Proceedings of the Iowa Academy of Science

Volume 83 | Number Article 3

1976

The Nature of Man as Identified from the Study of the History of Heart and Circulation

Leland P. Johnson
Drake University

The Nature of Man as Identified from the Study of the History of Heart and Circulation

LELAND P. JOHNSON*

Generic man has evidenced curiosity concerning self and the external world since the beginning of recorded history. How is the external world related to man and how does it affect man's nature? Possible answers to these understandings involve both objective and subjective experiences. The objective world can be perceived by others and verified. Similar interpretations are often functions of common environments and educational dogma. Subjective experience is a private matter which may deny communication, or if communicated, may deny common interpretation. It is hoped that primarily through focusing upon objective experiences as recorded in the history of the development of concepts concerning the heart and circulation that some insights into the nature of man may be identified.

Man is observed to be rational yet the environment imposes restrictions to rationality. Man's concepts of gods and nature are intimately associated with physical and climatic surroundings. This amalgamation of environment and the nature of man is illustrated in differences between concepts held by inhabitants of Mesopotamia and Egypt.[1]

Early Mesopotamian "gods" of the Fertile Crescent bounded by the Tigris and Euphrates rivers[2] included Marduk and Enlil. Marduk was alleged creator of heaven, earth, man, and was leader of the "gods" of magic. Enlil, one of the trinity of gods, was capricious and completely unpredictable. The actions of each included taking advantage of the other. They were as predictable as the diagnoses of Mesopotamian physicians, who used magic to divine the state of health and disease, and the prognosis of the ill person. Blood was recognized as the fluid of life and the liver as the central receptacle of the bodies' blood. Utilizing meat producing animals, the five lobes of the liver presented them with opportunities for diagnosing the diseased state of man. The goal of the Babylonian physician was to appease or circumvent the capricious gods. Little knowledge is available on heart and circulation although deciphered Mesopotamian tablets describe other medical and biological information.[3]

Early Egyptians, located along the Nile River, possessed a multiplicity of divinities. In many instances the gods were as cruel as those of Mesopotamia but typically much more consistent in their behavior.[4] Osiris, the god of the dead, and Isis, mother of all things, have been honored by historians of science in the titles of two periodicals. The publication Isis continues as an official journal of the History of Science Society. The Egyptian's preoccupation with death and the after life may have had some influence upon growth of information concerning heart and circulation. It was Imhotep, a man deified, who had great impact on early concepts of the circulatory system. The early Egyptian described objectively and in a consistent manner the vessels and associated the heart beat with the pulse. Of the papyri which have been saved and translated, the Smith Papyrus gives much information concerning the status of anatomy and medicine of Egypt.[5]

The capriciousness of the gods and fickleness of physicians of Babylonia compared to the consistency and objective approach of the Egyptians may be a function of the climate and weather. In Mesopotamia, the Euphrates and Tigris rivers had origins in the mountains of Cappadocia and Armenia and flowed beside the Syrian desert. In Egypt, the Nile had its origin in Ethiopia and Uganda. The Blue Nile and White Nile joined at Khartown and ran approximately 1,900 miles through a valley slit desert. One great difference existed, the Tigris and Euphrates rivers were subject to frequent flooding at inopportune times while the Nile was unusually constant in that an annual flooding occurred with the deposition of a rich layer of top soil. In Mesopotamia crops were often destroyed at or before harvest leaving the population without grain. The heavy rains in the hills caused flooding and devastation of both property and crops. The Mesopotamian gods were fickle as was the environment and the processes of diagnosis. In Egypt the flooding of the Nile was an indicator of a successful growing season. It was a dependable sign, similarly a casual relationship evolved in the medical science of the country.[6] The climate of the two areas has been similar to that of today for approximately the past 12,000 years, since regression of the last glaciation.[7]

Man is a part of his environment. Thoughts and actions cannot be separated from these limitations, especially in prehistorical or early historical periods when man had little control over phenomena of nature. This inexorable relationship with the environment is often not appreciated until man is transplanted into a different environment, physical or conceptual.

That man is rational, a collector and a collator of information, and political, is evidenced by Imhotep, vizier at the Court of King Zoser of the third dynasty of the Old Kingdom in Egypt. Imhotep was an architect and constructor of the Step Pyramid at Sakkara, exchequer, astronomer, scribe, sage, and priest who may have been associated with death and the mortuary cult. In addition, he was undoubtedly a physician since within a century he was made a demigod and raised to a full diety of medicine by 525 B.C.[8]

Strife, religious and political, including war, preceded the period of Zoser and Imhotep. Man's exposure to the injuries associated with battle may have allowed the development of knowledge of structure and functioning of the human. Breasted conjectures that the Smith Papyrus may have had its origin from the writing of Imhotep. Knowledge of the relation of the pulse to heartbeat was suggested in the Smith Papyrus with a notation that one counted the pulse in diagnosis as one would count or measure a bushel.[9] The Ebers Papyrus describes 22 blood vessels in man and identifies faintness as the heart does not speak to that part. These papyri are from the 17th and 16th centuries B.C.[10] Each papyrus contained directions to the medic, recipes and recitals for caring for illness. Diagnoses were always initiated and terminated with a statement dependent upon the condition of the patient. The medic was cautioned to state: 1. An ailment which I will treat (if the patient will recover). 2. An ailment which I will contend (if the state of recovery is not evident). 3. An ailment not to be treated (if recovery seems impossible). Retribution was costly to the medic if failure occurred.[11]

The medic had little experience in dissection of the vascular system except as he may have prepared the body of a high official or of the royal family for the nether world. Embalming was not a task for the educated but for shunned ones who reeked with the aroma of natron solutions. Embalmers were essential to insure that all body parts arrived intact in the nether world. Cults deifying Osiris as god of the dead existed before early pyramid texts. The nature of man as exemplified in his myths and dogmas limit actions as surely as physical barriers. In Egypt delegating the embalming task to the unedu-

*Drake University, Des Moines, Iowa 50311

cated is in a large part associated with a religious hierarchy in which the physician was of second rank only to the priests. The medic refrained from soiling or contaminating self through dissection. The embalmer was at the lower echelons of the hierarchy, thus, little communication occurred between the embalmers and physicians. Knowledge which had been developed from earlier observations became ossified as man so venerated the past that both concepts and procedures were dogmatized. This dogmatization is characteristic of the nature of man and evidences of its occurrence is duplicated repeatedly in the annals of science and religious doctrine. Nevertheless, a person has always appeared to challenge the dogma. Science is in constant flux because of this challenge. Progress is made in science when the old is refined or overthrown and when something better is substituted.

Imhotep may have been the synthesizer of concepts which were dogmatized as he was deified. The ideas of the authority are often boxed in by minds of the insecure or memorizer. The modest concepts concerning heart and circulation conceivably known by Imhotep were not changed significantly for over 4,000 years. This lack of change occurred in spite of the fact we know the scribe and physician who copied the Smith Papyrus gave evidence of being an influential and wise person as indicated by marginal notes.[12] The neophyte physician undoubtedly learned his medicine from the scribes who recopied the papyri and who practiced the medical art in religious temples.

The interlude between the Egyptian papyri and Hippocrates is veiled in the reorientation of power and cultures. Communication occurs whenever man contacts others. The Egyptians, Phoenicians, and Greeks vied for supremacy of the eastern Mediterranean with the Agean culture ultimately flourishing and dominating. That exchanges of knowledge occurred is common knowledge as the present alphabet and number system are proof. The asclepiad healing temples of the Hippocratic physicians were models of the Egyptian temples of healing. Excavations near Cos offer evidence of the structure of asclepiad temples including reproductions of the symbolic serpent.[13]

Knowledge of anatomy and physiology of organisms was often hidden in the writings of Hippocrates, but included concepts of the elements and humours plus a primitive description of the blood vessels. The concept of the Hippocratic doctrine of the four humours — blood, phlegm, black bile, and yellow bile were retained for some 1,500 years and were enlarged and refined by both Aristotle and Galen.[14] Much of the Hippocratic medicine was based upon the natural balance between these fluids and the environment. The greatness of the Hippocratic cult was based upon: (1) Diseases have a natural cause; (2) diseases are caused by disturbances in the composition of the constituents of the body which is related to external conditions; (3) nature tries to bring irregularities to normal state; (4) there are "critical" and fixed dates during a disease, and (5) all a physician can do for the patient is give nature a chance.[15] Concern for others is also evidenced in the Hippocratic Oath and admonitions as to the proper decorum of physicians.[16]

Hippocrates understood the physiological differences and roles of the brain, heart, and Homer's Pneuma of the Iliad. These distinctions are described in Chapter XX of the writings on the Sacred Disease:

> "Wherefore I assert that the brain is the interpreter of consciousness. The diaphragm has a name due merely to chance and custom, not to reality and nature, and I do not know what power the diaphragm has for thought and intelligence. It can only be said that, if a man be unexpectedly over-joyed or grieved, the diaphragm jumps and causes him to start. This is due, however, to its being thin, and having a wider extent than any other organ; it has no cavity where it can receive any accident, good or bad, but it is disturbed by both owing to the weakness of its nature. Since it perceives nothing before the other parts do, but is idly named as though it were the cause of the perception; just like the parts by the heart called "ears," though they contribute nothing to hearing. Some people say that the heart is the organ with which we think, and that it feels pain and anxiety. But it is not so; it merely is convulsed, as is the diaphragm, only more so for the following reasons. From all the body veins extend to it, and it so encloses them that it feels any pain or tension that comes upon a man. The body must, too, when in pain, shiver and be strained, and the same effects are produced by excess of joy, because the heart and the diaphragm are best endowed with feeling. Neither, however, has any share of intelligence, but it is the brain which is the cause of all the things I have mentioned. As therefore it is the first of the bodily organs to perceive the intelligence coming from the air, so too if any violent change has occurred in the air owing to the seasons, the brain also becomes different from what it was. Therefore I assert that the diseases too that attack it are the most acute, most serious, most fatal, and the hardest for the inexperienced to judge of."[17]

The dual nature of the vessels of the circulatory system in man are described in the treatise of the Sacred Disease Chapters VI and VII. No distinctions are made between arteries and veins. A suggestion is made that closure of vessels will cause a paralysis of that part of the body because it cannot breathe. The wise one who copied the Smith Papyrus associated the heartbeat with the pulse yet this is not recognized in early Greek medicine.

Others having impact upon nearly every field of thought were Socrates, Plato, and Aristotle. Aristotle, son of a physician and student of Plato, influenced the biological sciences and medicine for 2,000 years and teleological concepts advocated by him haunt us. Plato imbued Aristotle with the concept of the ideal which influenced Aristotle's concepts of causations and teleology. Nevertheless, Aristotle was one of the world's great observers, describers, organizers and model builders. Aristotle's ideal and Hippocrates' qualities, elements and humours were welded into a system which influenced explanations of the operations of the heart and circulatory system for centuries. Singer gives a concise statement of Aristotle's system.

> "He held, following more ancient writers, that there were four primary and opposite fundamental qualities, the *hot* and the *cold;* the *wet* and the *dry*. These met in binary combination to constitute the four essences or existences which enter in varying proportions into the constitution of all matter. The four essences, or to give them their usual name, *elements*, were *earth, air, fire,* and *water*. Thus water was wet and cold, fire hot and dry, and so forth. With this theory, later writers combined the Hippocratic doctrine of the four humours — *blood, phlegm, black bile* (melancholy), and *yellow bile* (choler). The idea, now departed altogether from our scientific discipline, still persists embedded in our language."[18]

Aristotle was a comparative anatomist but it was unlikely that he dissected a human. He was a student of embryology and made valuable contributions to habits and breeding of fish. In fact, it is reported that description on the breeding habits of the fresh water catfish was written on his honeymoon. He also described the development of the chick which replicated a description by Hippocrates.

Aristotle failed to appreciate Hippocrates understanding of the role of the brain and heart. Aristotle placed the seat of intelligence in the heart. The importance of the heart, according to Aristotle was the fact that the heart is the first structure to show activity or motion in all blooded animals and is associated with viscera which carry ves-

sels. Nature gives the honorable place of an organ, the heart is centrally located so that the vessels may go to the various parts of the body as well as guarding the heart. The heart is hollow to form a receptical for blood, dense to guard the heart, and the need to store blood is obvious because it is a starting point for blood vessels. The heart has an abundance of sinews with three cavities in the largest hearts. The right side contains the most blood and is the hottest. The large vessel and aorta exort from the heart and carry materials to every part of the body, and in so doing get smaller and become hidden in flesh.[19]

Aristotle, a vitalist, advocated that the presence of psyche or soul separated the living from the non-living. He holds that the soul is related to form. Matter is identical with potential, form with actuality. The rationale for this position is intimately associated with his causes:

"(1) The Final Cause, the End or Object towards which a formative process advances, and *for the sake of which* it advances — the *logos*, the rational purpose.
(2) The Motive (or Efficient) Cause, which is responsible for having set the process in motion; it is that *by which* the thing is made.
(3) The Formal Cause, or Form, which is responsible for the *character* of the course which the process follows (this is also described as the *logos*, expressing what the *thing* is).
(4) The Material Cause, or Matter, *out of which* the thing is made."[20]

Aristotle stressed the final cause, the end which dominated every process. The processes and development is in every way subservient to the final cause. Nature does nothing without a purpose. It can be inferred that Aristotle understood much concerning functioning or organisms but his faulty causal concepts and assumptions concerning the functioning of the ideal organism perverted comprehension of the physiology of organisms. Such comprehension was within the grasp of Aristotle and his contemporaries. His ideas of nutrition aeration and the blood are effectively presented in the following quotes from De Partibus Animalium:

"The food masticated in the mouth, but not otherwise altered, reaches the stomach, where it is concocted; the heat for this purpose, which is not common heat but a heat with special powers, being supplied by the liver and spleen, which are hot organs in close contiguity with the stomach. The solid and indigestible portion passes off by the lower bowel, but the fluid portion, which alone can be serviceable in nutrition, is absorbed by the blood-vessels of the stomach and intestine, over the surface of which they are spread like the roots of a plant. These blood-vessels open by very minute and invisible pores into the intestine, pores like those in jars of unbaked clay that let water filter through. The matter thus absorbed passes up to the heart in the form of vapour, not as yet being blood, but only an imperfect serum. In the heart and vessels it undergoes a second concoction, these being the hottest parts of the body, and by this second concoction the serum is converted into blood, the ultimate food of all the organs. The amount of blood thus formed is extremely small, as compared with the original materials. The blood when made passes from the heart by the vessels (arteries and veins alike), being mingled with air inhaled by the lungs and thence conveyed to the heart, and is carried to all parts of the body. Each organ selects from the common stock those materials which it requires. The nobler parts, such as the flesh and the organs of sense, take the choicer elements, while the inferior parts, such as bones and sinews, are fed on the inferior elements or leavings of the former. This nutrition of the parts goes on most actively at night.

Thus every part of the blood that can be turned to account is utilized; but such as from its quality is unfit for use, for instance any bitter substance, is excreted as bile, urine, sweat, etc., in company with the matter which results from the decay of the parts themselves.

Such surplus of nutritious matter as there may be, after all parts are satisfied, is either stored up in the body as fat or the like, or passes out to form hairs, scales, feathers, and other cutaneous appendages."[21]

"It is not necessary to infer with Frantzius from this passage, that Aristotle thought that the windpipe communicated directly with the heart. For he supposed that air could pass without any such direct channel, as the following passages show: 'When the windpipe reaches the lung, it divides and subdivides, each division producing smaller and smaller branches, till the whole lung is permeated by them.' 'There are also ducts which lead from the heart to the lung; and these also divide and subdivide, their branches accompanying the branches from the windpipe. But there is no communication between the two. Notwithstanding this, however, air can pass from the former into the latter, owing to the close contact in which the two lie, and be transmitted to the heart.' This passage shows that Aristotle not only had a fair knowledge of the anatomy of the lung, but also believed the air to pass from the air-passages into the blood-vessels through their unbroken walls, just as we hold the oxygen to do."[22]

"The 'great vessel', as I interpret Aristotle's account, consists of the upper and lower Venae cavae, with the right auricle, considered by A., as by Galen and later anatomists, to be no part of the heart but merely the dilated junction of the two Venae cavae. This communicates with the largest cavity (right ventricle) by the wide auriculo-ventricular opening, and from this same cavity issues the pulmonary artery, regarded by A. in virtue of its connexion with the same cavity, its having a similarly thin wall, and being found after death similarly gorged with dark blood, as a part of the 'great vessel', though separated from its main trunk by the interposition of the right ventricle, this being the cavity referred to. The middle cavity from which the aorta proceeds is the left ventricle, and the smallest is the left auricle. All three cavities are connected with the lung, but in only one (right ventricle) is the connexion distinctly visible. Thus 'the great vessel' comprises all the vessels connected with the right side of the heart, and the aorta comprises all that are connected with the left, that is all the systemic arteries and the pulmonary veins, and each side has its distinct and completely separate blood, which is more abundant, denser, and less pure on the right side than on the left. Lastly, the opening by which the aorta communicates with the heart is much smaller than that by which 'the great vessel' so communicates, i.e. the right auriculo-ventricular opening, not the aperture of the pulmonary artery, as stated by error in my former translation."[23]

The center of Greek medicine was transferred to Alexandria soon after the loss of Athenian liberty and the death of Aristotle in 322 B.C. Herophilus, the Father of Anatomy, practiced dissection of both human and animal bodies. He understood the nature of nerves, both motor and sensory, and made the first clear distinction between veins and arteries but considered the pulse to be an active process of the arteries themselves in contrast to the ancient Egyptian who associated the pulse with the heartbeat. A contemporary of Herophilus was Arasistratus, the Father of Physiology, who was a scientific materialist. This materialism was incorporated into the pneumatic theory involving the "vital spirit" which in turn was associated with the nutritive and animal spirit. Later Galen effectively espoused

these Alexandrian concepts and they dominated[24] physiology until the period of Harvey.

One section of the great medical library at Alexandria was destroyed at the direction of the Christian Bishop Theophilus about A.D. 390 due in part to an antithesis for human dissection and secular learning. Again in A.D. 640 the Muslims destroyed what was left, whether deliberate or accidental has not been validated.[25]

Galen of Pergamum, A.D. 129-199, was the last of the great Greek medical anatomists and physiologists. Although associated with Rome and a dissector of the Barbary Ape, he was Greek trained and was both a successful physician and prolific writer. He followed the Aristotlelian principle in which nature makes naught in vain and Galen seeks to justify that organs are so perfect in relation to the functions performed that it is impossible to imagine anything better. His works are not the relationships of structure to function but how anatomy and physiology are subservient to the doctrine of final causes in the study of animals or to justify the ways of God to man. He assumes complete knowledge of the Laws of Nature which few modern scientists are willing to accept. Although trained in the Stoic philosophy, Galen accepted a determinism of perfection which was fixed by a far-seeing God.[26]

In his writing, Galen was most lauditory of the work of Hippocrates including the genesis of humours and relationship of man to the environment in terms of healing. At the same time he is most critical of Erasistratus because of his disregard for humours. He used concepts of spirits of Erasistratus but was most critical of Erasistratus theories. Galen resembled Aristotle who used the platonic concept of the ideal yet at the same time was critical of Plato's contributions.[27]

Galen's circulatory system contains a rather accurate representation. He follows hints from the Hippocratic collection. The venous system is compared to a tree with the roots initiating in the abdominal viscera, the vena cava being the trunk, and branches are found in the lungs and other parts of the body. One of the most important branches is the right ventricle. In addition the veins are represented as arising from the liver. In the case of arteries, the left ventricle and aorta were regarded as the trunk from which branches arose. He understood pulmonary arteries to be the roots of the arterial system. The arteries were described as being thicker than the veins and filled with blood as demonstrated by double ligaturing an artery and incising.[28]

Galen understood the course of veins from the intestine to the liver via the portal vein. The materials were transformed into the natural spirit in the liver and carried (an ebb and flow) in veins. The natural spirit is the subconscious vegetative life, a kind of nutritive substance or state. In the heart there is an exchange of pneuma (air) with blood through minute pores forming a concoction in the left ventricle known as the vital spirit which is a higher spirit associated with motion. The vital spirit was carried by the arteries to structures and the vessels reaching the rete mirabile at the base of the brain changing the concoction to form a third spirit, the animal spirit. The animal spirit was then carried to all parts of the body via nerves considered to be hollow.[29] This system of spirits survived until Harvey published in 1628.

Galen contributed much to anatomical knowledge. The Church accepted Galen's thesis and formed a dogmatic association of scientific and religious concepts which hampered a more rapid development of satisfactory concepts of heart and circulation. There have been many such instances where the Church assimilated physical and biological concepts with religious creed. This in effect did a disservice to both science and religion.

An event, Nestorious and his followers were found to be heretics at the Council of Ephesus in A.D. 431, was to be a significant factor in perpetuating the concepts of Hippocrates, Aristotle, and Galen. About A.D. 435 Nestorius was banished to Petra in Arabia. These Nestorians settled at the University of Gondisapor bearing Greek manuscripts. They were favorably received by Chasroes, the incumbent Persian King. As Mohammandism developed and was evangelized, the Muslims assimilated intellectual knowledge with vigor and respect. "The teaching of Islam eloquently decreed: 'Science light the road to Paradise. Take ye knowledge even from the lips of an infidel. The ink of the scholar is more holy than the blood of the martyr'."[30]

Following the initial growth and evangelism of Mohammed, the Arabs conquered Arabia, Syria, Persia, and Egypt. In the ninth century Harun-al-Rashid, one of the most famous of the Caliphs, fostered translations of the Greek authors into Syriac and Arabic languages. Two physicians, Rhazes born 850 and Avicenna born 980 had great impact upon anatomy and medicine. Avicenna translated works of Aristotle and Galen and added his own concepts of medicine, human anatomy, and physiology. Avicenna's Canon of Medicine, or Compendium of Medicine, was a codification of the Arabic knowledge of the period. The term Canon gives an indication of the self esteem with which Avicenna held himself. The Canon was used in the study of medicine in parts of Europe until the mid 1600's and until the 1800's in the Arabic world. Little new was added to what had been written by Galen. There are many apocryphal tales concerning Avicenna. He is supposedly to have memorized the Koran by the age of ten and had read the metaphysics of Aristotle no fewer than 40 times by early adolescence. He initiated his study of medicine at fifteen. Avicenna began his medical career at Bukhara in Persia, now in southern USSR and is reported to have read all scientific literature available by the age of eighteen. The library burned soon after that, and Avicenna's enemies accused him of deliberately destroying the manuscripts so that he would have a monopoly on medical and scientific learning.[31] It was the Canon of Avicenna which was carried across the north of Africa into Spain and to the cities of Toledo and Cordoba. Gerard of Cremona, working in Toledo in the 12th century, translated from Arabic into Latin the Canon of Avicenna and ninety-two philosophical manuscripts.[32] This was of significance in stimulating scholasticism. Arabic sources also entered the western world through southern Italy via a monk known as Constantine the African, who died in 1087 A.D. He began a series of medical translations from the Arabic to Latin, and was called an ignorant and dishonest worker due to many inaccuracies. Following the death of Constantine, medicine and its foundation subject, anatomy and physiology thrived in northern Italy. The University of Bologna possessed a medical faculty in 1156. The basic knowledge was derived from Latin translations and Arabic literature. Later dissection of the human body was fostered and by the early 14th century Mondino de Luzzi performed them openly. His dissections were basically to aid the memorization of Arabian textbooks which had been translated into Latin. While Mondino was professor of anatomy, and holder of the "chair", he unlike other professors was his own demonstrator. Usually the professor sat in the chair and read in Latin the text while a demonstrator without adequate training dissected.

The work of Andreas Vesalius was preceded by that of Leonardo da Vinci, Guinther and Sylvius. The efforts of Leonardo were extensive and varied.[33] In fact, his genius may not be fully recognized to date. He describes the heart and blood vessels but did not contribute to the main line knowledge in the field of heart and circulation although he completed illustrations. It is not known whether Vesalius was cognizant of the endeavors of Leonardo da Vinci.[34] Guinther and Sylvius were humanists of a different bent in that they placed great emphases upon translating the Arabic writing into Latin and in reinstituting the original work of Galen. Vesalius was a student and younger colleague of both. Because of the esteem placed upon the writings of Galen, Vesalius became trapped into erroneous concepts

elucidated 1300 years earlier.[35]

Because Vesalius was as revolutionary to the biologists as Copernicus was to the astronomers, greater attention will be focused on his contributions and life. Andreas Vesalius was born in 1514, five years before the death of Leonardo, in Brussels of a physician to royalty. His great-great-grandfather acquired a costly collection of medical treatises and wrote concerning the writings of Avicenna. Some of the collection was available to Andreas who concentrated on the ancient authors at an early age. Andreas Vesalius matriculated at the University of Louvain in 1528 concentrating in Latin with Greek, Hebrew and science as allied studies. His biographers indicate that his interest in science handicapped his attaining competency in Greek and Hebrew commensurate with the humanistic conceptions of the 16th century.[36]

In 1533, Vesalius went to Paris to obtain a formal medical education following the profession of his father who was physician to Charles V. A friend of the family, Florenas, acted as spiritual mentor and director of Vesalius studies. Medical education at Paris was greatly acclaimed. It had been based upon the information from the Arabic writers Rhazes and Avicenna. Prior to the coming of Vesalius, medical humanism was stressed and the works of Galen and Hippocrates were followed. Johann Guinther and Jacobus Sylvius were devoted to the humanistic approach and each had impact upon the life and work of Vesalius. It was under the direction of Guinther that Vesalius wrote "Paraphrase of the Ninth Book of Rhazes" in 1537 after his return to the University of Louvain in 1536. They were to remain friends during their lives. This was not the situation with Vasalius and Sylvius, who devoted himself to literary studies until late in life receiving a doctorate of medicine at the age of fifty-two. Although dissection was practiced, Sylvius the professor, read Galen from the Chair, and berated the barbers if their dissection did not agree with the dictated description. Vesalius had dissected independently and it is reported that he became so dissatisfied with the work of the barbers that he took their place causing the displeasure of Sylvius who was in the Chair. Vesalius and his fellow students who desired to learn practiced zealously outside of formal classes to understand the human anatomy inasmuch as there was little assistance on the part of the teachers. There is no evidence that Vesalius received the doctorate in Paris.

Vesalius returned to Louvain. It is assumed that the baccalaureate was awarded at the time he presented the "Paraphrase of Rhazes." His stay was short and stormy. Professor Drivere at the University of Louvain supported the practice of blood letting as followed by the Arabic writers. Vesalius, following the medics of Paris, attacked publicly these concepts. The malicious response of Drivere would not have allowed Vesalius to prosper in Louvain.

Vesalius migrated to the University of Padua, a center of intellectual life and scientific endeavor. On December 5, 1537, he was granted a Doctor of Medicine with highest distinction and paid an inverse fee of seventeen and one-half ducats. The next day he performed a dissection and was immediately nominated Professor of Surgery which included teaching anatomy. Vesalius immersed himself in the teaching. Large charts were used as ocular illustrations to assist his lectures. These grew into the "Tabulae Sex" published in April 1538. It consisted of three sketches of the vascular system and three views of the skeleton. The publication was an instantaneous success and was duplicated many times later by Vesalius and others.

Other publications followed rapidly. A revision of Vesalius' professor, Johann Guinthers' Institutiones, was published in 1538, Vesalius explained the need for revision was due to numerous typographical errors in the first edition and that it was not wholly satisfactory for students when used with "Tabulae Sex". The work was dedicated to the Professor of Medicine and Rector of the University of Louvain. It also included a complete vita of Vesalius. It may be that Vesalius was looking to the future and another position. In 1539, he published the famous "Venesection Letter". He sided with the classics and against Arabic medicine. He described the azygos vein, including valves. The valves were to be important to Harvey in explaining circulation. Vesalius did not appreciate the significance of his own observations. Vesalius, an avowed anti-Galenist, contributed revised texts, the "Dissection of the Nerves", the "Dissection of the Veins and Arteries", and the "Anatomical Administrations" to the "Opera Galeni" edited by Joannes Boftista Montaures. Vesalius performed this task at the same time he was working on the now famous "De Humani Corporis Fabrica".

In the same year that Copernicus published the "Revolution", 1543, Vesalius published the "Fabrica" and "Epitome". Each broke with the past. Vesalius stressed observation and illustration rather than depending upon the authority of revered ancients. The "Fabrica" was illustrated by Stefan Van Kalkar, a fellow countryman, and a student of the great Titian. The text and illustrations gave excellent descriptions of the human anatomy but Vesalius offered little in the way of valid physiological explanations concerning the circulatory system. He continued to follow Galenic physiological concepts. He cast doubts on the concepts of Aristotle and Galen, suggesting that blood could not go through the septum of the heart from the right to the left ventricle but failed to make an outright statement on the subject. He may have feared the criticism of theologians since both Aristotle and Galen were thought to be infallible.[37]

The "Fabrica" was published by Johannes Oporinus in Basel, Switzerland. The wood plates were made of pear wood and immersed in oil to insure that the plates would not split through dehydration. The work was unique in that the scientist, artist, and wood carver worked in a cooperative fashion. The plates were used numerous times in texts of anatomy, lost and rediscovered in the attic of the Library in Munich. It was through the stimulus of the renowned neurosurgeon, Dr. Harvey Cushing, that 400 sets of reprints were made from the original plates in 1934. Among the casualties of World War II was the destruction of the Vesalius "Fabrica" plates as the allied bombers rained destruction on Munich.

It may be that Vesalius wished a court appointment, since he dedicated the "Fabrica" to the Emperor, Charles V. Vesalius delivered as gifts, the "Fabrica" and "Epitome" to Charles V. These were destroyed in the library at the University of Louvain in 1914 during the invasion of Belgium.[38] He was made court physician under Charles V and continued under Philip II after the abdication of Charles V. He remained in this position until shortly before his death.

Vesalius was recognized as one of the great physicians of his period. Whether fact or myth, he became known for his prognoses and skill as a surgeon. In the case of the Count of Buren, ill with quinsy of the throat, he predicted to the exact hour the Count's death. Similarly, Vesalius predicted that a wound received by Henry II of France in a joust celebrating the marriage of Henry's daughter to Philip II would be fatal. Vesalius, along with the court of Philip II, was transferred to Madrid from the Netherlands. He was met with envy by the Spanish physicians. Illustrative of the situation was the injury of Don Carlos, son of Philip II, who fell while chasing a chambermaid. Ten days following a critical situation occurred. Philip II and Vesalius went to Don Carlos. Vesalius' diagnosis was ignored but three days later the crisis occurred. Relics and charms were applied to the wounds. Among other efforts, the corpse of a friar who died a century earlier and who was cannonized because of his miracles was placed on the bed with Don Carlos. Nearly a month after the injury, Vesalius performed surgery incising the orbits and recovery occurred in five days.[39]

Vesalius left Spain under the shadow that he may have performed

dissection on an individual presumed to be dead. He departed on a pilgrimage to the Holy Land visiting Padua and Venice on the way. It was reported that he was reawarded his old position at the University of Padua before leaving on the trip. On his return trip, death occurred under questionable circumstances. It has been suggested that shipwreck occurred, that an epidemic occurred, and that he succumbed to illness associated with miserliness in saving money on food.

Saunders and O'Malley described in a thumbnail sketch their concept of the personality of Vesalius:

> "Vesalius was essentially the student possessed of an intense enthusiasm for his profession. No one, say his contemporaries, spent more time in the library reading, exploring, and digesting the technical literature. Truly a child of the Renaissance and deeply influenced by humanistic teachings, he sought not refuge in his books but the restoration of the golden age which had been destroyed. This was the same impulse which motivated the artists of the period in their pursuit of nature. Impetuous he most certainly was, but seldom did he allow his ardor to outrun his sense of decency. In fact, unlike his contemporaries, he seldom descended to personalities in his criticisms, which are usually overt without mention of names. He was not quarrelsome nor did he like argument for argument's sake, says his friend Jerome Cardan, who holds up Vesalius as an example to a disputatious age which had bred such vicious battles as those between Fuchs and Cornarius, Fuchs and Ryff, Argentarius and Fernel, Matthiolus and Amatus Lusitanus, to mention but a few. Like every ambitious and successful man Vesalius made enemies, but he had many friends to whom he appears to have been deeply attached. He was fully aware of the significance of his work and jealously defended it. Possessed of an artistic temperament, he was perhaps unduly sensitive and deeply resentful and hurt by the attitude of his former teachers at Paris to whom he had given his affection. He has been accused of being avaricious, but we suspect that the charge was the outcome of envious regard for the considerable fortune which he acquired in practice. We doubt that he, fully conscious of his intellectual superiority, was able to tolerate his less progressive colleagues who, in their pursuit of imperial favor, sought every opportunity to undermine his authority. His mind was intensely visual, and he retained his great powers of observation to the end of his days as may be gathered from the last pathological report which he wrote. His approach to problems was exceedingly direct, and he was not much concerned with philosophical speculations. He was strangely the epitome of a modern scientist in outlook but with this difference that specialization was entirely foreign to his conception of the province of a physician. He saw medicine as a whole, and as he had done for anatomy so it was his ambition to restore the art of surgery which through ecclesiastical prohibition and other influences had been relegated to menials. In this laudable endeavor he was almost completely frustrated and unable to overcome tradition. Indeed, had he received his doctorate from the University of Paris he would have been required to take an oath not to demean himself with the work of barbers. His attitude was misunderstood by his fellow physicians and threatened the vested interests of the surgeons' guild. This frustration would seem to have robbed him of much of the satisfaction to be derived from practice and appears to have been one of the factors which eventually made his life as court physician intolerable to him. He was not one who found it easy to conceal his feelings, which only served to increase his difficulties among jealous and servile men overly anxious for court favor and ever ready to seek personal advantage through criticism. That he should have reacted by remaining aloof and responding with cynicism is not surprising, but his friends recognized in his behavior only the earnestness and desire for the advancement of his profession."[40]

Contemporary with Vesalius was Michael Servetus, a theological disputant, a so called Unitarian and Anatomist. In 1553 he published anonomously "The Restitution of Christianity" which he dedicated "To the Glory of God". A lesson on pulmonary circulation was included as a part of the thesis since he considered knowing the spirit of God was to know the spirit of man. He was a literalist seizing upon quotations which associated blood with life and that it was the heart of Adam that God breathed the spirit. He believed the blood to carry the spirit was derived from the liver. He understood the modern concept of anastomoses and the structure of the heart and attributed the generation of spirit to occur in the lungs. He stated:

> "The vital spirit is generated through the mingling in the lungs of the inspired air with the subtle blood which is communicated to it from the right ventricle to the left. This communication does not, however, take place, as is generally believed, through the septum of the heart, but by a remarkable device the *subtle blood is driven from the right ventricle through a long passage in the lungs*. It is prepared by the lungs, and is there rendered lighter in colour, and from the artery-like vein (pulmonary artery) it is poured into the vein-like artery (pulmonary vein). Then in the vein-like artery (pulmonary vein) it is mixed with the inspired air, and by expiration is cleansed from its fumes. So at length completely mingled (with the air) it is drawn in by the left ventricle during its expansion, ready to become vital spirit."[41]

In 1546, the Restitution was in manuscript form which was shared with Calvin in Geneva who was disturbed by the theological concepts including unitarianism. Calvin dictated that it was not to be published and did not return the manuscript. A revision by Servetus was nevertheless published in 1553. He was apprehended, tried and found guilty of heresy, and burned at the stake along with copies of the book. Three copies are known to exist. The death sentence was confirmed by the Catholic ecclesiastical tribunal at Viene and he was burned in effigy nearly a year and one-half later.[42]

Realdus Columbus, a student of Vesalius, succeeded him in teaching anatomy at the University of Padua. He was critical of Vesalius, again typical of master and student. He accused Vesalius of having used the ox rather than the human in dissections. Evidence would indicate that if it were not man, Vesalius described the dog. Columbus published posthumously in 1559 on the heartbeat and arterial activity. It is unlikely that Columbus was familiar with the work of Servetus in 1553 even though both descriptions of the lesser circulation were similar. The concepts of Columbus were well known to Harvey who later studied at the University of Padua.

The posthumous writing of Columbus, 1559, concerning vivisection correlated cardiac systole with arterial expansion, and cardiac diastole with arterial contraction, not greatly dissimilar from concepts of the ancient Egyptians but significantly different from the Greeks. Columbus demonstrated that blood passes from the lung into the pulmonary vein.[43]

Fabricius taught anatomy at the University of Padua during which time he published "On the Valves of the Veins" in 1574. He noted that the valves were open towards the heart and closed away from the heart. Fabricius notes also that swelling occurs when veins of the arm are bound. He failed to understand the function of valves, suggesting that they delayed blood passing in the extremities. In a publication "On Respiration and its Mechanisms", 1603, Fabricius retains unaltered the physiological explanation of Galen and Aristotle.

Harvey broke from the past as did Vesalius who set a pattern at the University of Padua. Harvey accomplished for physiology what Vesalius did for anatomy. He observed, measured, experimented, made comparative studies, and developed analogies to aid functional explanation. He matriculated at the University of Padua in 1597 and was graduated with the M.D. degree in 1602. Upon his return to England he was made a lecturer at the College of Physicians in 1615. His initial series of lecture notes still exist and are a mixture of scribbles, Latin and English. In these first notes, he outlined the essential concepts presented in "An Anatomical Dissertation Concerning the Motion of the Heart and Blood in Animals" published in Frankfurt, Germany in 1628.[44]

Harvey published the small volume in Frankfurt. Was he fearful of criticism and retribution in breaking with the past? Perhaps so, in that Harvey revered the works of Galen and Aristotle and knew well the penalties associated with heresy. As others, he was careful to dedicate the manuscript to "The Most Illustrious and Indomitable Prince Charles, King of Great Britain, France, and Ireland, defender of the Faith".[45] A secondary dedication was made to Doctor Argent, President of the Royal College of Physicians and to other learned physicians. The dedications may suggest that he was at least apprehensive. Although his observations and reasoning were meticulous, the book was filled with printer's errors.

Proof of lesser and greater circulation was described by Harvey in 1628, but the proof was most difficult to understand because of brevity, awkward sentences in Latin, and faulty proofing.

He described the heart action as that occurring in any muscle and when the ventricles contract in cold blooded organisms they become light in color and when expanded, darker in color. The contractions of the heart are simultaneous with and the cause of the expansion of the arteries, as felt at the pulse. This conclusion was confirmed by the spurting of blood in arteries at the moments of ventricular contractions, not ventricular expansion. The auricles perform a similar function as do the ventricles. If the tip of the ventricle is removed there is a corresponding spurt of blood from the tip of the ventricle when the auricles contract. Also, the auricle beat precedes the ventricle, therefore the same blood that is driven by the auricle into the ventricle is subsequently driven into the arteries by the contraction of the ventricles, and once in the great arteries the blood cannot come back by the same path. Harvey also describes the action of the heart valves which insure the blood moves in only one direction, and continuously on.

Harvey uses reason and counting as a most powerful tool in his explanation. If the pulse beats 72 times per minute forcing two ounces at each beat, in one hour the ventricle will throw into the aorta no less than 72 x 60 x 2 = 8,640 ozs. = 38 stone 8 lb. i.e., three times the weight of a heavy man. Where does this blood come from, where does it go? The earlier concept that it is compounded in the liver becomes absurd. To this, Harvey adds that if an artery is cut, the animal bleeds to death due to the fact that blood being lost does not reach the vein and heart to be repurified.[46]

Harvey asked two questions. How does blood get from the venous system to the left side of the heart and how does it get from the artery to the veins? He demonstrated that blood flows in circles. Blood leaves the right side of the heart only through the pulmonary artery and cannot return via that vessel to the heart because of the valves. Harvey never freed himself from the influence of Galen as he gives credit to the ancient one, the divine man, that blood passed from heart to lungs and to the heart via pulmonary vein and pulmonary artery. Harvey took pride in his conservative viewpoint but it is extremely difficult to decipher this concept from Galen.

Harvey's primary thesis summarized in his own words are:

> "I began to think whether there might not be a *movement, as it were, in a circle,* and this I afterward found to be the case. I saw that the blood, forced by the action of the left ventricle into the artery, was sent out to the body at large. In like manner it is sent to the lungs, impelled there by the right ventricle into the arterial vein (pulmonary artery)."[47]
>
> "The true cause is that there is no passage to the arteries save through lungs and heart. When an animal ceases to breathe and the lungs move, the blood in the arterial vein (pulmonary artery) no longer passes there from the venal artery (pulmonary vein) and thence to the left ventricle. But the heart not ceasing to act as soon as the lungs, but surviving them and continuing to pulsate for a while, the left ventricle and the arteries continue to distribute their blood to the body at large, and to send it into the veins."[48]

Crucial experiments were performed by Harvey on serpents. In these he demonstrated that if the vena cava is compressed with forceps, the vein becomes empty towards the heart, the heart becomes smaller and a slower beat occurs. Once this obstruction is removed the size and normal heartbeat is restored. Opposite results are obtained when the aorta is compressed. Similarly bandaging the arm of man above the elbow, Harvey was able to compress either the vein alone or arteries together with veins and observe reactions similar to the vessels in serpents. The position of the valves of veins were located via fissures and their function was described as by his former professor, Fabricius. With the work of Harvey in 1628, the basic concepts of heart and circulation were expressed for the future.

Deriving the nature of man from the lives of individuals and the events contributing to our knowledge and understanding of heart and circulation is not a simple task. The man of today and yesterday appears to be much the same. Observing and judging the past possesses advantages over making judgments concerning those presently living. The universality of scientific agreement concerning knowledge of heart and circulation allows one an objectivity difficult to obtain in the complex science of the present. The alleged pressures, peer and otherwise, of the present are an inescapable part of man's nature. Among other things, is a system intimately interwoven with the environment, past and present, physical and spiritual, and educational and social. One is constantly confronted with the choices of what to retain from the past and what to accept of the newest creations whether ideas or ideals.

Man is an integral product of the environment. The assumptions and concepts, conscious or subconscious, can not be separated from the world in which one lives including the physical as well as the knowledge of ideas and dogma of the day. As the physical environments of Mesopotamia and Egypt influenced concepts of the universe, gods, and science, so have the facts and errors of one generation limited conceptual developments of following generations.

Man is an observer, describer, compiler, collator, doer, and conserver of the past. This is well illustrated in the life of Imhotep, Grand Vizar to King Zoser and through the scribes of papyri in Egypt. Imhotep was indeed a doer. He designed and directed the building of the step pyramid and must have been proficient in medicine as well as many other areas. The fact of a mortal achieving full God stature, as God of medicine, adds validity to the concept. Even though Imhotep may have been objective and creative, conservatism to the point of dogmatism developed as evidenced in the Smith Papyri. In fact, the wish to preserve the past was so great that authority was utilized to maintain the practice of the past through legalistic mechanisms.

What does one conserve from the past and what does one accept of the new? It is an eternal dilemma which man faces. Too often man clings to the erroneous concepts of predecessors as in the case of so many who followed Hippocrates, Aristotle, and Galen. European workers did not break with the past because of a desire for authority within themselves or pressures from society. The three

venerated scholars were nevertheless theorizers and model builders. They were rational to the degree that their models fit certain basic assumptions, many of which were incorrect. Galen's concepts of anatomy and physiology of circulation including natural, vital, and animal spirits must have seemed rational since they remained the same for nearly 1300 years or it may be that dogma simply overruled rationality.

The path that knowledge traveled from the past to reach the present cannot be separated from the nature of man. The dispersal of the writings of the Greek medics is built upon intolerance and an unyielding stubborness. Nestorius and his followers were banished to Persia following the synod of Ephesus 431 A.D. because of differences in viewpoint. Nestorius held that Mary should not be called "Mother of God" since she was human. Because of the great value which the Arab placed upon learning and exchanges between the Nestorians and Arabs, the knowledge of Galen and others was to be reintroduced to Western Europe. Although the Moors greatly valued knowledge and wisdom, the Christian was loath to accept the same from the Arab. The Arabic manuscripts were shunned. The Christian returned to the Greek originals to insure no contamination from the Muslims. This culminated in the Renaissance which stimulated in science the reawakening of curiosity, inquisitiveness, and an independence.

Vesalius exemplified these characteristics and made a break with the past in studying nature not books, as well as developing visual methods for communicating anatomical information. He nevertheless failed to discard the Galenic dogma concerning the physiology of heart and circulation. He was able to overcome the pressure of his contemporaries, Guinther and Sylvius, and to transcend the anatomical tenets of Galen.

The saga of Vesalius also illustrates characteristics of destructiveness, envy, pride, curiosity, and love of money. The Vesalian plates were duplicated by numerous individuals and publishers with a profit motive. The plates used in the "Fabrica" were reproduced by Dr. Cushing in 1934 because of historical interests. The plates were shortly destroyed during the bombings of Munich by U.S. planes during World War II.

As Nestorius held to his beliefs, so did Servetus. He held a unitarian concept of God to include the Father, the Son, and the Holy Spirit. This was in conflict with Calvin, the reformationist. He nevertheless published his unitarian concepts and in the text included a near description of the lesser circulation. Servetus had been warned in 1546, seven years before not to publish his concepts and was reported to have said, "This manuscript will be the death of me." Notwithstanding, he revised and published the book anonymously. He was taken into custody, tried, and found guilty of heresy. The penalty was burning at the stake.

The Inquisition placed fear into the hearts of many persons. This may well be the explanation of why Harvey published in Frankfurt, Germany and dedicated the book to Prince Charles and to greats in the medical profession. Was this an indication that he was fearful of breaking with the past?

The values of the past which are found to be worth conserving, often became incorporated in religion. For example, the concepts of Aristotle and Galen became intertwined with the religious concepts of Christianity and were defended by the Church in association with creed. How often are independent concepts linked together to the detriment of both, and is man incapable of rational separation or integration as the case may be?

Harvey demonstrated that man is rational. This is a bold statement after observing the irrationality which man demonstrated over nearly 4500 years in the development of our understanding of the heart and vessels in the lesser and greater circulation. Nevertheless, Harvey's work is true evidence of rationality. He was an observer, a measurer, one who reasons, and an experimenter.

One would like to believe that man is curious, an observer, analyzer, model builder, rational, and can be objective enough to break the barrier of environmental biases and pressures of peers. Man, nevertheless, is also inclined to possess false pride, authoritarian characteristics, subjective biases, and tenacity which may or may not be valuable in the evolution of ideas and society. All of this is demonstrated in persons associated with the history of ideas on heart and circulation. Can man unlock minds so that objectivity joins with empathy to insure man's use of her/his fullest potentials?

REFERENCES

1. SARTON, George, *A History of Science – Ancient Science Through the Golden Age of Greece,* Harvard University Press, Cambridge, 1952, pp. 19-99.
2. Ibid., pp. 57-99.
3. Ibid., pp. 90-94.
4. Produced by Paul Hamlyn Limited, *Egyptian Mythology,* Tudor Publishing Company, New York, 1965, pp. 9-38.
5. BREASTED, James Henry, *The Edwin Smith Surgical Papyrus, Vol. I,* The University of Chicago Press, 1930, pp. 7-165.
6. BROOKS, C.E.P., *The Evolution of Climate,* Ernest Benn Limited, London, 1922.
7. Ibid.
8. HURRY, Jamieson B., *Imhotep – The Vizier and Physician of King Zoser, Afterwards The Egyptian God of Medicine,* Oxford University Press, 2nd Edition, 1928, pp. 5-228.
9. Ibid., Breasted, pp. 165-167.
10. Ibid., Sarton, p. 44.
11. Ibid., Breasted, p. 47.
12. Ibid., Sarton, pp. 49-50.
13. Ibid., pp. 384-391.
14. SINGER, Charles, *A Short History of Anatomy and Physiology from the Greeks to Harvey,* Dover Publications, 1957, p. 14.
15. JONES, W.H.S., *Hippocrates, Vol. II, The Loeb Classical Library,* William Heinemann, London, 1923, p. XVI.
16. Ibid., pp. 299-301.
17. JONES, W.H.S., *Hippocrates, Vol. II, The Loeb Classical Library,* William Heinemann, London, 1923, pp. 179-181.
18. Ibid., Singer, 1957, p. 27.
19. PECK, A.L., *Aristotle – Generation of Animals. The Loeb Classical Library,* Harvard University Press, 1943, pp. 233-250.
20. PECK, A.L., Aristotle — *Parts of Animals,* William Heinemann, London, 1937, p. XXXVIII.
21. OGLE, William, *The Works of Aristotle Translated into English, Vol. V.,* Oxford at the Clarendon Press, 1912, pp. 667b-668a.
22. Ibid., p. 665a.
23. Ibid., pp. 667a-667b.
24. Ibid., Singer, 1957, pp. 28-29.
25. DAMPIER, Sir William Cecil, *A History of Science,* Cambridge, At the University Press, 1952, p. 46.
26. Ibid., Singer, 1957, pp. 46-52.
27. BROCK, A.J., *Galen on the Natural Faculties,* William Heinemann, London, 1928, p. 167-195.
28. Ibid., pp. 91.
29. Ibid., pp. 319-331.
30. Medicine and Pharmacy — Ancient Jews and Arabs, Schering Corporation, Bloomfield, New Jersey, 1957.
31. Ibid.
32. SINGER, Charles, *A Short History of Scientific Ideas to 1900,* Oxford University Press, New York and London, 1959, p. 162.
33. MacCURDY, Edward, *The Notebooks of Leonardo Da Vinci,* George Braziller, New York, 1958.
34. SINGER, Charles, *The Discovery of the Circulation of the Blood,* Wm. Dawson & Sons Ltd., London, 1956, p. 21.
35. SAUNDERS, J.B. and O'Malley, Charles P., *The Illustrations from the Works of Andreas Vesalius of Brussels,* The World Publishing Company,

Cleveland and New York, 1950, pp. 12-13.
36. Ibid., Singer, 1956, pp. 23-28.
37. Ibid., Singer, 1956, p. 26.
38. Ibid., Saunders, p. 30.
39. Ibid., pp. 37-38.
40. Ibid., pp. 33-34.
41. Ibid., Singer, 1956, pp. 33-34
42. Ibid., pp. 29-36.
43. Ibid., Singer, 1957, p. 142.
44. Ibid., Singer, 1956, pp. 42-49.
45. HARVEY, William, *The Motion of the Heart and Blood,* Henry Regnery Company, Chicago, Illinois, 1949, p. 1.
46. Ibid., pp. 50-68.
47. Ibid., p. 56.
48. Ibid., Singer, 1957, pp. 180-181.