The history of the discovery of blood circulation: unrecognized contributions of Ayurveda masters

Kishor Patwardhan

Department of Kriya Sharir, Faculty of Ayurveda, Institute of Medical Sciences, Banaras Hindu University, Varanasi; and Institute of Ayurveda and Integrative Medicine, Bangalore, India

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Patwardhan K. The history of the discovery of blood circulation: unrecognized contributions of Ayurveda masters. Adv Physiol Educ 36: 77–82, 2012; doi:10.1152/advan.00123.2011.—Ayurveda, the native healthcare system of India, is a rich resource of well-documented ancient medical knowledge. Although the roots of this knowledge date back to the Vedic and post-Vedic eras, it is generally believed that a dedicated branch for healthcare was gradually established approximately between 400 B.C.E and 200 C.E. Probably because the language of documentation of these early textbooks is in Sanskrit, a language that is not in day-to-day use among the general population even in India, many significant contributions of Ayurveda have remained unrecognized in the literature related to the history of medicine. In this communication, the discovery of blood circulation has been taken up as a case, and a few important references from the representative Ayurveda compendia that hint at a preliminary understanding of the cardiovascular system as a “closed circuit” and the heart acting as a pump have been reviewed. The central argument of this review is that these contributions from Ayurveda too must be recorded and credited when reviewing the milestones in the history of medicine, as Ayurveda can still possibly guide various streams of the current sciences, if revisited with this spirit.

Indian medicine; cardiovascular physiology; Charaka Samhita; Sushruta Samhita; Bhela Samhita

Although the roots of Ayurveda, the native Indian system of healthcare, date back to the Vedic and post-Vedic eras, prominent historians such as G. J. Meulenbeld and K. G. Zyks regard 400 B.C.E as the approximate period during which a systematic medical theory started emerging (7, 24, 35). The knowledge base of Ayurveda is documented in the form of compendia known as “Samhitas.” These compendia are composed in Sanskrit, a language that is not in day-to-day use among the general population, even in India. Therefore, one needs to have a working knowledge of Sanskrit, along with the associated sociocultural contextual understandings to comprehend and interpret the documented material sensibly. However, the many unclear and confusing translations and interpretations of these compendia have given rise to a general perception that the basic facts related to human physiology were largely unknown when these compendia were documented. This probably is also the reason why some of the important contributions of Ayurveda have gone unnoticed and unrecognized in the process of documentation of the history of medicine. In this communication, the discovery of blood circulation has been taken up as a case, and it is argued that Ayurveda masters, who authored different compendia, such as the Charaka Samhita, Bhela Samhita, Sushruta Samhita, Ashtanga Hridaya, and Shangadhara Samhita, too need to be credited for their contributions in this area along with personalities like Hippocrates, Aristotle, Erasistratus, Galen, Vesalius, Servetus, William Harvey, and others.

Generally Documented Milestones of the Discovery of Blood Circulation

When examining the documented historical milestones, it becomes evident that the expansion in the knowledge of human cardiovascular physiology occurred in a stepwise fashion not attributable to a single discoverer. It was William Harvey, who, for the first time, compiled these different bits of information in a logical sequence and drew a convincing big picture delineating the complete process of circulation. In fact, before William Harvey described circulation, there were many errors in the understanding of the facts, and three of them were the most important ones: 1) the arteries contained air that was derived through the act of respiration; 2) the interventricular septum was porous and facilitated the movement of contents between the left and right ventricles; and 3) the veins, instead of bringing blood from the periphery, carried it to all parts of the body (12).

William Harvey, in his work “On the motion of the heart and blood in animals,” effectively refuted all these erroneous ideas while supporting his arguments with a strong mathematical model and with observations derived out of robust experiments that he had conducted (11, 16, 21, 31). Table 1 shows the prominent contributors who helped in resolving these errors. These contributions are generally well recognized and are mostly cited by authors when they review the history of the discovery of blood circulation (1a, 4, 10, 12, 13, 19–23, 30).

However, upon careful consultation of the diverse sources of mainstream medical literature in an attempt to list these prominent contributions, one does not come across with any of the contributions credited to Ayurveda literature. For instance, a search on PubMed does not give any results that satisfy the criteria of crediting Ayurveda literature for its contribution in the process of the discovery of blood circulation when the keyword “Ayurveda” is entered in combination with search items such as “discovery blood circulation,” “circulation physiology,” and “cardiovascular physiology.” This communication is an attempt to review some of the important contributions of Ayurveda masters to understandings related to blood circulation in human beings.

A Brief Introduction to the Representative Compendia of Ayurveda

Charaka Samhita. Charaka Samhita (17a) primarily deals with the principles of internal medicine also known as Kayachikitsa. Four authors have contributed to what is available as
Table 1. Prominent and recognized contributions in the history of the discovery of blood circulation in chronological sequence

<table>
<thead>
<tr>
<th>Author/Investigator</th>
<th>Time Period</th>
<th>Contributions</th>
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<tbody>
<tr>
<td>Egyptian physicians</td>
<td>1500 BCE</td>
<td>Proposed the importance of the arterial pulse, its character, and its force in</td>
</tr>
<tr>
<td>in medical papyrus</td>
<td>460–370 BCE</td>
<td>understanding health.</td>
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<tr>
<td>Hippocrates</td>
<td></td>
<td>A clear description of the ventricles, the vessels (recognizing the difference</td>
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<td></td>
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<td>between arteries and veins), and the semilunar valves is found in his writings.</td>
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<tr>
<td>Aristotle</td>
<td>384–322 BCE</td>
<td>Described that the heart was central, mobile, and well supplied with structures</td>
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<td></td>
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<td>that served to communicate between it and the rest of the body.</td>
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<tr>
<td>Erasistratus</td>
<td>304–250 BCE</td>
<td>Air, attracted by the lungs, passed into the pulmonary veins, from there into</td>
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<tr>
<td></td>
<td></td>
<td>the left ventricle and from the left ventricle it passed into the arteries,</td>
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<tr>
<td></td>
<td></td>
<td>which distributed it to all parts of the body.</td>
</tr>
<tr>
<td>Claudius Galen</td>
<td>129–217 CE</td>
<td>Stated that the arteries contain blood, not air.</td>
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<tr>
<td>Ibn al-Nafis</td>
<td>1213–1288</td>
<td>Stated that the interventricular septum is not porous and proposed the</td>
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<td>existence of the pulmonary circulation.</td>
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<tr>
<td>Leonardo da Vinci</td>
<td>1452–1518</td>
<td>He established through experiments that air doesn’t enter heart from lungs.</td>
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<td></td>
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<td>He also proved conclusively that the valves allowed the blood to pass in only</td>
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<td></td>
<td></td>
<td>one direction and prevented its regurgitation.</td>
</tr>
<tr>
<td>Andreas Vesalius</td>
<td>1514–1564</td>
<td>Observed that the interventricular septum is not perforated.</td>
</tr>
<tr>
<td>Michael Servetus</td>
<td>1511–1553</td>
<td>Described the pulmonary circulation.</td>
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<tr>
<td>Realdus Columbus</td>
<td>1515–1559</td>
<td>He independently discovered the pulmonary circulation. He also discovered</td>
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<td></td>
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<td>that the heart’s four valves permitted the flow of blood in only one direction.</td>
</tr>
<tr>
<td>Andreas Caesalpinus</td>
<td>1524–1603</td>
<td>Described the passage of the blood from the right heart through the lungs to</td>
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<td></td>
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<td>the left heart and used the term “circulation” to describe this process.</td>
</tr>
<tr>
<td>Hieronymus Fabricius</td>
<td>1537–1619</td>
<td>He discovered the valves in the veins. He noticed that the blood cannot move</td>
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<td>from the heart toward the periphery through the veins.</td>
</tr>
<tr>
<td>William Harvey</td>
<td>1578–1657</td>
<td>Explained the complete process of circulation.</td>
</tr>
<tr>
<td>Marcello Malpighi</td>
<td>1628–1694</td>
<td>He established the presence of capillaries with the help of a microscope. He</td>
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<td></td>
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<td>proposed that capillaries are the connections between arteries and veins that</td>
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<td>allow blood to flow back to the heart, thus completing the gap in the knowledge</td>
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<td>of circulation.</td>
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Charaka Samhita today. The original source of this compendium is Agnivesha Tantra, which was based on the teachings of Punarvasu Atreya to his students, including Agnivesha. Charaka (200 BCE) is said to have redacted this work, and, much later, another scholar, Dridhabala (4th century CE), further supplemented this by rewriting certain portions of the text and by providing with some new sections (25). Therefore, it is clear that the material available in this textbook today was documented before 500 CE.

Bhela Samhita. In Charaka Samhita, it is stated that Bhela was a direct disciple of Punarvasu Atreya and was one of the six disciples who composed their own compendia. Therefore, Bhela Samhita (20a) is to be placed in parallel to Charaka Samhita from a historical perspective (14). The only problem with this compendium, however, is that it is not available in its entirety, and the available version contains many errors (20a).

Sushruta Samhita. The contributions of Sushruta are well known in the field of surgery. This compendium, authored by Sushruta, mainly deals with the clinical specialty called Shalya Tantra, i.e., clinical surgery. At least three authors have contributed to what is available as Sushruta Samhita (1) today. The original textbook written by Sushruta (around 400 BCE) was redacted by Nagarjuna (400–500 CE) and was later amended by Chandrata (10th century CE) (25).

Ashtanga Hridaya. Ashtanga Hridaya (17b) is a summarized work on all eight major clinical specialties of Ayurveda (25). The author of this textbook was Vagbhata (600 CE), and the contents of this text are largely based on Charaka Samhita and Sushruta Samhita.

Sharangadhara Samhita. Sharangadhara Samhita (20b) is a comparatively recent textbook that was composed in 1300 CE by the author Sharangadhara. This text, although dealing mainly with the principles of pharmaceutics, also contains some information on physiology and clinical methods (25).

Physiology and Ayurveda

Generally, physiology is considered to be the function of biological structures. This structure-oriented definition of physiology assumes that a function can be understood only in terms of structures (anatomy). It is interesting, however, to note that many of the descriptions on human physiology recorded in Ayurveda literature are considerably accurate, even though they are not based on a precise knowledge of anatomy (18). Although Sushruta Samhita describes the method of cadaveric dissection, the anatomic details available in this textbook are not sufficient to draw a clear and convincing picture of the human body (7). A few researchers have discussed the subject of “human anatomy” as it was perceived in Ayurveda at length, and interested readers may refer to their works, as these details are beyond the scope of this communication (5–7, 15, 32, 33).

Physiology in Ayurveda is essentially based on the theory of three entities known as Doshas (often mistakenly translated as the theory of “three humors” or “three fluids”), namely, “Vayu” or “Vata” (often incorrectly translated as “wind”), “Pitta” (often wrongly translated as “bile”) and “Kapha” (often erroneously translated as “phlegm”).

In this context, it is to be noted that the scholars of ancient Greek medicine considered the four humors to be the regulators of all physiological processes: 1) blood, 2) phlegm, 3) yellow bile, and 4) black bile. In fact, it is actually on this similarity that historians compare Ayurveda theories with ancient Greek medical theories (7, 34). Most of the historians have suggested the possibility of various interactions having taken place between the scholars of ancient Greece and ancient India, especially when Alexander the Great (326 BCE) visited the places around Taxila, one of the ancient seats of learning (3). A few historians, on the other hand, have suggested that...
such interactions must have taken place even before Alexander the Great visited India (9, 17). One cannot deny the fact that there are striking similarities between some of the theories in these two streams of medical knowledge; however, the question as to which system got influenced by the other has been a matter of debate, as no system mentions these facts (7, 24, 34). Whatever may be the case, it is to be noted that the theory of Tridosha is not simply a “humoral theory”; rather, it is based on a considerably precise understanding of homeostatic principles (29).

Cardiovascular Physiology in Ayurveda

In Ayurveda literature, the heart and the different vessels attached to it have been described to transport the following four vital entities: 1) “Rasa” (often wrongly translated as “Chyle”), the nutrient fluid that nourishes rest of the tissues; 2) “Rakta,” the red fraction that is very essential for life; 3) “Ojas,” a white fraction, the functions of which are closely associated with immunity; and 4) “Prana,” a fraction that is derived through the act of respiration. Therefore, the tissue that is today known as “blood” should include all these components, and, hence, one should be careful when translating terms such as Rasa, Rakta, Ojas, and Prana. In this context, however, it is to be noted that most of the prominent translators have committed an error of translating only Rakta as blood and not others. This is probably one of the important reasons for some of the vital contributions of Ayurveda having gone unnoticed.

Similarities between Ayurveda and Galen’s model of cardiovascular system. There are some very important similarities between ancient Greek theories of medicine, especially those proposed by Galen, and Ayurveda with respect to the physiology of cardiovascular system. Galen believed that the digested food, called Chyle, reached the liver from the intestines, and it was then converted into blood there. Galen also described that the blood, after reaching the heart, was carried to all parts of the body through veins and was then converted into flesh. Thus, the blood got “consumed” in this process and was not “conserved.” Furthermore, he believed that the blood was continuously being produced from the food that a person ingested. According to him, the vital spirit, “Pneuma,” was derived through the act of respiration and was mixed with the blood in the left ventricle, and a portion of this passed through the septal pores into the venous blood of the right ventricle. In fact, Galen proposed that the function of arteries was to carry this Pneuma to the different parts (10).

On similar lines, in Ayurveda, it has been explained that “Ahara” (food), after undergoing complete digestion, gets converted into the nutrient fluid called Rasa and that this Rasa is then transformed into Rakta in “Yakrit” (the liver) and “Pilha” (the spleen) (Sushruta Samhita, Sutra Sthana, 14/4–5; Sushruta Samhita, Sutra Sthana, 21/10). Thereafter, Rakta enters the heart (Sharangadhara Samhita, Purva Khanda, 6/9). Prana derived through the act of respiration and was mixed with the blood in the left ventricle, and a portion of this passed through the septal pores into the venous blood of the right ventricle. In fact, Galen proposed that the function of arteries was to carry this Pneuma to the different parts (10).

In this context, Vyana Vayu and Prana Vayu denote the nervous control of circulation because Vayu, in general, represents all neural mechanisms (18, 29).

Control of circulation. Charaka describes that “Vyana Vayu” a component of Vayu, continuously ejects the blood out of the heart and distributes it all over the body (Charaka Samhita, Chikitsa Sthana, 15/36). Vagbhata, in Ashtanga Hridaya (Sutra Sthana, 12/5), further clearly stated that the “Prana Vayu,” located in the head, controls the activities of the heart. In this context, Vyana Vayu and Prana Vayu denote the nervous control of circulation because Vayu, in general, represents all neural mechanisms (18, 29).

The heart as a pumping organ. The forceful ejection of Rasa from the heart and the role of Vyana Vayu in making its ejection possible further hint at a preliminary understanding of the heart as a pumping organ (Bhela Samhita, Sutra Sthana, 20/3; Charaka Samhita, Chikitsa Sthana, 15/36; and Ashtanga Hridaya, Sutra Sthana, 12/7).

The pattern of blood flow. Sushruta identified that “the pattern of the blood [Rasa] flow is comparable with the movement of sound, fire and water” (Sushruta Samhita, Sutra Sthana, 14/16). It is interesting to note that the mean flow velocity of the blood goes on decreasing as it flows from the heart toward the periphery. Similarly, the sound moves fastest
Table 2. Major contributions from Ayurveda to understandings related to circulation

<table>
<thead>
<tr>
<th>Classical Textbook</th>
<th>Author</th>
<th>Time Period</th>
<th>Vital Information on Circulation</th>
</tr>
</thead>
</table>
| Charaka Samhita          | Agnivesha    | Composed between 400 BCE and 500 CE in several stages | • Describes that the heart and the 10 prominent blood vessels attached to it form the basis of the cardiovascular system ("Rasavaha Srotamsi") responsible for the transportation of nutrients to all parts of the body.  
• Describes that "Vyana Vayu," a component of "Vayu," constantly forces the blood out of the heart and distributes it.  
• Explains that all parts of the body are nourished in a circular fashion, similar to that of a rotating wheel.  
• Proposes that three different kinds of blood vessels exist: "Sirah" (vessels that carry the contents without pulsating), "Dhamanyah" (vessels that pulsate), and "Srotamsi" (vessels from which fluids can move out).  
• Described that the breath ("Prana") follows the blood in the body.  
• Described that 10 prominent blood vessels connected to the heart carry the blood ("Rasa" and "Ojas") to all parts of the body.  
• Observed that blood vessels go on giving branches, and as they do so, they go on becoming narrower and narrower in a fashion similar to the one observed in the pattern of venation on the leaves.  
• Described the importance of the clinical examination of arterial pulse.  
• Described that "Samana Vayu" controls the transportation of the blood ("Rasa") toward the heart. |
| Bhela Samhita            | Bhela        | Composed in parallel with Charaka Samhita |                                                                                                                                                                                                                                  |
| Sushruta Samhita         | Sushruta     | Composed between 400 BCE and 1000 CE in several stages | • Documented that "The successive manner in which the blood moves is similar to the manner in which sound, fire and water move," hinting at the changes in mean flow velocity as the blood moves in the cardiovascular system.  
• Explained that after the complete digestion of food, the absorbed material reaches the heart and, from there, is propelled to other parts of the body.  
• Described that 10 prominent blood vessels connected to the heart carry the blood ("Rasa" and "Ojas") to all parts of the body.  
• Observed that blood vessels go on giving branches, and as they do so, they go on becoming narrower and narrower in a fashion similar to the one observed in the pattern of venation on the leaves.  
• Described the importance of the clinical examination of arterial pulse.  
• Described that "Samana Vayu" controls the transportation of the blood ("Rasa") toward the heart. |
| Ashtanga Hridaya         | Vagbhata     | 600 CE                                |                                                                                                                                                                                                                                  |
| Sharrngadhara Samhita    | Sharrngadhara | 1300 CE                               |                                                                                                                                                                                                                                  |

among the three symbols that Sushruta has used to compare the movement of blood. The speed with which the fire spreads is dependent on the velocity of the wind, which is less than that of sound but greater than that of water.

The three segments of the vascular tree. Charaka documented three different kinds of blood vessels: “Sirah” (vessels that carry the contents without pulsating), “Dhamanyah” (vessels that pulsate), and “Srotamsi” (vessels from which fluids move out) (Charaka Samhita, Sutra Sthana, 30/12). This explanation is important because it assumes the presence of three distinct segments in the vascular tree: the pulsating (arteries) segment, the exchange (capillaries) segment, and the transporting (veins) segment.

Bhela too explained that the 10 great vessels called Dhamanyah arise at the heart and then divide to give rise to another set of blood vessels known as Sirah (Bhela Samhita, Sutra Sthana, 20/1–3). Therefore, it may be inferred that Bhela possibly knew the differences between arteries (Dhamani) and veins (Sira).

Closed circuit. Bhela Samhita is important from a historical perspective, because Bhela was the first individual in the history of Indian medicine who described the process of greater circulation explicitly for the first time. He said that “The blood [Rasa] is first ejected out of the heart, it is then distributed to all parts of the body, and thereafter, it returns back to the heart through the blood vessels known as ‘Sirah.’”

Charaka also used an expression similar to that of circulation when explaining that all parts of the body are nourished in a circular fashion, similar to that of a rotating wheel (Charaka Samhita, Chikitsa Sthana, 15/21).

Sharrngadhara described that “Samana Vayu” helps in the transportation of Rasa toward the heart (Sharrngadhara Samhita, Purva Khanda, 6/9).

Arterial pulse. In Sharrngadhara Samhita (Purvakhanda, 3/1), Sharrngadhara described the importance of examination of the arterial pulse in clinical medicine, including a description on various characters of the radial pulse.

Inadequacies

Across all Ayurveda textbooks, the following inadequacies are found in relation to cardiovascular physiology. First, anatomic details pertaining to the chambers of the heart, atrioventricular valves, and semilunar valves are missing. Second, the presence of valves in the veins is not mentioned. Third, the specific number, origin, and course of the great blood vessels are not documented. Fourth, terms (such as Sira and Dhamani) are often used interchangeably. Fifth, the heart is considered to be the seat of higher mental functions, although the “head” too received equal importance. Hence, a few Dhamanyah have been described to be carrying certain sensations, like hearing and smell. Sixth, details of pulmonary circulation are not documented. Finally, explanations are scattered at various places and are not arranged in a sequence.
Conclusions

Despite some gross inadequacies pertaining to the anatomical details of the heart and the blood vessels, it can be said that the ancient Ayurveda masters had acquired considerable understanding related to the blood circulation in the human body. Therefore, these masters deserve to be recognized for their contributions in this area. It is also suggested that efforts should be made to review and recognize other contributions of Ayurveda to various streams of biology and medicine in a systematic manner, as Ayurveda can possibly still guide further advances in biomedical sciences, if revisited with this spirit.

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A preliminary sketch of Ayurveda perception of human cardiovascular physiology

Fig. 1. Preliminary sketch of Ayurveda perceptions of human cardiovascular physiology. Cha., Charaka Samhita; Su., Sushruta Samhita; A.H., Ashtanga Hridaya; Sha., Sharngadhara Samhita; Bh., Bhela Samhita.
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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

K.P. conception and design of research; K.P. prepared figures; K.P. drafted manuscript; K.P. edited and revised manuscript; K.P. approved final version of manuscript.

REFERENCES