SPECIAL ARTICLE

Knowledge of the Circulation Before William Harvey

By Arnold M. Katz, M.D.

Our present understanding of the function of the circulatory system began to emerge from the confusion of ancient writings scarcely 300 years ago. Yet thousands of years before, man had wondered about the pulsations of the heart and blood vessels. The records of many of these speculations have been preserved and, though often fragmentary and distorted in translation, they tell the story of one of the first discoveries in the science of physiology. Some of the conceptions of the cardiovascular system held before Harvey's clear formulation of the circulation of the blood in 1628 are presented here, and the environment that promoted the growth of these earlier ideas is considered.

The first explanations of natural phenomena were based on supernatural forces, and the mysteries of the body were understood in terms of the greater mysteries of the gods. Since the questions raised in primitive societies, both ancient and contemporary, found a ready answer in mythology, there was little incentive for investigation into the workings of the body.

The dependence of scientific thought upon the cultural environment can be seen in the writings of ancient Egypt and Mesopotamia. Unlike the records of the contemporary Mesopotamians, the papyri of Egypt are surprisingly free of references to magic and gods, and represent an attempt to understand the functions and illnesses of the body in natural rather than supernatural terms. This secular attitude reflected the position of the physician in ancient Egypt, for though the Egyptian physician received the privileges and titles of the priesthood as did his Mesopotamian counterpart, he was able to remain quite independent of the great temples. Even the administration of the Egyptian medical schools was often in the hands of physicians rather than priests. As a result, Egyptian medicine developed in the shelter of the priesthood without being subverted by the mystical and demoniacal beliefs that dominated the medicine of the Mesopotamians.

The earliest known reference to the heart and circulation is in the Edwin Smith papyrus, transcribed in the seventeenth century B.C., but based on observations recorded as long ago as 3000 B.C. Here is found the statement: "Now if . . . any physician put his hands or his fingers upon the head, upon the two hands, upon the pulse, upon the two feet he measures the heart because its vessels are in the back of the head and in the pulse; and because its pulsation is in every vessel of every member."1 As Dr. Breasted pointed out, "[The writer] . . . was already aware that the heart was the center and the pumping force of a system of distributing vessels."2 However, this passage does not reveal the true deficiency of knowledge in ancient Egypt for in the Ebers papyrus, derived from the same sources as the Edwin Smith papyrus, there are such statements as: "There are four vessels to the nostrils, two of which convey mucous and two blood" and "There are four vessels to the liver which convey to it moisture and air."3 Thus it is clear that Egyptian medicine contained only the beginnings of our modern concept of the circulation.

The principles of Egyptian medicine provided the foundation for the medical science of ancient Greece. Here elaboration of ideas continued in the tradition of the ancient Egyptians with careful observation in the search for natural causation. This, coupled with the rejection of superstition and dogma, enabled Hellenic medicine to become a model of scientific thinking. Castiglioni attributes this to "the critical but speculative Greek mentality and the political and religious life of the Greeks." "In Greece," he continues, "there was never a closed priestly caste; religion was

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726 Circulation, Volume XV, May 1957
a poetical myth, never a political edifice and it never dominated critical thought. Ideas therefore could develop freely, contradictions with and discussions of the most venerable traditions could flourish; culture, without established boundaries or dogmatic laws, offered to the Greeks assistance to their imagination unhindered by the fear of punishment."

The religion of Aesculapius with its magical attempts at healing did not obstruct the development of a medical science, though the extent to which it actively furthered scientific medicine is not clear. The great medical schools of Cos and Cnidus were located near temples of Aesculapius, though the teachers at these schools were lay physicians rather than priests. Here, as in ancient Egypt, a lay science flourished in the shadow of a religious cult.

Unfortunately, the finest of Greek thinking was not revealed in their conceptions of the workings of the body. Although advances were made in descriptive anatomy, an accurate gross anatomic picture of the heart and blood vessels was not brought forward and there was little insight into the functions of the cardiovascular system. Elaborate formulations of the vital functions from the various schools of philosophy were applied to physiology with little or no experimental basis, and the resulting confusion persisted over 2,000 years.

Medical thinking felt the impact of the Greek philosophers as long ago as the fifth century B.C. Rejecting the theory of Thales of Miletus that water is the essence of all things and Anaximander's proposition that man is the admixture of earth and water, the philosophers of the Pythagorean school believed that living beings were composed of 4 elements, each of which had its corresponding quality. The elements were the familiar Air, Fire, Water, and Earth and the corresponding qualities were Cold, Hot, Moist, and Dry. From these were derived the 4 humors of the body: Blood, which is hot and moist; Yellow Bile, which is hot and dry; Black Bile, which is cold and dry; and Phlegm, which is cold and moist. The idea that health is the state of the body when the 4 humors are in harmony and that disease results from the excess or deficiency of 1 of these humors can be traced to the writings of these philosophers of the fifth century B.C. This concept was the rationale for bleeding and expurgation to restore the balance of the body's humors, and provided the foundation of medical thinking until the ascendancy of the morphologists of the nineteenth century.

The hundred years before Hippocrates saw many attempts to link the functions of the body to specific organs. Alcmaeon of Croton (ca. 500 B.C.), though primarily a philosopher, was one of the first to practice human dissection and animal experimentation in Greece. He proposed that the brain and not, as had previously been believed, the heart was the center of the intellect, and that the life of the animal depended on the movement of the blood. About 50 years later Empedocles of Agrigentum returned to the doctrine that the heart, or the blood around it, was the seat of consciousness. He believed that breathing took place through the pores of the body as well as the lungs and that to and from the heart there were a flow and reflux of blood by which a pneuma, or vital spirit, was carried through the body. Diogenes of Appolonia elaborated Empedocles' idea of the movement of the pneuma, which he considered to be a special form of air circulating as the vehicle of sensory perception and giving rise to pleasure. Diogenes was familiar with the pulse and probably performed human dissection, though his description of the blood vessels was confused and he failed to recognize the origin of these vessels from the heart. These writers concentrated more on philosophy than on medicine and often attempted to grasp the whole before understanding its parts.

The works attributed to Hippocrates represent the high point of Greek medicine. While rich in clinical material these writings have surprisingly few speculations about the nature of man and the workings of his body. Hippocrates, who considered himself a physician rather than a philosopher, wrote: "certain sophists and physicians say that it is not possible for anyone to know medicine who does not know what man is. . . . But I think whatever such has been said or written by sophist or physician concerning nature has less connection with the art of medicine than with the art of painting. And I think that one cannot
know anything certain respecting nature from any other quarter than medicine." In his few writings about physiology, Hippocrates subscribed to the theory of the 4 humors and believed that the brain rather than the heart was the center of intelligence. Neuburger wrote of the Hippocratic concept of the cardiovascular system: "The circulatory system is described ... in a most confused manner. The starting point was first supposed to be the head, later the aorta and vena cava, which were thought to spring from the spleen and liver. The word φλέβες signified ... [veins], ἀρτηρίη in the first instance meant the trachea and bronchi; later the arteries, principally or exclusively containing air. The best known were the large and superficial ones, but their ramifications are, for the most part, fantastically described. In the description of the heart* mention is made of the pericardium, the auricle, the septum, the ventricles, the semilunar valves (including their action as valves) and the chordae tendineae. Both ventricles communicate, the left being nourished from the best portion of the blood of the right." Thus the few physiologic writings of Hippocrates do not show the insight that is found in his clinical observations.

Aristotle was responsible for the most important advances in physiology made by the ancient Greeks. Unlike Socrates and Plato, who added some discussion but little factual material to the science of physiology, Aristotle performed experiments and dissections (usually on animals). In addition, he assembled the observations available from the writings of the entire western world, which was then being unified under his patron and pupil, Alexander the Great.

Although the writings of Aristotle available today are often notes for, or from, lectures and have been transmitted to us through many translations, they contain a wealth of knowledge. Aristotle's contributions to the understanding of the circulation covered the fields of embryology, anatomy, and physiology. He wrote of the chick embryo that "its heart is seen in motion as though it were a living creature ... it being the starting point of their nature ... in all animals that have blood." He believed the heart had 3 chambers, writing: "All hearts contain chambers ... The largest chamber is on the right and highest up, the smallest on the left, that which is intermediate in size is between the two ... the vena cava is attached to the largest chamber, that which is uppermost and on the right ... the aorta springs from the middle chamber." The basis for this concept of the anatomy of the heart is not known with certainty; Galen believed that Aristotle's middle chamber was the outflow tract of the right ventricle while Vesalius believed it to be the vestibule of the aorta. It seems most likely that Aristotle was describing 3 of the 4 chambers of the mammalian heart, the right atrium having been considered to be a part of the venae cavae, with the middle chamber the left ventricle, lying between the right ventricle and left atrium and giving rise to the aorta. Aristotle also described vessels connecting the lungs to the heart, one going to the right chamber (the right ventricle) the other† to the left chamber (the left atrium). Believing these vessels carried air, he had no conception of a pulmonary circulation and thought that air was mixed with blood in the heart. He recognized and differentiated structurally the vena cava and aorta and wrote of the peripheral vasculature: "As the blood vessels advance, they become gradually smaller and smaller until at last their tubes are too fine to admit the blood. This fluid can therefore no longer find its way through them, though they still give passage to the humor which we call sweat, and especially so when the body is heated, and the mouths of the small vessels are dilated." The heart to Aristotle occupied a primary position in the body's function. He wrote: "For the motions of the body commence from the heart and are brought about by [its] traction and relaxation. The heart ... is as it were a living creature inside its possessor." He thus returned to the proposition that the heart is the seat of intelligence and believed the brain existed to cool the heart.

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* From the time of Galen the work referred to here has not been considered to be a genuine work of Hippocrates but rather a later work attributed to him.

† It is the rule in ancient writings for the pulmonary veins to be described as a single vessel.
After the death of Alexander the Great in 323 B.C. the intellectual primacy of the ancient world moved from the mainland of Greece. The division of the Macedonian Empire resulted in civil wars, which, coupled with the changes in the structure of Hellenic society and commerce following the expansion to the east, brought about a rapid decline in the importance of the Greek city-states. The city of Alexandria, created by Alexander on the Nile delta, became for a time the center of medical science, possessing a great museum and probably the finest library of the ancient world. Under the enlightened reigns of the early Ptolemys, study and teaching were encouraged and Alexandria became a melting-pot for the ideas of physicians of many nations.

The writings of Herophilus and Erasistratus, leaders of Alexandrian medicine in the third century B.C., were the basis for much that was to be written hundreds of years later in Rome. Herophilus was, according to Galen, the first to publicly dissect the human body. He differentiated arteries from veins on the basis of the thickness of their walls and he counted the pulsations of the arteries, though he probably regarded pulsation as an active property of the arteries themselves. Herophilus subscribed to the theory of the 4 humors and considered the brain to be the seat of intelligence, the heart serving to warm the blood. Erasistratus, a younger contemporary of Herophilus, broke with the humoral school of causation of disease and looked instead to the organs of the body for the sources of illness. In his description of the cardiovascular system, Erasistratus wrote that the right ventricle contained blood that was made in the liver and the left ventricle received from the pulmonary veins the vital spirit, a *pneuma* derived from the inspired air. During cardiac systole these substances were ejected from their respective ventricles into the great veins and aorta to be carried to all parts of the body. Erasistratus described the valves of the heart and recognized their function. He thought a second kind of *pneuma*, the animal spirit, was formed in the ventricles of the brain from the vital spirit and carried throughout the body by hollow nerves. Erasistratus did not significantly advance the ancient concept of the circulation, but in rejecting the humoral theory of disease for one based on organic malfunction he is often regarded as the Father of Physiology.

The decline of Alexandrian medicine followed this single generation of investigators. There arose a “Rational” School of medicine, which, by reasoning from the principles laid down by Hippocrates, attempted to explain all medical problems. In reaction to this, an “Empiric” School was founded in Alexandria which pointed out the clinical uselessness of the speculations of the philosopher-physiologists and held that attempts to understand natural functions were useless. The attack on the philosophic approach to the problems of physiology was not without justification, but it effectively blocked the further study of physiology and sounded the death knell of Greek medicine.

The next chapter in the history of medicine was written in Rome. Like the medicine of all civilizations, Roman medicine began in mythology, and while physicians are occasionally mentioned in the writings of Rome from the fourth century B.C., the Romans did not go on to develop a medical profession of their own.

With the conquest of Greece in the second century B.C. Roman medicine came to feel the strong influence of the Greek physicians. At first the Romans resisted the influence of the adventurous Greek physicians who moved into Rome with their foreign ideas. Cato, in the third century B.C. wrote: “The Greeks are a hard and perverse race. Believe me when I tell you that each time this nation brings us some new knowledge it will corrupt Rome; but it will be worse if it sends us its physicians; they have sworn to kill all the barbarians by means of drugs and they call the Romans barbarians.”

In spite of this warning the Greeks came to dominate Roman medicine. However, medicine did not flourish in Rome as it had in Greece, a fact that Neuburger attributed to “a constant succession of wars [which] stifled scientific interest, the whole energy, the whole intellect of the worker being devoted to a single idea—the good of the state, the growth of power.” Roman medicine is more noted for its encyclopedic compilations and practical accomplishments such as the aqueducts and Cloaca
Maxima than for theoretical propositions like those of the imaginative medicine of Greece. Little was added by the early Romans to the Greek ideas about the circulation. Asclepiades, born in Greece in the first century B.C., was the most noteworthy physician of this period. Using the atomic theory of the Epicureans then in vogue, he attempted to explain the workings of the body by the movements of countless particles through tubular spaces formed by other particles, different attributes of the organism being represented by different types of particles. Though a good clinical observer, Asclepiades did not apply the empiric method to physiology.

The medical writings of the first century A.D. were dominated by the works of 2 great encyclopedists, Pliny and Celsus. Neither was a physician, and the writings of both covered fields other than medicine in an attempt to organize all the knowledge recorded at the time. Pliny said of his works: "[They are written] to give a general description of everything that is known to exist throughout the earth." Of the 2, Pliny was the least scientific; his Natural History was an unselected collection of fact and fable that has been called a lasting monument to Roman ignorance. Celsus, on the other hand, showed a good deal of insight and advocated human dissection and the use of observation, rather than a priori speculation, to form medical theory. Unfortunately the works of Celsus were not discovered until 1478, and it was Pliny, the "voluminous, industrious, unphilosophical, gullible, unsystematic old gossip" who influenced the thinking of the early middle ages.

The writings of Aretaeus of Cappadocia, a contemporary of Pliny and Celsus, show the continued dominance by the Greeks of Roman thought. He regarded the heart as the source of heat and the "origin of life and respiration," but gave no indication that he understood the relationship of the heartbeat to the movement of the blood. Like other ancient physicians his comments about physiology were not worthy of his clinical acuity.

The final chapter in ancient medicine was written at the end of the second century A.D. when Rome was at the height of her power. Wars were fought on the frontiers of the Empire far from the Imperial City where industry and commerce flourished. The resources of the western world were at the disposal of the Antonine emperors whose enlightened government actively furthered the development of art and science. This was the Golden Age of Rome.

Into this environment came Clarissimus Galen whose writings were to dominate western medical thought for over a thousand years. He was born in a Greek city in Asia Minor in 130 A.D., and after 11 years of study in Greek schools and in Alexandria he became physician to Marcus Aurelius. Under the patronage of this enlightened emperor, Galen found the opportunity to study, and he wrote over 150 books on medicine containing almost 4 million words. In his writings on physiology Galen tried to bring order out of the chaos of observations and theories of the ancient writers. He believed that no part of the body was made in vain, that each organ had a function to which it was perfectly adapted and that he, Galen, could uncover and describe the purpose of every structure in the body. Though destined to failure by the nature of his objective, his work reveals much intelligent observation in addition to a critical evaluation of past writings.

Galen's experiments resolved 2 of the misconceptions of the past. By opening an artery between 2 ligatures tied while the animal was living Galen proved that the arteries carried blood and not air. He also showed that the nervous system and not the heart was associated with sensation when he silenced a squealing pig by cutting its recurrent laryngeal nerve.

Since the Galenic conception of the circulation was an attempt to bring order out of the many conflicting observations and ideas of the past, his concept became as complex as it was imaginary. Some believe Galen knew the importance of the pulmonary circulation, while others regard his ideas as little advanced over the ancient theories that he had tried to correlate. The truth probably lies between these points of view. An outline of Galen's circulation, compiled from several translations, is presented here.

The essence of life, according to Galen, is in the pneuma. The function of the blood vessels
and nerves is to transport the natural precursors of the pneuma to the places of its formation and to distribute the final products throughout the body. The 3 final forms of pneuma are: the vital spirit derived by the lungs from air, the animal spirit formed from the vital spirit in the brain, and the natural spirit, the nutritive material made in the liver. The movements of these substances are described in the following manner: The liver forms the blood from chyle brought to it from the alimentary tract via the portal vein, and the liver adds the natural spirit to this blood. The resulting mixture is then carried to the entire body by way of the venous system, the movement being an ebb and flow rather than continuous. One major branch of the venous system is the right heart from which this nutritious blood can leave by 1 of 3 pathways. Most of the blood goes into the pulmonary artery from which it enters the lung to have impurities removed and exhaled. This purified blood then can return and re-enter the right heart where it passes through the veins to the periphery.* Finally, some of the blood leaves the right heart to enter the left ventricle through tiny pores in the interventricular septum. Meanwhile, the lungs and pleura have separated the vital spirit from the inspired air. This pneuma travels to the left ventricle by way of the pulmonary vein and mixes with a small fraction of blood coming to the pulmonary vein from the pulmonary artery after percolating through the lungs. Galen pointed out that this flow through the lungs is dependent on a competent pulmonary valve. The left ventricle thus receives blood containing the natural spirit through the septum and blood with the vital spirit from the pulmonary veins. When the heart contracts this mixture is forced out of the left ventricle through the aortic valve and is carried to all parts of the body by the arteries. The brain receives some of the arterial blood in a rete mirabilis (an arterial plexus at the base of the brain seen in some animals). Here the vital spirit is removed and made into the animal spirit, which is stored in the cerebral ventricles later to pass down the cerebral aqueduct, through the fourth ventricle to be distributed to the body by hollow nerves. Thus, through an ebb and flow in the great veins, with the passage of blood through the interventricular septum, and with the movement of fluid down the nerves, Galen transports the pneuma about the body. His description of the pulmonary circulation, of cardiac ejection during systole and of the function of the semilunar valves seems lost in a mass of unscientific conjecture.

The Roman Empire after the death of Marcus Aurelius in 180 A.D. was torn by war and internal strife. In addition to political disorders within the Empire and inroads of barbarians from without, natural forces were taking their toll of imperial glory. There were floods and earthquakes, and repeated epidemics decimated the cities. The inability of the science of the time either to cope with or to explain these terrible happenings led the people to turn away from the established systems of knowledge to more primitive explanations. Scientific exploration ceased and the questions raised in western civilization found their answers, as they had thousands of years before, in the workings of a God. The rise of Christianity marked the end of the ancient schools of science. These latter were not abolished by Christianity; they were assimilated into it. Christ became the God of healing and the medical traditions of the ancients became part of the Church. The writings of Greek and Roman physicians were hidden in monasteries where they were slowly and laboriously copied, traveling but little from place to place.

During this early medieval period the center of medical science moved to the Eastern Roman Empire. From the fourth to seventh centuries of the Christian Era the most important medical works were written in Constantinople and were compilations of ancient writings with little of note added to the understanding of the functions of the cardiovascular system.

Arabian medicine enjoyed a period of ascendancy from the time of the conquests of Mohammad in the seventh century to the thirteenth century when the decline of Arabian culture accompanied the disruption of the world of Islam by wars. Like their Byzantine predecessors, the Arabian physicians devoted

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* Galen did not recognize the function of the tricuspid valve and here ignores the pulmonary valve.
most of their energies to copying and commenting on ancient texts, a task that resulted in the preservation of many of the classical writings. There was little experimentation and almost no dissection. In the thirteenth century, however, a physician of Damascus, Ibn Nafis denied the possibility of blood passing through the interventricular septum and said instead: "Blood passes in the [pulmonary artery] to the lung to permeate its substance and mingle with the air . . . and then passes in the [pulmonary vein] to reach the left cavity of the . . . heart."  
This gifted Arabian physician had no conception of a systemic circulation and his description of the pulmonary circulation was lost and did not contribute to the work that came after him.

The present era of experimental science began in the European universities founded in the tenth through thirteenth centuries. These were started by groups of interested young men who hired scholars to dispute before them. Later the Church sanctioned the degrees given to the students, and in so doing gave prestige to the universities at the same time it was able to regulate their teachings. When the practice of medicine was forbidden to the clergy in the twelfth and thirteenth centuries, these universities became the center of a new medical culture.

Like the city of Alexandria a thousand years before, the school at Salerno became a crossroads of medical culture. Latins, Greeks, Mohammedans, and Jews studied and taught here and the writings of the ancient world were carried in from European monasteries and the Mohammedan countries. Anatomic studies began with the annual dissection of a pig over which were read the misconceptions of the past. Mention of human dissection began to appear quietly in the writings from the universities of the late thirteenth and early fourteenth centuries. The early anatomists were more influenced by past writings than the dissections they witnessed and it is not surprising to find them pictured sitting at least 6 feet from the cadaver that was being dissected by a servant. However, these humble dissections, with their very limited use of the observational method, can be considered to contain the beginnings of our scientific medicine.

Mondino of Luzzi published a manual for human dissection in 1316 at Padua. He described a 3-chambered heart consisting of right ventricle, left ventricle, and small cavities in the septum through which passed blood moving from right to left. Henri de Mondeville, a contemporary of Mondino at the medical school of Montpellier, also described a third ventricle within the septum and his description of the movements of the blood was clearly based on the writings of Aristotle and Galen.

This state of ignorance could not survive the advent of careful and thoughtful dissection. The last major barrier to anatomic study was removed about 1480 by a bull of Pope Sixtus IV sanctioning human dissection. In the sixteenth century the distribution of medical texts using movable type and printed illustrations furthered the search for knowledge. The number of anatomists increased, many parts of the body were accurately described for the first time, and the foundations for a new science were being built.

Andreas Vesalius took up these beginnings when he published De Humanis Corporis Fabrica in 1543. The impact of this book on anatomy is so familiar as to need no further elaboration. In the field of physiology Vesalius was skeptical of Galen's teachings about the circulation, writing: "I do not see how even the smallest amount of blood could pass from the right ventricle to the left through the septum." However, Vesalius did not advance a theory of his own and did not upset Galenic physiology as he had Galen's anatomy.

With the disruption of a part of Galenic dogma the remainder of the ancient ideas became vulnerable to new teachings. Many physicians advanced the knowledge about the circulatory system, each adding to the work, gaining more and more insight into the true nature of the movements of the blood. It is not surprising that at least 6 men have been credited with the discovery of the circulation.

Michael Servetus described the pulmonary circulation in a theological book published in 1553. He wrote that blood reaches the left
heart from the right "not...through the septum...but...from the pulmonary artery to the pulmonary vein by a lengthened passage through the lungs."9 Of this passage through the lungs he wrote: "The blood must...be poured in such large measure...from the heart to the lungs for another purpose than for the nourishment of these organs. Moreover, it is not simply air, but air mingled with blood that is returned to the heart by the pulmonary vein."9 Servetus did not extend the concept of the circulation of the blood to the systemic vessels and his writings were lost for almost 150 years after his books were burned for theological reasons.

Realdo Colombo wrote an accurate description of the pulmonary circulation in Italy 6 years after Servetus' publication. There is little doubt that this was an independent discovery. Colombo also described the actions of the 4 valves of the heart in directing the flow of blood, but in attributing to the veins the function of carrying nutritive blood to the periphery he fell into the trap of Galenism.

Fabricius of Aquapendenti was the first to describe the functions of the valves in the veins. Although he recognized that venous blood could move in only 1 direction, he held to the ancient theory of an ebb and flow in the arteries. This sixteenth-century physician was a teacher of William Harvey and the latter's drawings of the venous valves are strikingly similar to ones prepared by Fabricius.

Andrea Cesalpino, of all of Harvey's predecessors, was the most deserving of credit for the discovery of the circulation of the blood.18 In 1593 this Italian wrote: "...from the vena cava a flow takes place into the right ventricle, whence the way is open into the lung. From the lung, moreover, there is another entrance into the left ventricle of the heart, from which then a way is open into the aorta, certain membranes being so placed at the mouths of the vessels that they prevent return. Thus there is a sort of a perpetual movement through the heart and lungs into the aorta."19 If he had stopped here, this account would be ended, for this is indeed a description of the circulation through the heart and lungs. However, Cesalpino's final word on this subject was published in 1606, 3 years after his death. As if reluctant to give up the ancient idea of an ebb and flow of blood, he wrote that blood leaves the heart by way of the aorta and pulmonary artery, and by way of the vena cava and pulmonary vein.4

Three others who have been honored for the discovery of the circulation are Carlo Ruini, an Italian, François Rabelais of France, and Bernardino Montaña de Monserrat, a Spaniard. There is, however, little good evidence to support the claims that these men accurately described the circulatory system.

As with anatomy before Vesalius, the physiology of the circulatory system was awaiting a gifted observer to fit together the many existing fragments of knowledge to arrive at a new concept. Such a man was William Harvey. Harvey gathered for his theory the anatomic knowledge of the heart and great vessels, the idea that the heart is a muscular pump, knowledge of the functions of the cardiac valves, the observation that venous blood is permitted to flow only toward the heart by the venous valves, the concept of the pulmonary circulation, and the earlier suggestions of a systemic circulation. To these he added one of the first mathematical proofs in the history of physiology, the calculation that the quantity of blood ejected by the heart is far greater than could be formed from the ingested food. From the synthesis of all these ideas, this chapter of medical history ends with Harvey's positive statement: "...it is absolutely necessary to conclude that the blood in the animal body is impelled in a circle, and is in a state of ceaseless motion; that this is the act or function which the heart performs by means of the pulse; and that it is the sole and only end of the motion and contraction of the heart."20

REFERENCES


The authors showed previously that in the period 1949–52 the “sudden death” rate and “three-month mortality” rate from coronary artery disease was twice as great in the drivers of London buses as in the male conductors. It was suggested that physical activity accounted for the difference. It was evident to the authors, however, that a difference in physique of persons who become conductors or drivers might be responsible. They conceived checking on this possibility by analysis of the records of trouser waist line and jacket breast measurements, data readily available from the department that issues uniforms to the men. For all age groups, the percentage with trouser waist of 36 in. or more and jacket breast of 40 in. or more was consistently greater in the group of drivers. The average height of drivers was greater, partly because a maximal height was prescribed for conductors. In both occupations girth increased progressively with age. The data indicate that the differences in the physiques of the 2 groups are constitutional and that the men brought the differences with them to their job. Other considerations are discussed.

McKusick
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ARNOLD M. KATZ

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