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Original Article

The Contributions of Greek and Arab Scholars in the Advancement of Neuroscience: A Comprehensive Analysis

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ABSTRACT

Background: The history of neuroscience goes hand in hand with the discoveries of ancient Greek doctors and the Arabic medieval scholars, whose joint efforts have formed the solid base of neuroanatomy and neurophysiology. Although it is true that Greek pioneers gave the basic concepts of the functioning of the brain and the structure of nerves, they were preserved and translated and developed by Arab scholars who combined them with primary empirical observations. **Methods:** This research paper is a qualitative historical research based on primary and secondary research, such as original Greek texts, Arabic translations, and recent academic interpretations. The works of such important Greek authors as *Buqrāt* (Hippocrates), *Herophilūs*, and *Jalinūs* (Galen) are discussed along with Arab scholars like *Ḥunayn Ibn Ishāq*, *Al- Tabar, Al-Rāzī, Al-Majūsī*, *Al-Zahrāwī*, and *Ibn Sīnā*. The comparative analysis brings to the fore the development of the anatomical knowledge, clinical neurology, and surgical innovations. **Findings:** The first systematic theories of the role of the brain in cognition, the differentiation of sensory-motor nerves, and the structure of the central nervous system were formed by the Greek physicians. *Herophilūs* described the anatomy of the cranial nerves, ventricles, and meninges in his dissections and *Jalinūs* (Galen), in his experiments (especially on the recurrent laryngeal nerve), made contributions to functional neuroanatomy. Arab scholars did not only provide cross-cultural transmission of medical knowledge by translating them widely but also refined them critically; *Ḥunayn Ibn Ishāq* facilitated the spread of medical knowledge; *Al-Rāzī* enhanced neurological diagnostics; *Majusi* provided accurate classification of spinal and cranial nerves; *Al-Zahrāwī* taught how to perform neurosurgery, and *Ibn Sīnā* synthesized a **Conclusion:** Neuroscience is a continuum of intellectual interaction between Arab and Greek scholars. Their joint heritage of careful observation, comparative anatomy and clinical practice still forms the basis of the sciences of the nervous system today. This review makes it clear that intercultural cooperation is essential to the progress of medical knowledge and brings useful information to the historical development of neuroscience.

***Keywords**: P Neuroscience, Greek medicine, Arab-Islamic medicine, Neuroanatomy, Cranial nerves, spinal cord.*

INTRODUCTION

Neuroscience is the science of the nervous system, its structure, works, and formation mainly the brain. It tries to learn how the nervous system produces and controls emotions, thoughts and behaviours. [1]

Dimāghī ʿAṣāb (cranial nerves) are the nerves linked to the brain, which are mainly in charge of the functions of the head and the neck, and to a minor extent, the functions of the thoracic and abdominal organs. Cranial nerves are 12 in number with each pair being identified using Roman numeral and a particular name. They are categorized into sensory, motor or mixed according to their functionality. The special sensory nerves are cranial nerves, i.e. cranial nerve I (Olfactory), cranial nerve II (Optic), and cranial nerve VIII (Vestibulocochlear), which are responsible to sense smell, sight, and hearing and balance respectively. The five nerves (III, IV, VI, XI, and XII) are motor in nature, that is, they have motor neuron axons alone. [2]

Greek great philosopher and doctor, *Alcmeon* was the one who gave a comprehensive account of the optic nerve. *Buqrāt* (Hippocrates) who is considered the father of medicine defined the *Dimagh* (Brain) as a gland which was used to release mucus to cool the body. He found that the brain is surrounded by thick and fine membranes and the spinal cord runs out of it. [3],[4]

Herophilūs named nerves of the brain as sensory organs and differentiated them to the organs that were related to voluntary motor functions. His observations defied the existing theories and set the stage on the later anatomical research that would focus on the relevance of the brain in sensory perception and motor control.[5]

Jalinūs (Galen) also greatly contributed to neuroanatomy, with his descriptions of the cranial nerves, corpus callosum, tectum, fornix, pineal body, sympathetic chain, and the anterior and posterior roots of the spinal nerves, among others,[6] and he discovered the major cerebral vein, later named *Galen* vein, and the recurrent laryngeal nerve, now called the Speech nerve He also described the structure of the brain ventricles which he thought was the center of the mental spirit. [7]

Jalinūs (Galen) studied the function and structure of the spinal cord, especially with traumatic injury in the area of neurophysiology. He found out that complete sectioning of the spinal cord transversely resulted in overall paralysis and anesthesia below the lesion. He traced out motor and sensory loss distribution through animal experiments on pigs, apes etc. He discovered that transverse semi section resulted in ipsilateral deficiency of voluntary movement and contralateral deficiency of pain and temperature below the level of the injury. [8,9]

According to *Ḥunayn ibn Ishaq*, nerves and brains are intrinsically the same and the roots of nerves are within the brain. Despite the fact that nerves are hard and strong, the brain is soft which makes it to withstand to unfavorable conditions. [10] Some of the earliest theorists of the encephalocentric view were *Alcmaeon* of Croton and the *Pythagoreans*, *Anaxagoras*, *Hippons of samos*, *Philalaos*, *Hippocrates* and, subsequently, *Erasistratus* and *Herophilūs*. [11]

Al-Ṭabarī (Al-Ali Ibn Sahl Rabban Tabri) likened the dispersion of nerves in the body to the tree branches that have their root in the ground. *Al-Rāzī* explained the laryngeal nerve recurring and thought that it was out of proximity with the trachea; he identified seven cranial nerves and knew their motor and sensory roles. *Al-Majūsī*, also reported seven pairs of nerve plexus of the head, and is credited with being the first scholar to give an account of the trochlear nerve. [12]
Abu Bakr Mohammad ibn Zakriya Al-Rāzī (Rhazes) in his masterpiece, *Kitab-al-Mansuri*, dealt with the issue of anatomy in 26 chapters. He was also a notable contributor in the field of neuroanatomy because he gave an elaborate account of the cranial and the spinal nerves and thus contributed to the knowledge on the nervous system in the era. [6] Moreover, his careful observations preconditioned the further anatomical researches and practice, which made him an iconic figure in the history of medicine.

On the same note, *Ibn Sīnā* (Avicenna) also did an exceptional job in the study of anatomy by his masterpiece, *Al Qanun fii al-Tibb*. He arranged the principles of anatomy in a systematic manner in this comprehensive work and a particular chapter of the work was devoted to the detailed elaboration of functional neuroanatomy. Not only did *Ibn Sīnā* approach the intricacies of the human body in a systemic manner, but he also incorporated the knowledge of the neuroanatomy into the overall framework of medical science, which is why he is regarded as a pioneer when it comes to the evolution of medical knowledge. [14]

OBJECTIVES

To analyze the foundational contributions of classical Greek physicians and anatomists to the early understanding of neuroanatomy, neurophysiology, and neurological disorders.

To examine the role of Arab and Islamic Golden Age scholars in preserving, translating, expanding, and refining Greek neurological knowledge.

To evaluate the lasting impact of Greek and Arab scholarship on the evolution of modern neuroscience and neurosurgery.

MATERIALS AND METHODOLOGY

This research employs a historical-descriptive and analytical study design, aiming to trace, evaluate, and compare the contributions of Greek and Arab scholars to the advancement of neuroscience. The methodology integrates historiographical analysis with content evaluation of primary and secondary sources, enabling both chronological and thematic synthesis.

The primary sources for this study comprised original works and translations of prominent Greek physicians and anatomists, including On the Sacred Disease by *Hippocrates*, De Anatomic is Administration by *Herophilūs*, and Galen's on the Usefulness of the Parts. Additionally, Arabic manuscripts and their Urdu translations were examined, notably *Kitāb al-Hāwi* by *Abū Bakr Moḥammad Ibn Zakriyā Al-Rāzī*, *Kitab al-Maliki* by *'Alī Ibn Al-'Abbās Al-Majūsī*, *Al-Qānūn fī al-Ṭibb* by *Ibn Sīnā*, and *Kitāb al-Tasrīf li-man 'ajiza 'an al-ta'lif fī al-tibb* by *Abū Al-Qāsim Khalaf Ibn 'Abbās Al-Zahrāwī*. Historical medical illustrations and anatomical diagrams preserved in libraries and digital repositories further enriched the analysis. The secondary sources included peer-reviewed journal articles addressing the history of neuroscience, neuroanatomy, and neurosurgery, as well as academic monographs and edited volumes on classical Greek medicine, Islamic Golden Age scholarship, and cross-cultural medical exchanges.

LITERATURE REVIEW

ALCMAEON (500B.C)

It was the first time that *Alcmaeon* knew *Dimagh* (Brain) and he said that it mainly serves sensation and cognition. [14,15] Further, he described how the brain is at the center of the body and it is the key controller of the intelligence to which any kind of senses is related. [16] This was the theory that developed into an encephalocentric study and in relation to this famous book, *Alcmaeon* is regarded as the Father of Neuroscience. [17]

Thinking and perceiving were different process according to *Alcmaeon* of croton. He considered that human beings can understand since they not only perceive but also reflection on whatever they perceive. *Alcmaeon* of Croton suggested that olfaction happens when the air with the scent enters the nostrils and the sensory information is passed to the brain. [19] The eyes are linked to the brain via the optic nerve which allows visual perception implying that it possesses water as well as fire. [19] The eyes are connected to the brain through the optic nerve, enabling visual perception, indicating that it contains both water and fire. Fire since it can be struck on the eyes which make the mind have flashes of light and water due to their cool and wetness. The transparent crystal-clear water in the eyes also enhances the reflection in the eyes. This was explained by dissections. This brought out the fact that the optic nerve is a direct connection between the brain and the eyes. [20]

Paraxagoras suggested that there were minute arteries that carried the signals around the body, but became so narrow at their extremities that their lumen almost disappeared. He called this last section neuron which translated to the Greek word poroi or sinew, a developmental change of the previous idea of nerves as poroi. This was one of the major advancements in the field of neurology despite him not discovering neurons, although this was an important step in the field after the earlier notions of *Alcmaeon*. [21]

BUQRĀT (HIPPOCRATES) (460-377B.C)

Buqrāt (Hippocrates) (460377 B.C.) who was famously referred to as the father of medicine, assumed that the *Dimagh* (Brain) was a gland that was used to secrete mucus in order to cool the body. [22] He however also recognised the brain as the centre of consciousness, which is a cause of the human behaviour, thoughts, emotions and sensory perception. *Buqrāt* (Hippocrates) explained such conditions as madness, delirium, fear, insomnia and vague or forgotten thoughts as the dysfunction of the brain. [23] He was also one of the pioneers in discovering many nerves such as the optic, radial, sciatic and vague nerves - the latter extending out of the base of the skull and all the way to the coccyx- in addition to the bi-lobed structure of the brain which is separated by a thin vertical membrane and the covering of the brain and the spinal cord that grow out of it. [16,24,25]

HEROPHILŪS (325-225 BCE)

One of the first to make a distinction between nerves and blood vessels and tendons was *Herophilūs*, who was aware of the existence of neural impulses that are transmitted by nerves. [26,27,28] He and *Erasistratus* were probably well aware of the distinct action of dorsal and ventral spinal roots long before Bell and Magendie, and it was *Rufus* who described two kinds of nerves, sensation nerves and voluntary motion nerves. [29]

Herophilūs noted that when the motor nerves were damaged, paralysis ensued and the brain and not the heart was the seat of intellect, contrary to *Aristotle* who thought that the brain was a cooling organ. He described the meninges, brain cavities, distinguished between the cerebrum and cerebellum, and described a few cranial nerves, including the optic, oculomotor, facial, auditory and hypoglossal nerves. [30]

Research on ancient medicine indicates that *Herophilūs* performed extensive head dissections, involving the ventricles, choroid plexus, venous sinuses, cranial nerves and their openings, among other neuroanatomical structures. These structures were described depending on their shapes, and he coined names including the brain (encephalon), the cerebellum (parencephalon), torcular Herophili, calamus scriptorius and the choroid plexus. Vindicianus was also the one who made the contribution to the head anatomy especially the cranial sutures and referred to the work of *Herophilūs* on the cranium. Based on the work of *Herophilūs*, Vindicianus explained the structure as well as the role played by the cranium in the early anatomy.

Following *Herophilūs* on the cause of the psychic pneuma, *Galen* thought that the brain (encephalon) and cerebellum (parencephalon) were of primary importance. According to *Galen*, psychic pneuma grows in the lateral ventricles of the brain and it is received in the cerebellar ventricles which are quite large as the nerves inferior to the head are originated from either the cerebellum or the spinal cord. He thus concluded that there should be a pathway between the lateral ventricles and the cerebellar ventricle. [31]

Neural structures found by *Herophilūs*

In Alexandria, *Herophilūs* performed organized dissections on human bodies which produced new knowledge on the structure and operation of the nervous system. He was the initial to distinguish between nerves and arteries whereby nerves were solid cords that conducted motor and sensory impulses in contrast to arteries which were hollow cords that conducted blood. [21] *Herophilūs* also separated cerebrum and cerebellum noting the differences in their texture, size, and functions. [32] He also described the arachnoid membrane as a separate layer and wrote pioneering work on the structures of the ventricles, and associated their structures with the distribution of what were then known as vital spirits.

Galen (129-210 CE), extended the work of *Herophilūs* and described the optic nerve in more detail and gave a detailed description of the dural venous sinuses [33]. The two researchers firmly held the brain as the center of nerves and intellect to oppose the Aristotelian cardiocentric view. Superb anatomical accounts of the cranial nerves provided by *Galen*, such as the optic, oculomotor, trigeminal, facial, auditory, and hypoglossal, perfected the mapping of the neural pathways. This was applied to the medulla spinalis (spinal cord) which they recognized as necessary in transference of neural impulses, as well as motor functions. [32]

Moreover, *Herophilūs* and his successors separated the motor and sensory nerves, which is the basis of neurophysiological categorization in modern times. They as well distinguished between cranial nerves and spinal nerves and their respective origins and fields of operation. Their studies further on the vascular system also helped them to understand the differences between the veins and arteries, and the way the brain relies on a controlled blood flow in order to operate well. [34] All these findings together constituted the first structural and functional organization of neuroanatomy, which shaped the history of neurological science and became the basis of modern neurosurgical practices.

Galen confirmed that *Herophilūs* was right in stating that the nerve-like structures, which he called arteries, are the cause of voluntary movement. This was an observation that favored the difference between nerves and blood vessels in neuroanatomy. [21]

Herophilūs was convinced that the brain was the principle in the body that ruled it. Moreover, he proposed that spiritus vitalis (vital spirit) is propelled by the heart via the arteries to the cerebral ventricles and here he developed spiritus animalis (psychic pneuma). According to him, this sophisticated spirit was the cause of motion, sensation and thought. [35] In addition, He explained one of the meninges i.e. arachnoid membrane, layers of the eye and indicated the origin of optic nerve by brain. [36]

Herophilūs theorized on the separation between motor and sensory nerves and the fact that the sensation is carried by porous nerves and the muscular movement by the solid ones. Consequently, he realized the brain as the major controller of the nervous system. According to Galen, *Herophilūs* stated that there are seven pairs of nerve roots of the head, and six of them have their destinations, namely: optic, oculomotor, motor division of the trigeminal, facial, auditory, and hypoglossal nerves. [4,37,38] He outlined a potential three nerves (called poroi or passages or ducts) two of which went to the cerebellum, and one to the brain.

***JALINŪS* (GALEN) (129-200A.D)**

Jalinūs (Galen) was one of the pioneers of neuroscience whose influence remains significant in several centuries. [39] He contributed to the development of brain anatomy and physiology in which he explained a number of neurological diseases in terms of their structural and functional etiology. [40] By focusing on scientific rigor, opposing the cardiocentric theory of Aristotle and the Stoics, Galen argued in favor of the encephalocentric theory stating that the brain is the hegemonicon, the leading organ of all the body functions. [41]

Galen also contributed greatly in neuroanatomy by describing parts of the brain like the cranial nerves, corpus callosum, tectum, fornix, pineal body, sympathetic chain and the anterior and posterior roots of the spinal nerves. [7] He discovered the great cerebral vein (since renamed *Galen vein*) and the recurrent laryngeal nerve which he called the nerve of speech. He also described the brain ventricular system, as the locus of the psychic spirit.

Galen also made contributions in neurophysiology, especially the trauma and anatomy of the spinal cord. *[8]* He found out that complete sectioning of the spinal cord transversely resulted in overall paralysis and anaesthesia below the lesion. He traced out motor and sensory loss distribution through animal experiments on pigs, apes etc. He discovered that transverse semi section caused ipsilateral voluntary movement loss and contralateral loss of pain and temperature below the injury level. [9]

One of the most famous experiments of *Galen* was said to have started accidentally when he accidentally cut a recurrent nerve of the larynx of a pig, making it fall silent. Curiosity had led him as far as to follow the laryngeal nerves in some animals, dogs and goats, lions and monkeys. His work was so interesting that Boethius arranged a public demonstration, during which great scholars and politicians attended, and ultimately gave rise to the great works of *Galen* on the Voice and

On the Usefulness of the Parts of the Body. [42,43]
Galen discovered seven pairs of A‘sab dimaghiyya (cranial nerves), which he regarded as sensory, as compared to the 30 pairs of A‘sab nukha‘iyya (spinal nerves), which he regarded as motor. He also missed the olfactory nerve and the trochlear nerve, but in others, the optic, oculomotor, abducens, trigeminal, facial, Vestibulocochlear, glossopharyngeal, vagus, spinal accessory and hypoglossal nerves. [22] He also described the sympathetic system and found the repeated laryngeal nerves (" reverse"), which he found to be used in tongue movement and speech. [38]

Table 1: Contributions of Greek Scholars in the Advancement of Neuroscience

Greek Scholars	Era	Key Contributions
Alcmaeon	500 B.C.	Proposed brain as the center of sensation and thought; early ideas on sensory pathways
Buqrāt (*Hippocrates*)	460–377 B.C.	Described brain as seat of intelligence; linked brain to epilepsy and behavior
Herophilūs	325–225 B.C.E.	Performed human dissections; differentiated nerves (sensory vs motor)
Jalinūs (*Galen*)	129–200 A.D.	Detailed brain anatomy; proposed ventricular theory; experimental studies on nerves

***ḤUNAYN IBN ISHĀQ AL- ‘ĀBĀDĪ* (809-872A.D)**
The nervous system was described very extensively by *Ḥunayn Ibn Ishāq*. He states that the composition of the brain is similar to the nerves. In structure of nerves, he made the statement that majority of nerves are of brain and few are of spinal cord. He has also explained the brain. [25,44]

***'ALĪ IBN SAHL RABAN AL-ṬABARĪ* (775-875A.D)**
As per, the nerves are of two kinds, one of them has its origin in the back of the brain, and the other in the spinal cord as per, *Al-Ṭabarī*. He believed that the former controlled conscious movement and emotions and stretched all over the body just like tree branches. The spinal nerves are formed as a result of the spinal cord, but they eventually find their way to the brain since the spinal cord is part of the brain. *Al- Tabari* referred to nerves that are present in joints and muscles as being thin, supportive and non-sensory. He associated the role of brain to that of the sun which emits sensory and motor impulses to all the organs. The majority of nerves, he observed, are solid, and facilitate the action of sensations in the same manner that the sun warms the water in the bottom of a vessel. But optic nerves are grooved, and though they transmit power of vision, are not strong enough to sustain the functioning of organs. [45]

***ABŪ BAKR MOḤAMMAD IBN ZAKRIYĀ AL-RĀZĪ* (850-923 AD)**
The recurring laryngeal nerve was also among the earliest to be described by *Abū Bakr Moḥammad Ibn Zakriyā Al-Rāzī* who thought it began in the vicinity of the trachea. He made a lot of research regarding the role of nerves and their contribution to sensation and movement. In his argument, he is quoted as saying: When the nerve is cut longitudinally, there will be nothing done to that nerve, when cut transversally, there will be loss of sensation and loss of motor power and the nerve will be out of control and will not be a thing to treat. [45]
This observation was a preliminary knowledge of the aftermaths of neural damage. *Rhazes* was the first to relate clinical symptoms with lesions of the nervous system and the first to provide a documented history of spina bifida in his medical works *Al-Hawī* (Liber Continens).

Rhazes claimed that nerves have sensory and motor activities. He gave seven cranial nerves and thirty-one spinal nerves, in the order in which *Galen* had set them forth--a system to which we owe the permanence of the vertebrate system of nerves, until Vesalius and other anatomists started to perfect it. Soon thereafter, Soemmerring in his dissertation of doctorate formalized the system of twelve cranial nerves, which is currently in use today. [46] The optic nerve was then the first cranial nerve since the olfactory nerve was thought to be a direct continuation of the brain. The other nerve that was identified was the oculomotor nerve. What is currently referred to as the trigeminal nerve was linked to the third and fourth nerve. The fifth cranial nerve previously had a relationship with both the facial and acoustic nerve functions. The sixth was believed to contain the glossopharyngeal, vagus and spinal accessory nerves whereas the seventh cranial nerve corresponded to the hypoglossal nerve. [47,48,49]

***'ALĪ IBN AL-'ABBĀS AL-MAJŪSĪ* (930-994)**

There are seven pairs of cranial nerves that were determined and described by *Al-Majūsī*. Even though he did not give particular names to those nerves, he was quite descriptive when giving information about their origin, route, points of exit when the nerve left the cranium, where they were directed, and their functions. The fact that this description is so detailed, has permitted the present-day scholars to relate them to the twelve cranial nerves that are present in modern anatomy. [12,50,51] In his opinion, the abducens nerve (cranial nerve VI) is the first part of the third nerve and the trigeminal nerve (cranial nerve V) is the rest of the third nerve and the fourth nerve (together).

One of the first researchers to give a proper description of the trochlear nerve (cranial nerve IV) was *'Alī Ibn Al-Abbas Al-Majūsī*, which shows that he had a good knowledge of the anatomy of the cranial nerves. He refuted the previous mistakes by explaining that there were two nerves that did not serve the ear, face instead of one nerve, he separated the Vestibulocochlear nerve (cranial nerve VIII) and the facial nerve (cranial nerve VII). The sixth nerve in his special nomenclature was a complex of the vagus (X), accessory (XI) and glossopharyngeal (IX) nerves.

Surprisingly, he also discovered the recurrent laryngeal nerve as an extension of the third division of this sixth nerve, now in anatomy called the vagus nerve, and this shows just how accurate he was in his observations and contributions to the developing science of neuroanatomy. The fact that nerves were paired was important, with *Al-Majūsī* observing that in case one nerve was impaired, the other one could take over its functional role, a first appreciation of neural redundancy. [52]

***Nukhai Asab* (Spinal Nerves):**
An extremely detailed description of the *Nukha* (spinal cord) and the spinal nerves was given by *Al-Majūsī* (Haly Abbas) who pointed out their bilateral arrangement and anatomical distribution. He found 31 pairs of spinal nerves which he carefully classified into 8 pairs in the cervix, 12 pairs in the thorax, 5 in the lumbar and 3 in the sacrum and coccyx. This systematic classification did not only indicate how he observed the anatomy keenly, but also indicated how he was able to organize neuroanatomical knowledge in a manner that could be beneficial in clinical practice.

Al-Majūsī also documented the existence of one, extra nerve in the end of the spine, which coupled with the standard classification indicated that the former was conscious of anatomical variation. This point helps to highlight his zeal in recording the nervous system in detail and in exhaustive detail so that any anomalies to the norm were also captured in his work on medicine. The careful nature of this work helped to transmit and preserve neurological information in the Greco-Arabic tradition to subsequent medieval and Renaissance period thinkers. [45,52]

ABŪ AL-QĀSIM KHALAF IBN 'ABBĀS AL-ZAHRĀWĪ (936 -1036 A.D)
With a superb clinical intuition of neurological diseases, such as flaccid paralysis, *Abū Al-Qāsim Khalaf Ibn 'Abbās Al-Zahrāwī* (Abulcasis) acted. He could distinguish and define its causes including the cutting of motor nerves, what we now refer to as lower motor neuron lesions. He explained the paralysis of nerve activity by various factors, in particular, spinal abscesses, which in many cases were caused by tuberculosis of the vertebral column, or what is now called Pott's disease of the spine.

With the example of anosmia (loss of the sense of smell), *Al-Zahrāwī* (Abulcasis) provided a very precise and methodical description of the different causes of it that are quite similar to the present knowledge. He has differentiated between congenital and acquired anosmia and could trace the olfactory pathway of the frontal lobe, out to the nasal mucosa, along the cribriform plate of the ethmoid bone, along which the olfactory nerve fibres run. [53]

***IBN SĪNĀ* (980-1037)**
Ibn Sīnā (Avicenna) noted that the anterior section of the brain produces major sensory nerves, including the *ʿaṣab al-baṣar* (optic nerve) and the ʿaṣab al-sham (olfactory nerve) whereas the posterior parts of the brain and the *nukhāʿ* (spinal cord) give rise to the motor nerves. He stressed that the spinal cord brings nerves closer to target organs and it will lessen the chances of damage and enhance efficiency especially in reflex actions since the distance travelled by impulses will be minimal.

Ibn Sīnā (Avicenna) thought that there is a membrane between the sensory and the motor neurons at the location of their entry or exit of the spinal cord. This finding is in agreement with the anatomy of the present day: motor nerves run out of the anterior part, and sensory nerves, along with their ganglia, run into the posterior part. Moreover, he also explained nerves as being enclosed in fatty substance, which probably means the myelin sheath, a structure that not only shields the nerve fibers but also contributes to the conduction speed of the signal by saltatory conduction. [16]

Ibn Sīnā (Avicenna) was of the opinion that the brain is the main source of all the nerves and that some of them are direct derivatives of the brain and others are indirectly through the spinal cord which he considered to be an extension of the brain. There are nerves with direct functions, which are to generate the sensation and movement, and others, which play indirect roles, such as strengthening muscles and maintaining the functions of the body. Distress is also indicated by nerves around organs which are not sensory such as liver, spleen and lungs. In case of inflammation or distention of those organs by gas, the pressure is felt at the bottom of the nervine surface. Another observation made by Avicenna was that nerves end at the skin which has a fine network of fibres. Brain nerves only supply the head, face and the internal organs, and the other regions of the body have sensation and movement via the spinal cord nerves. [54]

Table 2: Contributions of Arab Scholars in the Advancement of Neuroscience

Arab Scholars	Era	Key Contributions
Ḥunayn Ibn Ishāq	809–872 A.D.	Translated Greek medical texts; preserved and transmitted neurological knowledge
'Alī Ibn Sahl Raban Al-Ṭabarī	775–875 A.D.	Early integration of Greek medicine into Islamic scholarship; discussed neurological disorders
Abū Bakr Moḥammad Ibn Zakriyā Al-Rāzī (Rhazes)	850–923 A.D.	Described neurological diseases; clinical observations on brain and nerves
'Alī Ibn Al-'Abbās Al-Majūsī	930–994 A.D.	Wrote *Kamil al-Sina'a*; described brain structure and neurological functions
Abū Al-Qāsim Khalaf Ibn 'Abbās Al-Zahrāwī (Albucasis)	936–1036 A.D.	Developed early neurosurgical techniques; described cranial procedures
Ibn Sīnā (Avicenna)	980–1037 A.D.	Explained brain physiology; described neurological and psychiatric disorders in *Canon of Medicine*

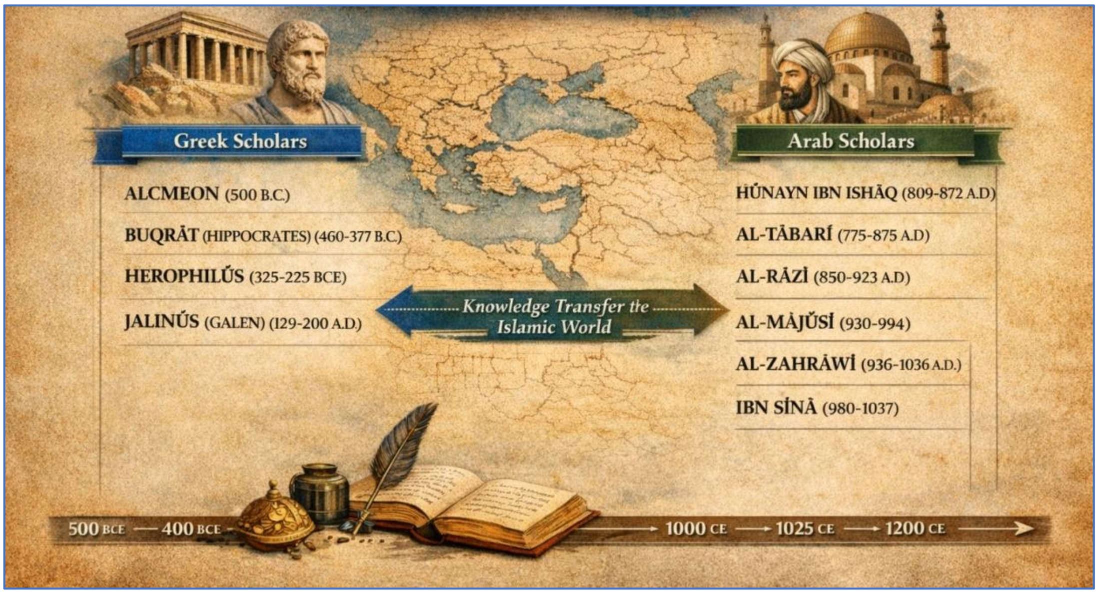

Figure: Illustrating Timeline in the Advancements of Neuroscience

DISCUSSION

Neuroanatomy has come to exist in part thanks to the initial observations of Greek doctors, and the refinements that were made by Arab scholars in the Islamic Golden Age. One of the first to posit that the brain was the location of intelligence, sensation and movement was *Hippocrates* (460-370 BCE), who argued that the brain and not the heart was the centre of this. [32] His theory has been the foundation of subsequent anatomical discoveries. In Alexandria, *Herophilūs* of Chalcedon (335-280 BCE) made an important contribution to empirical neuroanatomy, distinguishing between sensory and motor nerves, distinguishing between arteries and veins, determiners of the cerebrum and cerebellum, and the ventricular system of the brain. [21] These works were extended by *Galen* of Pergamon (129-216 CE), who named the optic nerve, wrote about cranial nerves, and stated that the brain was the centre of control of movement and sensation. [55]

Arab scholars translated, preserved, and critically analyzed these works of Greek but also made original contributions by translating *Galen* literature into Arabic and commenting on it, which elucidated the anatomical terms and resolving discrepancies. [56] *Al-Ṭabarī* is a mix of Greek neuroanatomy descriptions and clinical correlates, whereas *Al-Rāzī* (Rhazes 865-925 CE) described neurological conditions in detail, such as meningitis and facial paralysis. [57] *Al-Majūsī* (Haly Abbas). Later (982 CE) *Kitab al-Malik* was a systematic description of the menuce, cranial nerves, and spinal cord functions. *Abū Al-Qāsim Khalaf Ibn 'Abbās Al-Zahrāwī* (Abulcasis, 936-1013 CE) introduced practical methods of surgery to the head injuries and repair of nerves. [58] The Canon of Medicine by *Ibn Sīnā* (Avicenna 980-1037CE) incorporated previous work, and correctly described the pathways of motor and sensory nerves, and the functions of the cranial nerves and localisation of the intellect in the brain. [59]

This collective heritage of these scholars depicts a process of transmission and improvement of neuro-scientific knowledge. The anatomical foundation of Greek empiricism was extended by the Arab scholarship with the help of linguistic accuracy, systematisation and clinical use. Not only did this intellectual exchange between cultures preserve ancient discoveries but it also condensed them into a more clinically relevant and methodically ordered science that bridged the gap between classical anatomy and medieval medicine and formed the basis of the Renaissance resurgence in neuroscience.

CONCLUSION

The works of Greek and Arab scholars on neuroscience are a continuum of intellectualism that has contributed to the development of the field. The principles of the anatomy and physiology of the nervous system were outlined by *Hippocrates, Herophilūs,* and *Galen*, who discovered the brain structures, including the cerebrum, cerebellum, cranial nerves, and the ventricles, and stressed the brain as the centre of thinking and feeling. They were then passed on to the Islamic world where scholars such as *Ḥunayn Ibn Ishāq*, *Al-Ṭabarī, Al-Rāzī, Al-Majūsī*, *Al-Zahrāwī*, and *Ibn Sīnā* did not only preserve knowledge but added to the body of knowledge by classifying knowledge systematically, correlating clinical observations, and even developing new methods of surgery.

This combination of Greek anatomy and Arab medical learning produced a strong body of neuroanatomy literature, which had an impact on the medieval Europe and the early modern era. The elaborate grouping of both cranial and spinal nerves, the differentiation between motor and sensory tracts, and the physiological explanation of the structures of the brain are the result of the enhancement of knowledge over centuries. Although modern neuroscience is founded on state-of-the-art technologies and methodology, these contributions remain recognized to this day as key to the intellectual tradition of the field.

This common heritage is what makes the role of cross-cultural transmission in the history of science significant. An example of how co-preservation, co-criticism and co-expansion of knowledge may change speculative thinking into a systematic evidence-based science is the Greek-Arab continuum in neuroanatomy, which has served as the foundation of further neurological research and practice in medicine.

Conflict of Interest

The authors declare that there are no conflicts of interest to disclose in relation to the publication of this manuscript.

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Ethical Considerations

As this is a historical-literature-based study, no human or animal subjects were involved, and thus no ethical clearance was required. However, due academic integrity was maintained through proper citation and referencing practices.

REFERENCES

1. What is neuroscience? (n.d.). King's College London, School of Neuroscience. http://www.merriam-webster.com/medlineplus/neuroscience
2. Tortora, G. J., & Derrickson, B. (2017). Principles of anatomy and physiology (15th ed., pp. 353–355, 418, 446). Shree Maitrey Pvt. Ltd.
3. Gross, C. G. (n.d.). From Imhotep to Hubel and Wiesel: The story of cerebral cortex: Volume 12: Extrastriate cortex in primates.
4. Panegyres, P. K. (2015). The ancient Greek discovery of the nervous system: Alcmaeon, Praxagoras and Herophilos. Journal of Neurology and Neuroscience, 4.
5. Anatomy across centuries: From ancient Greeks to modern innovations. The merit and significance of autopsies today. (n.d.). Wikipedia. https://en.wikipedia.org/wiki/Neuroscience
6. Rahimi, S. Y., McDonnell, D. E., Ahmadian, A., & Vender, J. R. (2007). Medieval neurosurgery: Contributions from the Middle East, Spain, and Persia. Neurosurgical Focus, 23(1), 1–4.
7. Kaplan, E. L., Salti, G. I., Roncella, M., et al. (2009). History of recurrent laryngeal nerve: From Galen to Lahey. World Journal of Surgery, 33(3), 386–393.
8. Hankinson, R. J. (1991). Galen's anatomy of the soul. Phronesis, 36(3), 197–233.
9. Marketos, S. G., & Skiadas, P. K. (1999). Galen: A pioneer of spine research. Spine, 24(22), 2358–2362.
10. Kabīruddīn, M. (1916). Ifāda-i-Kabīr Mufaṣṣal (1st ed.). Qaumi Council Bara-e-Farogh-e-Urdu Zaban.
11. Ustun. (2004). Galen and his anatomic eponym: Vein of Galen. Clinical Anatomy, 17(6), 454–457.
12. Ali, M. J. (n.d.). Ali Ibn Abbas Al-Majūsī and medical ethics on the occasion of September 18, world medical ethics day.
13. Mavrodi, A., & Paraskevas, G. (2014). Mondino de Luzzi: A luminous figure in the darkness of the Middle Ages. Croatian Medical Journal, 55, 50–53.
14. Charles, G. G. (1960). Brain, vision, memory: The history of neurosciences (pp. 10, 18, 29, 31, 245, 393).
15. Persaud, T. V. N., Loukas, M., & Tubbs, R. S. (n.d.). A history of human anatomy (2nd ed.).
16. Zemelka, A. M. (2017). Alcmaeon of Croton—Father of neuroscience. Brain, mind and senses in the Alcmaeon's study. Journal of Neurology and Neuroscience, 8, 1–8.
17. Stanford University. (n.d.). Nerves. https://web.stanford.edu/class/history13/earlysciencelab/body/nervespages/nerves.html

18. Diels, H. (1879). Doxographici Graeci. Reimer.
19. Codellas, P. S. (1932). Alcmeon of Croton: His life, work, and fragments. Proceedings of the Royal Society of Medicine, 25, 1041–1046.
20. Beare, J. I. (1906). Greek theories of elementary cognition from Alcmeon to Aristotle. Clarendon Press.
21. Von Staden, H. (1989). Herophilos: The art of medicine in early Alexandria (Edition, translation, and essays). Cambridge University Press.
22. Wickens, P. A. (2015). A history of the brain from Stone Age surgery to modern neuroscience. Psychology Press.
23. Magner, L. N. (1992). A history of medicine. Purdue University.
24. Reverón, R. (2015). Herophilos, the great anatomist of antiquity. Anatomy, 9(2), 108–111.
25. Rehman, S. Z. (1967). Tareekh-Ilme-Tashreeh. Ibn Sīnā Academy.
26. Wiltse, L. L., & Pait, T. G. (1998). Herophilos of Alexandria (325–255 B.C.). The father of anatomy. Spine, 23, 1904–1914.
27. Smith, C. U. (2010). The triune brain in antiquity: Plato, Aristotle, Erasistratus. Journal of the History of the Neurosciences, 19, 1–14.
28. Longrigg, J. (1972). Herophilos. In C. Gillespie (Ed.), Dictionary of scientific biography (Vol. 6, pp. 316–319). Charles Scribner's Sons.
29. Tomey, M. I., Komotar, R. J., & Mocco, J. (2007). Herophilos, Erasistratus, Aretaeus, and Galen: Ancient roots of the Bell-Magendie law. Neurosurgical Focus, 23, E12.
30. Wills, A. (1999). Herophilos, Erasistratus, and the birth of neuroscience. The Lancet, 354, 1719–1720.
31. Furley, D. J., & Wilkie, J. S. (1984). De usu pulsuum. Princeton University Press.
32. Clarke, E., & O'Malley, C. D. (1996). The human brain and spinal cord: A historical study illustrated by writings from antiquity to the twentieth century (2nd ed.). Norman Publishing.
33. Finger, S. (2001). Origins of neuroscience: A history of explorations into brain function. Oxford University Press.
34. Haque, A. (2018). Contributions of Islamic scholars to the field of neuroscience. Journal of the History of the Neurosciences, 27(2), 196–210.
35. Munazir, M. (2022). A review of anatomical concepts of nizam-e-asabi in tibbe unani. European Journal of Pharmaceutical and Medical Research, 9(2), 136.
36. Wills, A. (1999). Herophilos, Erasistratus, and the birth of neuroscience. The Lancet, 354(9191), 1.
37. Oakes, P. C., Fisahn, C., Iwanaga, J., DiLorenzo, D., Oskouian, R. J., & Tubbs, R. S. (2016). A history of the autonomic nervous system: Part I: From Galen to Bichat. Child's Nervous System, 32(12), 2303–2308.
38. Rahman, S. U., & Hassan, M. (2013). Hearts role in the human body: A literature review. ICCSS, 2(2), 1–6.
39. Rajkumari, A. (2015). Galen and his contribution to anatomy: A review. Journal of Evolution of Medical and Dental Sciences, 4(26), 4509–4516.
40. Baloyannis, S. J. (2006). Galen on the functional expression of the soul by the brain. Encephalos, 43(1), 7–18.
41. Baloyannis, S. J. (2003). The neurosciences in the Greek world. In K. Sinha & D. Jha (Eds.), Some aspects of history of neurosciences (pp. 97–117). Catholic Press.
42. Gross, C. G. (1994). Galen and the squealing pig. The Neuroscientist, 4(3), 216–221.
43. Galen. (1968). On the usefulness of the parts of the body (M. May, Trans.). Cornell University Press.
44. Islamic medicine. (n.d.). Wikipedia. https://en.wikipedia.org/?title=Islamic_medicine&redirect=no
45. Rabban Tabri, A. H. A. B. S. (2010). Firdaus-ul-Hikmat (Hakeem Mohammad Awwal Shah Sanbhali, Trans.). Idara Kitab-us-Shifa.
46. Samuel Thomas Soemmerring (1755–1830): The naming of cranial nerves. (2017). European Neurology, 77, 303–306. https://doi.org/10.1159/000475812
47. Modanlou, H. D. (n.d.). A tribute to Zakariya Razi (865–925 AD), an Iranian pioneer scholar.
48. Tubbs, R. S., Shoja, M. M., Loukas, M., & Oakes, W. J. (2007). Abubakr Muhammad ibn Zakaria Razi, Rhazes (865–925 AD). Child's Nervous System, 23, 1225–1226.
49. Zarshenas, M. M., Mehdizadeh, A., Zargaran, A., & Mohagheghzadeh, A. (2012). Rhazes (865–925 AD). Journal of Neurology, 259, 1001–1002.
50. Rabban Tabri. (n.d.). Wikipedia. https://en.wikipedia.org/wiki/Ali_ibn_Sahl_Rabban_Al-Ṭabarī
51. Majūsi, I. B. A. (2010). Kamil-us-Sanaa (Urdu translation by Hakeem Ghulam Hussain Kantoori). CCRUM.
52. Abu Sahl MIBY. (2008). Kitabul Miat (Urdu translation). CCRUM.
53. Razi, A. B. M. B. Z. (1991). Kitab Al Mansoori (Urdu translation). CCRUM.
54. Mohamed, W. M. (2008, July 14). History of neuroscience: Arab and Muslim contributions to modern neuroscience. IBRO History of Neuroscience.
55. Temkin, O. (1973). Galenism: Rise and decline of a medical philosophy. Cornell University Press.
56. Pormann, P. E., & Savage-Smith, E. (2007). Medieval Islamic medicine. Edinburgh University Press.
57. Iskandar, A. Z. (2001). Al-Rāzī. In H. Selin (Ed.), Encyclopaedia of the history of science, technology, and medicine in non-Western cultures (pp. 40–41). Springer.
58. Spink, M. S., & Lewis, G. L. (1973). Albucasis on surgery and instruments. Wellcome Institute of the History of Medicine.
59. Gutas, D. (2001). Avicenna and the Aristotelian tradition: Introduction to reading Avicenna's philosophical works (2nd ed.). Brill.