

The Neurology of Erasistratus

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Abstract

Erasistratus was born c. 325 B.C. on the island of Ceos (Chios), and died c. 250 B.C. He is remembered for his discoveries especially in physiology which were based on human and animal dissections and experiments. These discoveries provided new insights and additions to the Hippocratic corpus and Aristotelian concepts. Erasistratus, probably with Herophilus, discovered four ventricles as well as the convolutions of the cerebrum. He appreciated the separate neural pathways for motor and sensory functions and believed that the psychic *pneuma* was transmitted through motor nerves to muscles which contracted. He devised a corpuscular theory for physiological mechanisms of particle behaviour.

Keywords: Erasistratus; Physiology; Cerebral ventricles; Motor and sensory nerves

Introduction

Alexandria, founded by Alexander the Great (356-323B.C.) and established by the Ptolemaic Pharaohs, was the seat of learning for many famous Greek physicians. Its teachers had access to a library of some 7,000 scrolls, probably the largest collection of any country. Hellenistic Alexandria's renowned scholars included the physiologist Erasistratus, Herophilus (c. 330-c. 260 B.C.) [1] (Figure 1)-named by many, the Father of Anatomy [2-4] and Aretaeus (c. 2nd century AD) a leading anatomist and physician in this period (Table 1).

Unfortunately their treatises were lost in the fire of 391 A.D. in the Alexandrian Library [5] where they were housed. Fragments have survived in the works of Galen (A.D. 130-201), and Caelius Aurelianus (fifth century). For Erasistratus our main sources are two treatises directed against him by Galen [6]. However the fragility of theories founded on disparate historical records [7] and on possible errors in translation must prompt caution. This account of their neurological advances is based on research in translated primary sources that allows a limited evaluation of his work in a historical context. Outstanding amongst them [8] is the exhaustive scholarship of Von Staden [9] and Dobson [2].

Erasistratus was born c. 325 B.C. at Iulis on the island of Ceos (Chios), and died c. 250 B.C. possibly in Mycale or Ionia or Alexandria. His father Cleombrotus was a physician as were his maternal uncle Medias and his brother Cleophantus [10]. He is best remembered for his discoveries especially in physiology which were based on human and animal dissections and experiments. These discoveries provided new insights and additions to the Hippocratic corpus and Aristotelian concepts, which paved the way for the influential Asclepiades of

Bithynia. He left Iulis to be apprenticed to physicians Metrodorus (third husband of Aristotle's daughter Pythias) and Chysippus in Cos. His subsequent career is uncertain but a famous love story is related in Plutarch's Life of Demetrius that he attended the court and treated the future King Antiochus 1st Soter- son of King Seleucus -who had a mysterious illness. The story tells how Erasistratus diagnosed it as caused by being in love with his stepmother Stratonice. Erasistratus persuaded King Seleucus to give his young wife to his son, who then recovered [11] (famously painted by Jean-Auguste-Dominique Ingres: 'Antiochus and Stratonice, 1860 and by Jacques-Louis David, 1774').

Although debated by scholars, it is likely that with wide acclaim he practised Medicine in Alexandria during the reign of the first Ptolemaic Pharaohs [12], contemporary with Herophilus. Soon after Herophilus and Erasistratus, dissection was abandoned until the mid-16th century [5]. Erasistratus wrote many texts on anatomy, abdominal pathology, haemoptysis, fevers, gout, dropsy, and hygiene. None have survived. Galen's frequent hostile comments (*De naturalibus facultatibus*, 1,7 II.71K) afforded the main source of many of Erasistratus's actual statements, later collected by Fuchs [13,14] and translated by Dobson into the sole English source [2].

Erasistratus espoused where possible a mechanical explanation for diverse functions [9], as opposed to Aristotle's concept of innate but invisible faculties. He relied on experiments to prove his ideas though his reasoning was often, like Aristotle's, teleological. From the lungs *pneuma* entered the body via a 'vein-like artery', the pulmonary vein, transporting it to the left ventricle, thence it was pumped as *spiritus*

	Approximate Dates	Main location	Principal work
Erasistratus	325 B.C.-250 B.C.	Cos, Syrian Antioch, Alexandria	Physiology experiments & Anatomical dissections
Herophilus	330 B.C.-260 B.C.	Alexandria	Anatomical dissections
Aretaeus	2 nd century A.D.	Alexandria	Description of disease and therapeutic principles

Table 1: Principal Alexandrian Neurologists.

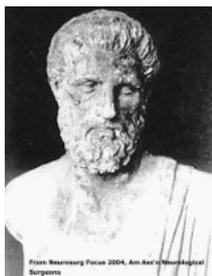


Figure 1: Erasistratus from Neurosurg Focus 2004, Am Ass'n Neurological Surgeons.

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vitalis to the arteries and onwards to the brain and other tissues. He based this on his belief that when an artery was cut the *pneuma* escaped and the artery was then filled with blood from the veins (Nature's tendency to fill a void that he called *horror vacui*) by means of *synanastomoses* or capillaries. Not until Galen showed arteries continuously contained blood was this erroneous idea disproved. He described the heart's valves and the one directional blood flow through them and the 'circular thrust' (*periosis*) mechanism of the heart: the heart dilated and contracted as a result of its own innate force. The arteries passively dilated to carry *pneuma*, but the veins carried blood. Galen was to be fiercely critical of much of Erasistratus's work, because he thought he had deserted many Hippocratic principles and concepts.

Brain and Ventricles

When examining the brain Erasistratus discovered four ventricles [15] as well as the convolutions of the cerebrum which governed the whole nervous system, and the cerebellum, which both he and Herophilus considered the site of the soul and intelligence (encephalocentric), unlike common Aristotelian (cardiocentric) opinions of their origins in the heart. This was a most important reference to the cerebral convolutions [11]. Until late in his life he considered the sensory nerves arose from the meninges; however this view he corrected:

He was quoted by Galen (pp.602-604 cited by Clarke and O'Malley [12]):

"He [Erasistratus], when he was old...learned how the medulla of the nerves originates from the brain. These are his words: And the brain in man was indeed bipartite as in other animals. It had a ventricle placed longitudinally on each side, and these were pierced through into [another] one at the junction of the [two] parts[foramen of Monro]. This [third] one extended to the so-called cerebellum, where there was another smaller ventricle[fourth], each side walled of by membranes' the cerebellum... was like the jejunum and very much folded. ...Since man greatly surpasses other beings in intelligence, his brain was greatly convoluted. ... the brain appeared to be the origin of the nerves of the body."

Motor and Sensory Nerve Functions

Like Herophilus, Erasistratus had appreciated the separate neural pathways for motor and sensory functions, denied by Asclepius, thus clarifying a long prevailing controversy. But nerves were hollow, importantly originating in the brain and cord and containing *psychic pneuma*, the equivalent of the Roman *spiritus animalis* [12]. "Thus," says Rufus (A.D. c. 80-c.150) (in *The names of the parts of the body*, 71-5):

"Erasistratus declares that there are two kinds of nerves, those of movement and those of sensation; these latter are hollow and their origin is on the meninges; the others arise from the cerebrum and cerebellum [16]."

Erasistratus, says Galen, proposes that "the nerve contains veins and arteries in itself like a rope formed by plaiting three strands of different kind." The cord contained a cavity filled with animal spirit. But Galen more accurately maintained there was no cavity and nerves were nourished by adjacent veins. Rufus, in *The names of the parts of the body*, the except pp.163-4 stated:

*"Among the nerves that issue from the brain and from the spinal marrow, the motor or sensory ones are called voluntary and tensor; the others that are around the articulations are called ligaments..."**

* There was general confusion between the anatomical identity of tendons, ligaments and nerves at this time, evident in this quotation.

He believed that the *psychic pneuma* was transmitted through motor nerves to muscles: "if the muscles are filled with spirit and increase in breadth, they are decreased in length and therefore shortened. This explanation of muscle contraction persisted until the 17th century (Rufus [16], *The site of diseases*, VI, 5, In: Daremberg 1879; 154-56, II: 693). In serious illness he thought that blocking of nerves by thick and sticky humours was a pathogenic process, a notion broadly in keeping with later developments [11] (p.145).

Corpuscular Theory of Physiology

Erasistratus combined a corpuscular theory of physiology with the doctrine of the *pneuma*, influenced by Diocles (375-300 B.C.), Praxagoras (c. second half 4th century B.C.) , and Herophilus, keen advocates of the *pneuma*. He was also influenced by Strato of Lampsacus, the third head of the Lyceum and the teacher of Ptolemy Philadelphus in Alexandria. Like Strato, Erasistratus conceived of his particles as very small, imperceptible, corpuscles or bodies surrounded by a vacuum of spaces or 'void interstices' [17]. He combined this theory with the prevailing notion of *pneuma*, the air or spirit entering the body through the lungs. Nutrition was achieved by absorption (*diadosis*) of nutritious particles through tiny pores in the walls of venous capillaries, and then passed to fill spaces when evacuated, by the principle of *horror vacui*. Disease was caused by *plethora*, a flooding of veins by excess of blood caused by too much nutriment. He treated them with dietetic restrictions rather than by venesection. Organic parts of the living creature were tissues composed of vein, artery, and nerve (the *τρυπλοκία των αγγειων*), bodies so fine that they were knowable only by reason. The vein carried the food; the artery the *pneuma*, not blood; and the nerve the *psychic pneuma*.

Discussion

Considering that Herophilus and Erasistratus worked at a time when neurological understanding was primitive, it is remarkable how much progress they made in anatomy and physiology of the nervous system. Both insisted on the primacy of observable phenomena, not as an attitude of the sceptics but as a cautious approach to unproved theories. They were pioneers in founding the principles of basic medical science.

Lacking significant instruments for physiological experiment, and partly limited by previous prohibitions for dissection, Erasistratus's Promethean advances are even more impressive.

The ethical issues posed by his probable use of vivisection can be explained if not excused, partly by Ptolemaic coercion and by the fact that it was common practice in his time in the quest for new knowledge.

Conclusion

The major legacy of Erasistratus is that together with Herophilus, he initiated the scientific study of physiology and anatomy; their accurate human and animal dissections provided a basis for the later anatomical investigations undertaken by Rufus, and by Galen and others centuries later. We can still see many of their discoveries in modern anatomy and significant influences reflected in clinical theory and practices.

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