inquiry into nature; and (iii) that there is no evidence to suggest that a “rational” approach, a label often applied to the medical works of Alcmaeon [1], was any more successful than old medical practice.

In the sixth century BCE, philosophers began to consider that it might be possible to detect animal illness and disease by investigating the structure of the human organism [2]. The aim of some of these philosophers was to make extensive documentation and theorisation about the different parts of the body, including their function, purpose, and inner workings. The problem in medicine was learning about the cause of illness. Physician-philosophers

such as Alcmaeon, and, in later centuries physicians such as Praxagoras and Herophilus, attempted to understand the biological form and function of the brain, and its relationship to the rest of the body [3]. Within this atmosphere of philosophical inquiry, questions about the nature of the mind arose [4]. From this inquiry came the origins of neuroscience and neurology.

Modern neuroscience often overlooks the contribution of early Greek thinkers in the evolution of concepts of the brain. The ancient Egyptians maintained that the heart was the place of mind [5]. Some Greek philosophers questioned this view and developed concepts implicating neurological localisation. Alcmaeon, Praxagoras and Herophilus promoted this cerebrocentric view, which was shared by Hippocrates, only to be later rejected by Aristotle who promoted a cardiocentric model. This historical note attempts to clarify the somewhat neglected contribution of these ancient thinkers by examining their work, as far as the record allows, in order to gain a better understanding of their legacy and appreciate the evidence which led them to their conclusions. The importance of the work of these early intellects and their contributions to the foundations of neuroscience is supported by scholars of ancient medicine [6–8].

2. Alcmaeon of Croton and his theory of the brain

Alcmaeon of Croton lived in the city of Croton in Magna Graecia (now southern Italy) around the beginning of the fifth century BCE

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[9]. He was a philosopher–physician. His works cover topics ranging from the details of the optic nerve to observations regarding the nature of the soul [3]. Some scholars argue that he was a member of the Pythagorean school of philosophy and had been a pupil of Pythagoras, but there is no agreement over this and the evidence is inconclusive [1]. It can nonetheless be said that Alcmaeon's work was philosophical in nature; it aimed, not merely to observe, but also to understand the nature of things [10]. To understand this, one must recognise that in Alcmaeon's day philosophy was not seen as a distinct and separate discipline; rather, it formed the basis of inquiry for the majority of areas which we would now segregate into separate “disciplines”.

The main theories of Alcmaeon relating to the brain are provided in summary below.

2.1. Human beings can both perceive and understand

Unlike animals, who can merely perceive, human beings have the capacity to interpret and place meaning on the objects they perceive [11]. For Alcmaeon, thinking and perceiving were two different things. Human beings are capable of understanding because they can perceive and think about what they perceive.

2.2. The brain is the centre of the senses

All the perceptions of which human beings are capable are connected to and transmitted from the brain. These sensations pass through passages which run to and from the brain. When the brain suffers some injury, these passages are severely impeded, leading to the inability to move or feel [11]. Because all the senses transfer what they perceive to the brain so it can be decoded, the brain is essential for perception [12].

2.3. Intelligence resides in the brain

The brain is hegemonic in the body [11]. The brain dictates not merely physical and mental function but also coordinates the relationship between the two. Mind and body are therefore not necessarily distinct, separate entities.

2.4. Smell is understood through the brain

When air is sucked up through the nostrils the smell is transmitted to the brain [13].

2.5. Mental maturity is attained around the age of 14 years

It is at the age of around 14 years that human beings become capable of reasoning and intuitive analysis of data presented to the brain [14].

2.6. Good health depends on the equilibrium of bodily faculties

In order to remain healthy, a human being must maintain a state of equilibrium in the body. The body, Alcmaeon states, contains opposites which work against each other: hot and cold, moist and dry, fast and slow, bitter and sweet, and others [11]. Each part of the body relies on another, but all these functions exist under the hegemony of the brain. Disease occurs where excess of one opposite exists (such as cold) or where there is a dire lack of one opposite (such as sustenance). Alternately, disease can occur when there is a fault in one part of the body (such as the brain) that affects all other parts adversely [11]. This idea presages Claude Bernard's concept of the constancy of the internal environment, a fundamental physiological principle; if say, there is low sodium, the body will correct it, otherwise disease will reign.

2.7. Eyes transmit perception

The eyes are connected to the brain by an optic nerve [14]. The eyes contain both water and fire; water, because the eyes are soft and wet and gluggy, and fire, because when the eyes are struck it produce flashes in the mind [11]. The diaphanous water in the eye allows it to reflect an image better because water is clear and pure [15]. The observation that the eyes are connected to the brain is said to have been the result of dissections which revealed that the optic nerve leads to the brain [16].

2.8. Ears transmit sound

The ears resonate and carry sound. The ears, Alcmaeon argues, are empty. Since all cavities resonate sound, and since the ears are empty and therefore cavities, the ears resonate sound when sound enters into them. Alcmaeon suggests that sound is conveyed first to an outer chamber, and then, by reverberating there, the sound is carried to the brain [16].

2.9. Passages connect sensory organs to the brain

There are passages which connect sense organs to the brain [17]. Alcmaeon called these passages πόροι (*poroi*) [15]; this word, like most Ancient Greek words, has many different meanings: “pores”, “channels”, “paths”, or “openings”; but in biology it can also mean “fibres” or “threads”. Taking into consideration this biologically directed meaning and Alcmaeon's observations that the senses were connected to the brain [11], it is possible that Alcmaeon posited the existence of channels which connected the brain with all other parts of the body. This is supported by Alcmaeon's observations of πόροι in the eyes and ears [15], most likely the optic nerve and the cochlear and vestibulocochlear nerves.

Alcmaeon's theories, based on his empirical investigations, suggest first the idea that “brain creates mind” [12], and second, the idea that the brain is connected to the rest of the body by channels (*poroi*). Alcmaeon thus conceives of the brain as the nucleus of all human perception. These were significant developments in the understanding of cognition and perception. Alcmaeon's investigations and theories were, however, provisional; so far as scholars are aware, his ideas were not conclusively proved or extended upon in his lifetime, and the doxographical writings in which his works were recorded were often prone to ornamentation [18]. Although Alcmaeon might have correctly established the link between the brain and mind, he did not himself articulate any specific scientific view regarding the nature of the nervous system that can be safely said to be a view about the nervous system as it was later conceived [1]. It has, for instance, been argued that he believed the πόροι to be an extended part of the brain, just as he thought sperm to be a part of the brain [13], rather than an instrument connected to the brain's faculty of perception. There are further problems with Alcmaeon's theory. It is possible that Alcmaeon conceived of these channels as pores through which the soul or *pneuma* flowed. This agrees with Alcmaeon's concept of the arteries as empty tubes containing not blood but *pneuma*; it also corresponds more closely to what the fragments record of his writings. These points do not, however, detract from Alcmaeon's most important contribution, the establishment of a theoretical groundwork for further investigations into the nature of the brain.

3. Praxagoras and Herophilus

The questions raised by Alcmaeon influenced all researchers of the head for the following thousand years. Understanding the

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