
History of Medicine

A Brief History of the Discovery of the Circulation of Blood in the Human Body

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Abstract

The present article describes briefly the development of the theories regarding the circulation of blood in humans, from the time of Galen (second century C.E.) to the work of William Harvey (17th century C.E.).

We shall summarize the views of Galen together with those of two prominent Iranian physicians of the Middle Ages (Razi and Ahwazi known in the West as Rhazes and Haly Abbas respectively) as well as that of Ibn-Nafis from Damascus (the discoverer of the pulmonary circulation) and the Spanish physician and cleric Michael Servetus and finally the definitive work of William Harvey, the English physician who described the mechanism of both the systemic and pulmonary circulation of blood in the human body.

Keywords: Blood circulation • Galen • Harvey • Ibn-Nafis • Rhazes

The mechanism of the circulation of blood within the human body had remained a mystery until the seventeenth century C.E.

Today it is known that the circulation of the blood consists of the greater or systemic and the lesser or pulmonary circulation. In systemic circulation, the blood is pumped by the heart into the arterial system and then via fine capillaries reaches the venous system which convey the blood back to the right ventricle of the heart. The pulmonary circulation consists of the blood in the right ventricle being pumped and distributed in the

lungs for oxygenation, via the pulmonary artery and its return again to the left atrium and ventricle through the pulmonary vein.¹

This concept of the constant circulation of the blood through the body stands in contrast to the ancient belief that the arteries and veins conveyed the blood to the periphery where it was consumed by the tissues and new blood was constantly produced centrally and replacing the consumed blood.

The significance of the heart in ancient times

The heart has always been considered a significant organ throughout history and in different cultures, not only anatomically but also metaphorically as well as symbolically. For instance, Professor *Frank Nager* of Zurich University has described the symbolic and metaphoric representations of the heart in literature, art and religious writings of the world in his well illustrated book, the "Mythology of the Heart".²

It is perhaps in the ancient Chinese medical literature that for the first time mention is made of the circulation of blood, but in their traditional medicine, it was not due to the mechanical pumping of the heart but was caused by the opposing and complementary forces of *Yin* and *Yang*. The ancient Indians thought of the heart as the center from which the nervous system sprang to travel to all parts of the body, and the Greek physician *Hippocrates* (460 – 370 B.C.) believed that the liver and the spleen were the central organs within which blood was constantly produced and then traveled to the heart to be warmed or cooled by the air entering the lungs and the heart via the trachea. *Aristotle*, the Greek philosopher and biologist (384 – 322 B.C.) attributed three ventricular chambers to the heart and described the main artery exiting the heart and gave its name as aorta.³

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Development of the concepts of blood circulation

In modern medical literature, the discovery of the blood circulation by the English physician *William Harvey* (1578 – 1657 C.E.) is regarded as a turning point in the history of modern medicine as much as *Copernicus'* views were in astronomy.⁴ But what is often overlooked is the gradual development of the concepts of blood circulation prior to Harvey. Thus, in this article, we shall survey briefly those concepts in their historical perspective.

Galen

Galen was born around 129 C.E. in *Pergamum*, on the Aegean coast in Asia Minor, which was then a part of the Roman Empire, and died aged 70. He was famed as an anatomist as well as a philosopher and as a physician he was considered second only to Hippocrates in ancient times. He had dissected many animals as well as a few human corpses to describe the anatomy and possible functions of the body organs.⁵ Galen described two kinds of blood: bright red carried by the arteries and dark red carried by the veins and he believed that it was the pulsations in the walls of the arteries which propelled the bright blood forwards, and that the darker blood carried by the veins was produced by the liver and that the bright blood carried by the arteries was produced within the heart. In his view, both the bright and the dark blood were distributed to the periphery only once and were totally consumed by peripheral tissues. Galen further believed that the blood passed from the right to the left ventricle directly through invisible pores in the septum separating the two ventricles. Galen's view that the arteries carried blood was a major advance from Aristotelian belief that the arteries carried air.⁶

Razi

Abu Bakr Mohammad Zakariya Razi, known as *Rhazes* in Latin (865 – 925 C.E.); the famous Iranian physician and scholar, like most physicians of that era followed the Galenic tradition.⁷ Razi in his medical book known as *Tebb-e Mansouri* (the Book of al-Mansouri) describes the arteries, veins, and the circulation of blood as such: "the origin of the arteries is the left cavity of the heart. Two large arteries spring from this ventricle, one of which is smaller and its wall has only one layer of fibers which is narrower than the two layers of the larger artery. This smaller artery goes to the lungs and

branches in its tissues. The other artery, aorta, is larger. As soon as it appears, two small branches spring from it (crown arteries), the smaller of which goes to the right ventricle and the other branch circles the heart and enters its wall, dividing the heart and there it distributes its branches."⁷ He also mentions that: "...between the right and the left ventricles there are several pores", and then goes on to describe the valves of the heart as such: "the right ventricle has two orifices, one of which is the orifice through which the blood coming from the liver via a great vein enters the right ventricle and its orifices has three membranes which close backwards, but open to allow the blood to enter the heart. The second orifice is at entrance of a vein, which travels from this ventricle to the lungs. This vein has no pulsation but its wall is thick and for this reason, the anatomists have named it the arterial vein." Then he adds that: "the left ventricle has two orifices one of which is at the exit of the large artery called the aorta. This valve has three membranes, which close from the outside inwards such that it allows the blood and vital spirit (pneuma) to exit the heart freely. The second valve is at the orifice of the artery which comes from the lungs through which the air reaches the heart from the lungs. This valve has two membranes which close from inside outwards, so that it opens to allow the air into the heart. The heart has two appendages like ears (auricles), one from the right and the other from the left."⁷

Ahwazi

Ali Ibn Abbas Majusi known as *Ahwazi* (*Haly Abbas* in the West) was a famous 4th century Hijri Iranian physician (10th century C.E.), who expounded a similar view to Galen regarding the circulation of blood.⁸ He writes in his famous book entitled *Kamil al-Sinaah al-tibbiya* (the Perfection of the Art of Medicine) or *Kitab Tebb-e al-Maleki* (the Royal Book known in Latin as *Liber Regius*) (Figure1): "when ingested food enters the stomach, it undergoes the first digestion and then passes through the pylorus (al-bawwab) into the duodenum and then into the small intestine where the veins extract the essence of the digested food and transport it via the portal vein to the liver, where it is transformed into blood and this blood is then distributed throughout the body via the great vena cava."⁹ Ahwazi goes on to describe the structure and function of the arteries and veins as such: "...the walls of the veins are softer and



Figure 1. Two sample pages of *Kamil al-Sinaah al-tibbiya* or *Kitab Tebb-e al-Maleki* (in Latin Liber Regius) of Ahwazi in Arabic describing the heart's anatomy and function.

weaker than arteries and are formed from a single layer only. These veins convey the absorbed food from the intestines to the liver and then distribute the blood from the liver to all the peripheral tissues which obtain their nourishment from the blood.” He pointed out that: “...the arterial walls have two layers. The fibers of the inner layer run obliquely and are hard, while the fibers of outer layer are softer and are circular as they should be, for the circular fibers have an expanding motion (diastolic) such that the air from the heart is sucked into the artery and the inner oblique fibers have a contractile function (systolic) such that the smoke-like excess is excreted.”⁷ [Quoted from *Tebb-e al-Maleki*] Ahwazi then describes the structure of the heart and its role in the circulation of blood as such: “the heart is made of several layers of strong muscle fibers whose function is to contract and dilate, and is surrounded on all sides by the lungs. It is cone shaped and its apex points to the left as the seat of the animal spirit is on the left side of the heart. From there, the arteries are distributed to the rest of the body and it is for this reason that one can feel the beating of the heart on the left side of the chest. The heart has two cavities, the right and left ventricles which are separated by a thick septum. This septum has a passage (manfadh) which some (meaning Aristotle) has called it the

‘third ventricle’ which is totally unyielding.”⁸ Then He added: “the right ventricle has two orifices from one of which the blood from the liver is transferred to it by the ‘vena cava’. This orifice has a valve with three small membranes which fall together and thus preventing the blood from returning into the vena cava. From the left ventricle two arteries exit, the smaller of which has a soft wall and is therefore called the ‘venous artery’. This artery conveys a large portion of the blood and the vital spirit (pneuma) to the lungs for its nourishment. In the lungs, the arterial vein divides into many branches and obtains air from the lungs and conveys the air to the heart from the opposite side. The second large artery is called aorta which divides into two branches, one of which travels upwards and the other downwards.”¹⁰

It seems that up to this time and for approximately a further 250 years until Ibn Nafis, the basic Galenic concept of the anatomy and function of the heart, blood vessels and blood circulation remained almost unchanged apart from minor modifications of anatomy such as coronary arteries described by Razi.

Ibn Nafis

Ala ad-Din Abu al-Hassan Ali Ibn Abi-Hazm al-Qarshi known as *Ibn Nafis* Damashqi (1210 – 1285 C.E.) was born in a small town near Damascus called Qarsh.¹¹ He was a physician and philosopher and spent most of his life in Cairo and died in Damascus aged 80. He was also an expert in religious jurisprudence and theology. Ibn Nafis wrote an encyclopedia of medicine called *al-Shamil fi -Tebb* as well as several other books and commentaries, one of which is on Ibn Sina's Qanun fi-al-Tebb (the Avicenna's Canon of Medicine). Most of these writings are still extant.¹² Up to the early twentieth century, it had been assumed that *Michael Servetus* was the discoverer of the pulmonary circulation but with the rediscovery of Ibn Nafis manuscript in Europe it became clear that he had described the pulmonary circulation at least two and a half century prior to Servetus.^{5, 10} In his 'Commentary on the Anatomy of Canon of Avicenna' or *Sharh-e Tashrieh-e Qanun*, written in 1242 C.E., Ibn Nafis describes the pulmonary circulation as such: "... and after the blood has been refined in the right ventricle of the heart, it must reach the left ventricle where in it is impregnated with the vital spirit (pneuma) but there is no opening between these two ventricles as the septum between them is thick and solid and in contrast to what some people have imagined, there is no visible pores and also contrary to what Galen has said there are no invisible pores connecting them. And thus this blood after it is refined must flow via the vena arteriosa (pulmonary artery) to the lungs where it must spread and be mingled with air and its most delicate substance be refined and then flow through the arteria venosa (pulmonary vein) so that the blood that has been mixed with air and is ready to receive the vital spirit reaches the left chamber of the heart."¹³

Ibn Nafis goes on to describe the anatomy of the lungs as: "the lungs are composed of parts, one of which is the bronchi; the second is the branches of arteria venosa (pulmonary vein) and the third, the branches of the vena arteriosa (pulmonary artery), all of them connected by loose porous flesh."¹⁴ (Figure 2)

Michael Servetus

Michael Servetus or in Spanish, Miguel Serveto (1511 – 1553 E.C.), a Spanish anatomist and theologian had until recently been credited with the discovery of the pulmonary circulation. In his theology, he was a Unitarian and denied the Holy

Trinity as he described in his book '*Christianismi Restitutio*' (the Restoration of Christianity) for which he was condemned by both Protestants and Catholics and was burnt at the stake in Geneva in 1553 on order given by *John Calvin*, the French Protestant theologian.^{14,15} In this book, he described the pulmonary circulation in support of his theological views, but it seems doubtful that this concept was from his own observations and he may have come across the writings of Ibn Nafis while he was assistant to Professor *Johan Guinter* who had translated most of Galen's works and those of other physicians from antiquity as well as several Arabic manuscripts of the Middle Ages, but Servetus does not cite his source. In 1559, the Italian physician *Realdo Colombo* (1516 – 1559) in a book published in Venice described the pulmonary circulation, which was probably based on Servetus writing but does not cite Servetus. In fact it seems a common practice both in ancient times by the Greeks and later in the Middle Ages up to modern times that writers failed to cite their referent sources and this practice was perhaps not considered as plagiarism through those centuries when it was common to regurgitate the dictums of authority as established facts.

William Harvey

The English physician and biologist, *William Harvey* (1578 – 1657) is credited with having discovered the mechanistic principles of the circulation of blood through the body. He was born in *Folkstone*, Kent in England, studied at Caius College, *Cambridge* in 1597 and then went to the University of *Padua* in Italy for two years to study medicine under the celebrated Italian anatomist and embryologist *Hieronymus Fabricius* (1537 – 1619). At that time, Fabricius had already published his discovery of the semilunar valves of the veins and established that these one-way valves allowed the blood to flow toward the heart only. After receiving his medical degree in 1602 from Padua, Harvey returned to England and was elected as a fellow of the College of Physicians and two years later was appointed as a physician to *Saint Bartholomew's Hospital* in London.¹⁵⁻¹⁷ Through a series of animal dissections and quantitative approach to the amount of blood that can be ejected by the heart in a unit of time and the total amount of blood that can be contained by the heart and blood vessels at any one time, he came to the conclusion that the same blood must be circulating throughout the body and returning



Figure 2. The title page and a sample page of the Commentary on the Anatomy of Canon of Avicenna' or Sharh-e Tashrieh-e Qanun of Ibn Nafis in Arabic describing the heart anatomy and pulmonary circulation.¹³

again to the heart. He compared the action of the heart to the hydraulic water pumps that had come into use at that time in England.^{4, 15} The concept of the pump-like action of the heart was consistent with the mechanistic world-view which was becoming prevalent in Europe in the seventeenth century and culminating in the ideas established by *Isaac Newton* (1642 – 1727), the English philosopher and scientist.

The scientific approach to nature through systematic observation, experiment, quantification of measurements, the quest for mathematical relationships and the establishment of natural laws governed by rational thought ushered in the post-renaissance age of the scientific world view during the seventeenth century Europe. Harvey was one of the pioneers of this revolution.

The final link in the chain of circulation, the passage of blood from the arterioles to venules via capillaries remained to be demonstrated microscopically by the Italian anatomist *Marcello Malpighi* (1628 – 1698) in 1661.⁴ Harvey's concept of circulation may have been based on Aristotelian ideology of perfect circular motion and his misconception that the purpose of blood

circulation was to impart heat rather than nutrients to the peripheral organs and then to regenerate the heat in the heart. These social and historical constructs have now been paved away and what is now known about the circulation of blood (see introduction) which were not known to Harvey at that time are nonetheless erroneously attributed to him as the final discoverer of the circulation of blood.

In conclusion, as may be surmised from this brief historical review, the modern concept of the circulation of blood has taken almost two millennia to reach its present state of empirical knowledge.

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Top Iranian Medical Research Awards (Dr. Hadavi's Award) 2004 – 2005

In order to promote medical research in Iran, the “Iranian Academy of Medical Sciences” annually chooses the top published Iranian medical research articles to receive “*Dr. Hadavi's Award*”. The award is named after Dr. *Nour Ad-din Hadavi*, the former Professor of Medicine at University of Tehran who donated 2,000 million Rials (around 200,000 US Dollars) to the Academy of Medical Sciences for this purpose. The Academy evaluated published medical papers by Iranian researchers (as corresponding or first author) on clinical and basic sciences in 2004 and 2005. The articles were screened based on their citations and journal impact factors and also their relevance to national and international problems by a team of expert internal and external reviewers. This year, of 164 published papers fulfilling the initial criteria, six were chosen and on 20th of March, 2008 the corresponding authors received the award.

The award laureates are listed below:

Basic sciences

- **First rank:** Abdollah Salimi PhD, Department of Chemistry, Kurdistan University
- **Second rank:** Reza Rajimehr PhD, Department of Cognitive Neuroscience, School of Intelligent Systems, Iranian Institute for Studies in Theoretical Physics and Mathematics
- **Third rank:** Abolghasem Joyban PhD, School of Pharmacy, Tabriz University of Medical Sciences

Clinical sciences

- **First rank:** Seyed-Alireza Taghavi MD, Department of Internal Medicine, Shiraz University of Medical Sciences
- **Second rank:** Gholamhossein Ranjbar-Omrani MD, Department of Biochemistry, Shiraz University of Medical Sciences
- **Third rank:** Parvin Mirmiran PhD, Endocrine Research Center, Shaheed Beheshti University of Medical Sciences