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GALEN AND HIS CONTRIBUTION TO ANATOMY: A REVIEW

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INTRODUCTION: Galen of Pergamum was the most famous Greek physician during the Roman period (129-200 AD). He was a brilliant anatomist and pioneer of experimental physiology.^{1,2} He was both a universal genius and a prolific writer. He pioneered the concepts of anatomy, physiology and therapeutics. He is credited as being the first to discover that arteries carry blood, not air, as was previously believed. He developed medical tools for surgery and dissection and wrote many volumes of his discoveries and observations.^{2,3} He was one of the leading thinkers in medicine and one of the best known physicians of all times.⁴

He was not only a gifted practitioner but also a first class anatomist, physiologist, pathologist, and pharmacologist of the ancient times. During fourteen centuries, Galen's works were undisputable textbooks for students of medicine and most valuable manuals for practitioners besides the works of Hippocrates. He established the fundamentals of the medical science which are still significant.⁵ Galen was the first to attempt to formulate a classification of diseases and symptoms with a strong basis in anatomy.⁶ In this review article, an exhaustive analysis and attempt has been made thereby depicting the biography of Galen and reviewing his multiple contributions in the fields of medicine and anatomy under various sub-headings and the same has been discussed with the available literatures.

GALEN'S EDUCATION, EARLY LIFE AND TRAINING: Galen was born in Pergamum on the Ionic coast of Asia Minor in 129 AD under Roman jurisdiction. His father, Nikon, was a well-respected, wealthy architect-engineer who took an active role in Galen's liberal early education concentrating on mathematical and philosophical subjects, notably geometry and logic. This seems to have influenced his methodological approach to medicine. His strong views on the importance of philosophy in medical training reflected his eclectic, extensive, philosophical education.⁷ His father was Galen's only teacher up to the age of fourteen and a strong role model. In his book "On the Passions and Errors of the Soul", Galen says he was "fortunate in having the most devoted of fathers". His first anatomy teacher was Satyrus, a pupil of Quintus, who through his students played a major role in the increase in activity in the field of anatomy that led to Galen's work.⁸

ANATOMICAL AND MEDICAL STUDIES: Galen regarded anatomy as the foundation of medical knowledge and he frequently dissected and experimented on such lower animals as the Barbary ape (or African monkey), pigs, sheep, and goats. He distinguished seven pairs of cranial nerves, described the valves of the heart and observed the structural differences between arteries and veins. He was seriously hampered by the prevailing social taboo against dissecting human corpses. However, the inferences he made about human anatomy based on his dissections of animals often led him into errors. His anatomy of the uterus, for example, is largely that of the dog's. According to Galen, blood is formed in the liver and is then carried by the veins to all parts of the body, where it is used up as nutriment or is transformed into flesh and other substances. While human dissection was not considered during his time, Galen performed dissections on animals assuming that human organs

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were identical.^{9,10} Treating severe injuries of the gladiators, he enhanced his knowledge of anatomy, physiology, trauma and sports medicine.¹¹

METHODS AND ACHIEVEMENTS: Anatomy was very important to Galen. He believed that "the working body is not understandable without knowledge of its structure". Galen did not dissect humans because of the negative social and religious stigmas associated with experimentation on the human body, but he performed dissections and vivisection experiments on many animals including apes, goats, dogs, and pigs. Because he could only study animals, some of Galen's anatomical assertions were inaccurate with respect to the humans. Galen's reliance on anatomy and experiment showed his belief in the value of observation in medicine. He argued that diseases were manifestations of impaired anatomical functioning, so in order to diagnose and to treat disease, a fundamental understanding of the human structure was critical.

One of Galen's major advances was his work on the movement of blood in the body. While he never explained how the blood circulated, he made many important discoveries regarding the movement of blood in the body, including the differences between veins and arteries and the anatomy of the heart and its associated vasculature. His precise descriptions and studies of neurological functions and anatomy also led to major breakthroughs. He used dissection to explore the anatomy of the brain and spinal cord, including the spinal nerves. Not only did he explore anatomy, but he also demonstrated the functions of nerves. He also explored many other aspects of the human body, including the eyes, tongue, larynx, fetal development and reproductive organs. In addition, his experiments with the kidneys showed that they were functionally related to the bladder. Galen viewed the body as consisting of three connected systems: the brain and nerves, which are responsible for sensation and thought; the heart and arteries, responsible for life-giving energy; and the liver and veins, responsible for nutrition and growth.

TREATMENT METHODS AND THEORIES: The foundation of all of Galen's treatment methods was his belief that disease resulted from an internal imbalance of the four humours: air (blood), fire (yellow bile), earth (black bile) and water (phlegm). Unlike Hippocrates, who believed that disease resulted from a humoral imbalance throughout the body, Galen believed that a disease-causing imbalance could be located within an organ. Drugs developed by Galen were made from herbs that he collected from all over the world. The drugs were classified by their properties - heating, cooling, drying, or moistening and were applied so as to counteract whatever humour disproportion existed. Galen was the first physician to use the pulse as an indicator of illness when compared to the normal pulse. Galen used pulse observations to diagnose diseases and symptoms such as fevers.⁶

He created his own theories from those principle and much of Galen's work can be seen as building on the Hippocratic theories of the body, rather than being purely innovative. He carried on the work of Hippocrates by teaching that Doctors should study the symptoms of a disease before they treated it. His medicine was based on the ideas of the Greeks and Romans. His ideas were widely accepted because they fitted in with other Greek ideas about nature, which were believed in the Middle Ages. A good example of this is the theory of the four humours.

THE THEORY OF THE FOUR HUMOURS: Greek thinkers emphasized the idea of balance in all things, including medicine. They believed in the importance of a balanced lifestyle; to eat in moderation, take

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some exercise, sleep regularly and keep clean. In their search for the natural basis of all things, these thinkers came up with the four elements: earth, air, fire and water. These elements were linked to the four seasons and also to the four "humours" inside each human being: yellow bile, black bile, blood and phlegm. Galen believed that imbalance in any of these caused illness. Doctors could restore the balance by treating patients e.g. if a patient had a fever, his body needed cooling to restore the balance of humours and therefore a cold drink might be prescribed.⁴

GALEN'S CONCEPT OF DISEASE: Galen defined disease as impairment of bodily activities. Whatever that impairs the bodily activities is the cause of disease. It is Galen's great contribution to Western medicine to have laid a foundation of pathology by combining physiological and anatomical point of view.¹² He was the first to attempt to formulate a classification of diseases and symptoms with a strong basis in anatomy.⁶

GALEN'S VIEWS ON THE ANATOMY OF THE EYE: He believed that the eye was composed of membranes and fluids. He distinguished the following membranes of the eye: the cornea, the sclera, the choroid, the capsula of the lens and the retina, as well as the structure covering the muscles of the eye and joining the individual elements of the eye with the orbital cavity and the skull. The following were considered as fluid substances of the eye: egg-shaped fluid (i.e. albuminous fluid), crystal fluid (i.e. the lens) and vitreous fluid. His theory of vision assumes the existence of a specific life force called pneuma, which is under a considerable influence of the soul and which reaches the eye from the brain through small channels in the optic nerve.¹³

OBESITY AND TREATMENT: Galen was among the first to establish scientific methods to describe and treat morbid obesity. He stated that obesity results from the surplus of "bad humours" in the body and specifically from a surplus of blood. Nevertheless, he proposed some treatments for obesity such as diet, exercise, and medications that are still valuable and are nearly the same as what is advocated today.¹⁴

GALEN AS A PIONEER OF SPINE RESEARCH: Galen marked the history of medicine for more than 14 centuries. His doctrines, expressed in his voluminous work, combined the medical heritage of the Hippocratic, the Alexandrian and some of the most important medical schools of antiquity. The strong influence of the Hippocratic tradition can characteristically be traced in orthopaedics and particularly in Galen's presentation of the spine. Based on his observations, derived from dissection and vivisection of animals, Galen established a pioneer model for the study of human spine. His research ended in an accurate description of the vertebral column and the spinal cord. He also described the course and the distribution of the nerves emerging from the spine. Galen was the first physician to demonstrate the neurological implications following transection of the spinal cord at several levels.^{3,11}

GALEN'S MAJOR WORKS: His "On the Elements according to Hippocrates" describes the philosopher's system of four bodily humours, blood, yellow bile, black bile and phlegm, which were identified with the four classical elements and in turn with the seasons. Amongst Galen's own major anatomical works are a seventeen-volume "On the Usefulness of the Parts of the Human Body" and

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"On Anatomical Procedure". He made extraordinary advances in anatomy which were not challenged until the time of Andreas Vesalius. His dissections were of animals, which he then extrapolated to human anatomy resulting in some unworthy errors.^{6,15} Galen was the first to describe the ureters with their functions, as well as organising the bones of the skeletons with their muscle attachments.¹⁶ On the basis of his own anatomical researches and logical conclusions, Galen established connections between (i) the brain and the mind, (ii) the heart and the emotions and feelings and (iii) the liver and certain appetitive sentiments like hunger or thirst.¹⁷

GALEN'S PHYSIOLOGY: Galen's genius was evident in physiological experiments conducted on animals. The work "On the Usefulness of the Parts of the Human Body" comprised seventeen books concerning with this topic. To study the function of the kidneys in producing urine, he tied the ureters and observed the swelling of the kidneys. To study the function of the nerves, he cut them and thereby showed paralysis of the shoulder muscles after division of nerves in the neck and loss of voice after interruption of the recurrent laryngeal nerve. Descriptions in the Galenic "On the Anatomy of Nerves" appear vague at first sight, but the described structures can be identified in most cases without doubt on the basis of anatomical knowledge.¹⁸

GALEN'S SUCCESS: His books were used to teach new Doctors and so his ideas remained important for the next thousand years until the Middle Ages. This meant that his mistakes were also passed on, which may have prevented the understanding and treatment of illnesses. Galen was not a Christian or a Muslim, but he believed in one God and talked about 'the creator'. This made his work acceptable to both Christian and Islamic cultures as it fitted in with their teachings. He is remembered among pharmacists for his classification of animal and vegetable extracts which are still known as Galenicals. As a practicing anatomist, Galen was possibly the first exponent of scientific method applied to the vivisection and post-mortem dissection of animals, especially the Barbary ape. It is not thought that he carried out any dissection of the human body. He concluded that the diaphragm and thoracic muscles were responsible for expansion of the chest cavity in inspiration. He was one of the first to describe correctly the function of kidneys and explain micturition. He proved that urine was formed in the kidneys. Before, Doctors had thought it was formed in the bladder. Among his many neologisms, he coined the term ureter and he was probably the first to recognize the value of a competent ureterovesical valve. Galen advocated catheterization for urinary obstruction.¹⁹

Galen, a prolific writer, produced hundreds of works, of which about 120 have survived. His most important contributions were in anatomy. His descriptions of bones and muscle were notable. He was the first to observe that muscles work in contracting pairs and described the heart valves and the structural differences between arteries and veins. He used experiments to demonstrate paralysis resulting from spinal cord injuries and the passage of urine from kidneys to bladder. Galen pioneered diagnostic use of the pulse rate. One of his most lasting technique that is still practiced by Doctors today is taking the pulse of a patient. In his extensive travels, Galen also collected plants with healing properties and explained their uses.

GALEN'S MISTAKES AND ERRORS: Unfortunately for medieval medicine, Galen made critical errors about the heart and blood vessels that remained virtually unchallenged for 1,400 years. Because his knowledge was derived for the most part from animals rather than human dissection, he made many

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mistakes, especially concerning the internal organs. One of Galen's most notable mistakes was to think that the heart was divided in two parts. He maintained that blood permeated the septum between left and right ventricle and persisted in the Hippocratic misconception that the body's fluids were composed of an equilibrium of four humours (black bile, yellow bile, blood, and phlegm) and the rationale of medicine was to restore any disease-causing imbalance. Galen accepted the common view that disease was caused by an imbalance of these 'four humours' in the human body.

He also believed that blood formed in the liver and was circulated from there throughout the body in the veins. He showed that arteries contain blood, but thought they also contained and distributed pneuma, a vital spirit. His error, which will become the established medical orthodoxy for centuries, is to assume that the blood goes back and forth from the heart in an ebb-and-flow motion. His errors were not seriously challenged in medical thought and teaching until the anatomist Andreas Vesalius in 1543 and the physiologist William Harvey in 1628 courageously questioned the infallibility of Galenic authority and effectively substantiated their findings through demonstration. Galen's teachings became the ultimate medical authority, approved by the Christian church because of his belief in a divine purpose for all things.

His "On Anatomical Procedures" describes in minute detail how to perform a remarkable series of experiments by which Galen demonstrated the anatomy and the functions of the respiratory muscles, when work on human corpses was forbidden and it became a standard text on anatomy when rediscovered in Western Europe in the 16th century.²⁰

GALEN AND ANATOMY: Galen was able to study skeletons, but not actual bodies. This was because religious restrictions forbade the dissection of human remains. He also stressed the importance of understanding the skeleton and the functions of parts of the body. He gained some knowledge of anatomy and physiology from treating wounded gladiators. Although he realized the need to carry out experiments, human dissection was not acceptable so he had to base his ideas on the anatomy of animals, especially the ape, which he said was closest to the human skeleton. Galen made extraordinary advance in anatomy which were not challenged until the time of Vesalius. His dissections were of animals, which ultimately resulted in some noteworthy errors⁶. The Anatomical Procedures is Galen's most complete treatise on anatomy, which the Western culture came to know only in the Renaissance.²¹

LATER YEARS: Galen's library and many of his own manuscripts were destroyed in a fire at Rome's Temple of Peace in 192 AD.²⁰ Yet in spite of this loss, information about his writings remains because he wrote two treatises "On My Own Books" and "On the order of My Own Books."⁶ From 179 AD to his death around 200 AD, Galen continued his medical research and writings producing such major works as The Method of Cure. During his last years, however, he wrote more nonmedical works, such as on the Equality of Sin and Punishment and The Slight Significance of Popular Honor and Glory.

BEYOND GALEN'S LIFETIME: His texts were kept alive primarily by the Arabs until they were retranslated in Europe in the Middle Ages. One of the crucial causes of this endurance was that Galen's concepts coincided, for the most part, with Christian beliefs. Of great importance was Galen's assertion that human organs were suited for their function; this notion fit in with the Christians' "belief in a system ordained by nature". In addition, although Galen was not Christian, his writings

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expressed his belief in one God and in the body as an instrument of the soul. He tried to differentiate between blood spitting and blood vomiting, between colic from kidney stone and colic from the intestines. He also understood well the psychosomatic element of illness. In the fields of therapy and of pharmacy, Galen is remembered mainly for his schematism and extremely complex prescriptions, sometimes containing dozens of ingredients.

Unlike some of his predecessors, Galen concluded that the brain controlled cognition and willed action. The initial evidence for this doctrine was that the brain was the site of termination of all of the five senses: touch, taste, smell, sight, and hearing. He presumed that the information from these five senses was organized by a part of the brain that generated a concept of an object common to all senses; this part of the brain he considered to be the area of common sense. He thought that he could differentiate sensory from motor nerves (not nerve fibers) by palpation. Galen considered that common sense, cognition and memory were functions of the brain. His studies of respiration and of the recurrent laryngeal nerve solidified the knowledge that the brain, not the chest, was the site of the rational power that guides human behavior.² Apart from being an outstanding physician, he had a great knowledge of medicines and ways of their production. Galen developed his general theory of body functioning. It was only after his death that his works attracted more general attention. Both theoretical developments and his works on various ailments were first recognised in the Arabic world. It was only this fact that resulted in his works being gradually translated from Arabic into Latin and published in Europe where they grew important among European university circles.²²

CONCLUSION: Galen's influence on medical theory, terminology and practice remained unquestioned in Europe and the Middle East throughout the Middle Ages and Renaissance. His work was so influential there that he has been described as the Medical Pope of the Middle Ages.¹⁹ He was one of the originators of the science of anatomy and was probably the most important physician of all time. His surviving writings make up about half of all ancient writings on medicine. The importance he placed on anatomy and verification of science led his followers to create a surge in inquiries about bodily structure and function. His influence on medicine was still crucial to modern medical science. The progress he made in his lifetime was astonishing, especially because he managed to influence medicine and philosophy simultaneously in dramatic ways.⁵

His description of experiments on the exposed animals and animal brain is remarkable and depicts the origins of experimental neurosurgery⁶. His achievements in anatomical science in antiquity are unequalled.²³ Galen brought neuroanatomical knowledge and physiology together in his study of the brain and nerves using experimental methodology which arguably represent the zenith of neurological investigation in the ancient world.⁶ Although it has been almost 2,000 years since Galen walked the streets of the Roman Empire, his legacy continues via multiple eponyms that bear his name. He became one of the most celebrated figures in the history of Science.¹¹

Urology occupies a considerable place in Galen's work. He was the first to describe the ureters with their function, as well as organising the bones of the skeleton with their muscle attachments.^{16,24} He remained the highest medical authority until Andreas Vesalius and William Harvey exposed the fundamental errors of his system. Nevertheless, his significant contribution in the fields of medicine and anatomy deserves to be appreciated by the medical professionals more particularly the anatomists. It is recommended that every medical professionals and anatomists study the biography of Galen and his multifarious contributions made in the fields of medicine and anatomy.

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