

## History of Medicine

# An Analysis of Historical Vignettes by Ibn Sina in the Canon of Medicine on the Structure and Function of the Cardiorespiratory Apparatus

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## Abstract

Ibn Sina is regarded as one of the greatest physicians, thinkers and medical scholars in the history of medicine. Ibn Sina, a Persian scholar in the medieval era, wrote a famous book of medicine, the Canon of Medicine. The book was adopted as the main textbook of medicine in most Western and Persian universities. In the present critique, we analyzed the functional and anatomic descriptions of the heart, airways and the lungs as viewed by Ibn Sina in volume three of the Canon of Medicine textbook, and compared them to modern anatomy texts.

**Key words:** Anatomy, Avicenna, Cardiorespiratory system, Heart, Ibn Sina, Lungs, Trachea

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## Introduction

Abu Ali al-Hossein ibn Adbullah ibn Sina (known as Avicenna in the West) was born in a village near Bukhara in August 980 and passed away in Hamadan in June 1037.<sup>1</sup> Ibn Sina is regarded as one of the greatest physicians, thinkers and medical scholars in history.<sup>2,3</sup> In volume three of his famous book, the Canon of Medicine, Ibn Sina explained explicitly the anatomy, function and pathophysiology of the diseases affecting the heart and lungs. On the anatomy and function of the heart, Ibn Sina regarded the heart as an organ which controls the function of other organs, including the brain.<sup>4,5</sup> He also referred to the heart as a point of origin/source of the vital power. Avicenna's views on the role of the heart contradicted those of earlier philosophers such as Aristotle who associated the heart with functions of sensation, pain, pleasure and nutrition.<sup>3</sup> However, Ibn Sina assumed that the heart was the source of psychic, and emotional activities and was involved in the supply of blood and/or breath to every part of the body.<sup>4,5</sup> Avicenna contributed significantly to cardiology, as he initially described blood circulation and valvular functions.<sup>6</sup> His most important contribution was the correct description of the pulse when he stated that, "Every beat of the pulse comprises two movements and two pauses. Thus, expansion: pause: contraction: pause".<sup>2,4,7</sup> The interpretation of the cardiac pulse is still emphasized in medical training as an important diagnostic tool for cardiac dysfunction.

Ibn Sina also discussed in detail the anatomy of the lungs and

the various diseases and treatments associated with the respiratory system during his time. On the mechanics of respiration, Avicenna described the events which take place during normal inspiration and expiration, the structures involved, and also forced respiration.<sup>4,7-9</sup> In addition, Ibn Sina described the various diseases, etiologies and treatments of respiratory disorders.<sup>8,9</sup> In the present critique, we analyze the functional and anatomic descriptions of the heart, airways and the lungs as viewed by Ibn Sina in the Canon of Medicine, and compare them to modern anatomy knowledge.

## Analysis of the cardiorespiratory system

The respiratory system consists of a system of interconnected air passages and the lungs. The respiratory system is closely related to the cardiac system, both structurally and functionally. In this critique, we will discuss the anatomy of the respiratory system first, followed by the cardiac system. The lungs are connected to the upper respiratory apparatus (the nose, oral cavity, pharynx and larynx) by the trachea. The trachea, as viewed by Avicenna, consists of a series of tracheal rings which are semi-circular in shape.<sup>4,7</sup> He further noted that the trachea is positioned anterior to the esophagus and the part that is closer to the esophagus posteriorly is membranous, to allow for distension of the esophagus during swallowing.<sup>4,7</sup> Proximally, the trachea connects with the esophagus through the upper portion of the larynx while distally, the trachea divides into two parts which enter the right and left lungs.<sup>4,7</sup> According to Ibn Sina, the larynx is made up of three cartilages joined together by muscles and membranes.<sup>4,7</sup> He also observed that the larynx contains vocal cords inside, which are responsible for the production of voice and obstruction of the breath during the production of groaning sounds.<sup>4,7</sup> These anatomic descriptions of the trachea and partly of the larynx complement well with modern anatomy and slight variations can be regarded as errors of omission emanating from the lack of finer dissections since technical development was still elementary

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during Ibn Sina's time. According to Moore and colleagues<sup>10</sup>, the trachea communicates superiorly with the larynx at the level of the sixth cervical vertebra (C6) in the neck. Distally, it stretches into the thorax where it terminates by dividing into the left and right bronchi at the level of the intervertebral disc between the fourth and fifth thoracic vertebra (T4/T5).<sup>10</sup> Structurally, the larynx is made up of nine small and large cartilages which are connected by joints, membranes and muscles.<sup>10,11</sup> In agreement with Ibn Sina, the vocal cords function in both voice production and preventing entrance of food particles and water into the respiratory tract during swallowing.<sup>11</sup> The trachea is made up of the incomplete circular cartilages posteriorly; the deficit is completed by the trachealis muscle, an involuntary smooth muscle.<sup>10</sup> On its function, Ibn Sina concurred with modern anatomic descriptions that it serves as a conduit or air passage between the lungs and outside environment.<sup>4,10</sup> In addition, Avicenna noted that tracheal rings serve to prevent collapse of the tracheal tube, and also act as a shield protecting the vital neck structures from the front, especially the muscular esophagus posteriorly.

According to Avicenna, the lung is made up of "slack and wobbly airy flesh that is created from the moist diluted and gentle blood".<sup>4,7</sup> The slackness and wobbly nature of the lungs enables them to take in air during breathing.<sup>4</sup> Topographically, Ibn Sina observed that each lung occupies a separate compartment in the thoracic cavity.<sup>4,7</sup> The partitioning of the thoracic wall consists of a wall of double membrane stretching from the sternum anteriorly to the vertebral column posteriorly.<sup>4</sup> In extant anatomy text books, the mediastinum is described, which represents the partitioning of the space in the middle of the thoracic cavity into three major spaces which house the great vessels and the heart.<sup>10,11</sup> Lateral to this space, on both sides of the thoracic cavity, the lungs are contained, a description which complements Avicenna's assertions. Moreover, Ibn Sina affirmed that the left lung has two parts/lobes while the right lung has three.<sup>4,7</sup> The right lung is larger than the left and is divided by oblique and horizontal fissures into three distinct lobes while the left lung only has one oblique fissure, hence two lobes.<sup>10</sup>

Avicenna noted that lung tissue is porous and white in color, to which he ascribed the porousness with the functions of distensibility during inspiration and the white color being as a result of less blood than air in the lungs.<sup>4,7</sup> Anatomically, the lung tissue is light, soft and spongy with an elastic recoil nearly to a third of its original size.<sup>10,11</sup> According to Moore and colleagues<sup>10</sup>, the terminal bronchioles divide and lead into respiratory bronchioles which are characterized by numerous air sacs called alveoli and surrounded by pulmonary and bronchiole capillaries, and pulmonary venules. Avicenna only noticed the association between the divisions of the trachea, arteries and veins in the lung tissue. Microscopic dissection was unavailable at the period when Avicenna wrote his treatises, hence the lack of fine descriptions on this matter. The organization of the alveoli and associated blood vessels represents a respiratory unit with a large surface area for gaseous exchange where oxygen is extracted from the alveoli into the blood vessels and carbon dioxide is excreted from the blood vessels into the alveoli and subsequently into the atmosphere during expiration. In line with this philosophy, Ibn Sina opined about respiration and stated that "respiration serves the purpose of taking air into the blood and exhaling the noxious mist".<sup>4,7</sup> Ibn Sina's descriptions of the lungs influenced not only the understanding of the anatomy and physiology of these organs

but also the pathology and surgical interventions. In support of these assertions, Avicenna noted that each lung is divided into parts which are functionally independent. He stated that, "the lung is in two parts because if one part of it is damaged, the other part will perform its own function and the function of the other one, as well".<sup>4,7</sup> Each lobe of the lung is further divided into structurally and functionally distinct units referred to as bronchopulmonary segments and these segments can be surgically removed during partial pneumonectomy.<sup>10</sup> In addition, pathologies of the lung can be localized to a focal point i.e. the bronchopulmonary segment, to the whole lobe and/or the whole lung.<sup>10</sup>

Apart from the fact that lungs facilitate gaseous exchange between the internal environment and the atmosphere, Ibn Sina proposed that the lungs also prepare and serve the air to the heart and this air will help to moderate the animal's heart beat and drive the vital energy.<sup>4,7</sup> Avicenna also suggested that the lungs help to cool the heart with each beat.<sup>4</sup> This arrangement can be likened to the wings of a bird and its body where the wings represent the lungs and the body or torso represents the heart and as the lungs flap they bring a cool breeze to the heart keeping it cooler. In addition, the lungs also surround and cushion the heart from the thoracic wall and protect it from penetrating objects.<sup>4,7</sup>

On the sensation of lungs, Ibn Sina stated that, "the lungs are surrounded by a neural membrane which is sensitive, and enables the lungs to perform their function".<sup>4,7</sup> In modern anatomic descriptions, the sensitive neural membrane can be compared to the pleural membranes, both parietal and visceral, which are sensitive to general and visceral sensation, respectively. The parietal pleura is closely associated with the thoracic wall and receives sensory innervation from the phrenic and intercostal nerves, while the visceral pleura which is closely associated with the lung tissue and is innervated by the autonomic nervous system through the vagus nerve and the sympathetic chain.<sup>10,11</sup>

Regarding the anatomy of the heart, Ibn Sina stated that the heart is located in the thoracic cavity, more to the left than right, and surrounded by a thick membrane which offers protection from injury.<sup>4,7</sup> Concurring with Ibn Sina's assertions, the heart is found in the thoracic cavity, covered by a double layer of pericardium and located in the middle mediastinum and oriented to the left.<sup>10,11</sup> Furthermore, the outer fibrous pericardium is a tough membrane which offers protection to the heart.<sup>10</sup> Although the heart is surrounded by the tough pericardium, the membrane allows enough space for the heart to expand during diastole and contract during systole.<sup>7,10</sup> Structurally, Avicenna concurred with Aristotle's views that the heart has three ventricles including the right, middle and left ventricles.<sup>4,7,12</sup> The middle ventricle was ascribed to act as passage between the right and left ventricles and also as storage chamber for nourishment of the heart.<sup>4,7,9,12</sup> The function of the middle cavity as a communication passage between the right and left ventricles was drawn from Galen's views, who noted a porous interventricular septum linking the right and left ventricles.<sup>12</sup> Ibn Sina also mentioned that the heart has two ear-like structures at the site of entrance of blood vessels, and that the left ventricle was thicker than the right.<sup>4,7</sup> Ibn Sina's anatomic descriptions about the heart were not entirely erroneous; one would argue that the three chambered heart was still at that stage during the embryonic partitioning of the heart where common atrium has partitioned into two and the interventricular septum is yet to be fully formed. However, this can be contentious considering that accurate medical imaging devices were not yet

popular to enable viewing of the various stages during embryonic development. The adult heart has four chambers: two atria and two ventricles, separated by the interatrial septum and interventricular septum, respectively.<sup>10,11</sup> The ear-like structures referred to by Ibn Sina represent the auricular appendages which are remnants of the embryonic atria and are located close to the site of entrance and exit of the great vessels of the heart on its superior border.<sup>10</sup> The left ventricle of the heart pumps blood to the rest of the body and its walls are thicker in order to generate the greater force needed, while the right ventricle only pumps blood to the lungs, and hence its walls are thinner.<sup>10</sup> Functionally, Avicenna mentioned that the heart fills with blood during diastole.<sup>4</sup> He also observed that the aorta contained three valves at its origin, which open when blood flows into the aorta during systole, and closes during diastole, thereby preventing back flow of blood into the left ventricle.<sup>4,7</sup> Ibn Sina's description of the circulation of blood between the heart and lungs and also to the rest of the body set the ground stage for Ibn al-Nafis (1288 A.D) and William Harvey (1 April 1578 – 3 June 1657), who later refined and described the pulmonary circulation.

In conclusion, whilst Ibn Sina's anatomy of the lungs and the heart as described in the Canon of Medicine is not as accurate as it is today, his pioneering work contributed immensely to the evolution of the knowledge of the cardiorespiratory system. Some of the techniques like pulse taking and assessment of breathing are still valuable in modern medical practice. However, his anatomy on the structure and positioning of the lungs and the heart brings an added dimension that illustrates perfection in the creation of the human body. This is illustrated in Ibn Sina's description of the larynx where the vocal cords function in both voice production and preventing entrance of food particles and water into the respiratory tract during swallowing; as well as his description that the lungs surround and cushion the heart from the thoracic wall and also protect it from penetrating objects.

**Conflicts of interest:** None

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