

WILLIAM HARVEY, M.D.:
MODERN OR ANCIENT SCIENTIST?

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William Harvey was born in England in 1578 and died in 1657. He received his grammar school education at the famous King's School in Canterbury. In 1593 he entered Caius College, Cambridge, and received his B.A. degree in 1597. In this period, it was not unusual for English Protestants interested in a scientific education to seek it in a continental Catholic university. Harvey chose the *Universitas Juristarum*, the more influential of the two universities which constituted the University of Padua in Italy and which had been attended by Thomas Linacre and John Caius, and where, incidentally, the Dominican priests were associated with University functions.

Competency in the traditional studies of the day was characteristic of William Harvey's intellectual development. The degree of Doctor of Physic was awarded to Harvey in 1602 with the unusual testimonial that "he had conducted himself so wonderfully well in the examination, and had shown such skill, memory, and learning that he had far surpassed even the great hopes which his examiners had formed of him. They decided therefore that he was skilled, expert, and most efficiently qualified both in arts and medicine, and to this they

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put their hands, unanimously, willingly, with complete agreement, and unhesitatingly."¹

In 1616 he gave his first Lumleian lectures in surgery at the Royal College of Physicians in London. The manuscript notes of his first course of lectures, the *Prelectiones*, are preserved and have been reproduced in facsimile and transcript.² In these lectures he first enunciates the circulation of the blood.

He waited for 12 years, however, until 1628, before he published his great work entitled, *An Anatomical Exercise on the Motion of the Heart and Blood in Animals*. In this classic he formally demonstrated the true nature of the heart and that the motion of the blood was circular. This work is relatively short and takes up 86 pages in the standard English edition of his collected works.³ In 1648 Harvey's demonstration was attacked in a treatise published by Dr. Jean Riolan of Paris. Harvey answered his critic in two lengthy letters published in Cambridge in 1649.

Harvey's second famous work, *Anatomical Exercises on the Generation of Animals*, which is over five times the length of the first, appeared in publication in 1651 through the solicitation and under the direction of Dr. George Ent, a well-known physician of the period.

In his personal life and professional career Harvey had a wide circle of acquaintances and friends. Though it is not certain whether he knew Galileo who was a fellow student

¹ D'Arcy Powers, *William Harvey* (London, 1897), pp. 26-27.

² William Harvey, *Prelectiones Anatomiae Universalis* (London: J. & A. Churchill, 1886).

³ *The Works of William Harvey, M. D.* (London: Printed for the Sydenham Society, 1847): Translated from the Latin by Robert Willis, M. D. It includes *An Anatomical Exercise on the Motion of the Heart and Blood in Animals*; *The First Anatomical Exercise on the Circulation of the Blood to John Riolan*; *A Second Exercise to John Riolan, in Which many Objections to the Circulation of the Blood are Refuted*; *Anatomical Exercises on the Generation of Animals, to Which are Added, Essays on Parturition, On the Membranes and Fluids of the Uterus, and on Conception*; and miscellaneous items (Harvey's will, autopsy of Thomas Parr and nine short letters).

at Padua, he knew most of the leading contemporaries of his day. This included Boyle, Hooke, Hobbes, Dryden, Cowley, Descartes, Gilbert, Wren, Bacon and others, in addition to prominent physicians and anatomists.

Harvey was extremely well-read and made reference in his lectures and writings to the Greek philosophers and scientists of the fourth through the seventh centuries, B. C., to many Greek writers of the Christian era, to numerous Latin writers including many of the poets, to Albert the Great, and to numerous Renaissance men of the fifteenth and sixteenth centuries. In all, he made reference to approximately 100 authors in his writings. In particular, he had a comprehensive working knowledge of Aristotle, as well as Aristotle's commentators, Avicenna and Averroes. According to one Harvian lecturer, Harvey refers to Aristotle 269 times.⁴ References are made to Aristotle's logical, physical, biological and metaphysical works. It is clear that Harvey's superior intellectual formation through ancient authors—the Great Books of his day—proved no block to his momentous contribution to the future.

Finally, it is pertinent to note his basic religious belief as it relates to his scientific work. On the title page of his *Prelectiones* he prefixes from his favorite poet, Virgil, the motto "Stat Jove principium, Musæ, Jovis omnia plena." Over thirty years later he explicates this motto in Exercise 54 of the *Generation of Animals*:

... in the same way, as in the greater world, we are told that 'All things are full of Jove,' so in the slender body of the pullet, and in every one of its actions, does the finger of God or nature no less obviously appear . . . We acknowledge God, the supreme and omnipotent creator, to be present in the production of all animals, and to point, as it were, with a finger to his existence in his works, the parents being in

⁴ D. E. Fraser-Harris, "William Harvey's Knowledge of Literature Classical, Mediæval, Renaissance and Contemporary." *Proceedings of the Royal Society of Medicine*, XXVII (1934), 195-199.

every case but as instruments in his hand. In the generation of the pullet from the egg all things are indeed contrived and ordered with singular providence, divine wisdom, and most admirable and incomprehensible skill. And to none can these attributes be referred save to the Almighty, first cause of all things, by whatever name this has been designated,—the Divine Mind by Aristotle; the Soul of the Universe by Plato; the *Natura Naturans* by others; Saturn and Jove by the ancient Greeks and Romans; by ourselves, and as is seeming in these days, the Creator and Father of all that is in heaven and earth, on whom animals depend for their being, and at whose will and pleasure all things are and were engendered.⁵

In his last will and testament he states, "I doe most humbly render my soule to Him that gave it and to my blessed Lord and Savior Christ Jesus and my bodie to the Earth to be buried at the discretion of my executor . . ."⁶

Before we can determine whether Harvey was a modern or an ancient scientist, we must first know him as the great scientist he was. The twentieth century scientist, more narrowly educated for the most part, pays only lip service to Harvey's greatness. We can say about most contemporary scientists concerning Harvey, what Galen said about his contemporaries concerning Hippocrates: they admire him, but do not read him; when they read him, they do not understand him; when they understand him, they fail to put into practice what he has taught.⁷

Characterizing the lip service of contemporary biologists and physicians is the unexpressed and hidden belief—a reflection of our current pride and prejudice—that what Harvey enunciated was so obvious, so easily discoverable, so easily observable by all beginning students, that the uniqueness of

⁵ Harvey, *Works*, ed. cit., pp. 401-402.

⁶ *Ibid.*, p. lxxxix.

⁷ Galen, *Si quis optimus medicus est, eundem esse philosophum*, among *Isagogici libri*, in *Opera omnia*, 9th ed. (Venetiis, apud Juntas: 1625), fol. 6r-v.

his discovery was principally his ability to liberate himself from the yoke of ancient traditions, thought and terminology—from dark ages, sterile scholasticism, authoritarianism and philosophical encroachments—sufficiently to see what in itself was so patently observable. Even then, Harvey's liberation was incomplete according to many historians.

Part of the modern difficulty stems from not reading him. Typical of the difficulty is the belief that Harvey's discovery of the circulation of the blood was a sense observation rather than a conclusion resulting from reason utilizing inductions from sense observations, as principles or propositions in a demonstration.

Part of the modern difficulty also stems from those who have read him, but not well. Many such readers have failed to appreciate the complexity of obtaining a new and true conclusion within a context in which the old conclusion was a plausible part of an integrated body of knowledge. The modern reader, by reading Harvey retrospectively as if his work were merely the beginning of what came afterwards, tends to miss what is more basic: that Harvey's discovery like most scientific discoveries results from a scientific methodology which is related to one's education, philosophy, habits, and experience as a scientist. Rather than relate Harvey's discovery to the past out of which it emerged, the modern reader acts as if it sprang *de novo* from a pair of eyes newly able to observe through the Renaissance liberation from the medieval blinders that enveloped this age.

The following comments are characteristic of those made by critics who dissociate Harvey's demonstration from the tradition of his predecessors. Harvey "with one blow demolished the structure, compounded of metaphysics, far-fetched analogy, and mysterious 'principles' and 'spirits,' which constitute the method of medieval biology." Harvey's method was characterized "by the rigid exclusion of mysterious forces

and agencies.”⁸ “Harvey . . . never entirely emerged from the mystifying language of his contemporaries, and even regarded himself as a loyal Aristotelian, but he builded better than he knew.”⁹

The contemporary translator of the most widely read version of Harvey’s classic on *The Motions of the Heart and the Blood*—an outstanding scientist in his own right—has this to say:

In his more scientific passages, Harvey is remarkably terse and ‘snappy,’ in the current style. In his philosophical discussions he becomes vague and his sentences grow beyond control . . . At the same time, he tried to complete his demonstrations by metaphysical arguments based on the traditional teleology. This was the antithesis of the method by which he had achieved such brilliant success in the preceding chapters . . . There is a good discussion of the comparative and embryological aspects of the subject, and then a peculiar use of the traditional authority of Galen as evidence. One may find almost all kinds of logic in Harvey.¹⁰

If these comments truly delineate Harvey’s contribution, we are faced with the following paradox: Harvey, who was educated superbly in the traditional education of his time, who considered himself a loyal traditionalist in science and philosophy, and who utilized philosophical arguments based on the established teleology of the day, all of which are alleged to be antithetical to scientific advance, was also the same Harvey who produced a brilliant, original and revolutionary work of science which laid the groundwork for modern physiology and medicine.

To explicate this paradox, it seems incumbent upon us to keep open the possibility that the fruit of his labors bears a

⁸ Franklin Fearing, *Reflex Action* (Baltimore: William & Wilkins, 1930), p. 29.

⁹ A. Wolf, *A History of Science, Technology and Philosophy in the 16th and 17th Centuries* (London, 1935), p. 415.

¹⁰ Chauncey D. Leake, *An English Translation with Annotations of De Motu Cordis* (Springfield: Charles C. Thomas, 1931), Translator’s Preface.

direct relationship to the tree that bore it and the intellectual soil that nourished it. That Harvey was well educated, and respected and utilized his learning heightens this possibility. Furthermore, Harvey was one of the few successful investigators in the history of science who actually thought about and wrote on scientific methodology, and whose thinking on this permits us to measure his reciprocal accomplishments.

It is ironic, in contrast, that the modern scientist looks upon Harvey’s contemporary, Francis Bacon, as the father of modern science, despite history’s testimony that no scientific discovery can be attributed to the Baconian method. It is particularly ironic since there is no indication that Bacon even recognized Harvey’s striking contribution. A leading Bacon scholar writes, “The probability is that . . . he regarded the theory as hardly worthy of serious discussion.”¹¹ Contrariwise, Harvey, who was Bacon’s personal physician, said of him derogatorily that, although he enjoyed his wit and style, Bacon “writes philosophy like a Lord Chancellor.”¹²

The alternative of the hypothesis that Harvey’s contribution flowed from his past is a dismal one. It forces one to conclude that Harvey was a schizophrenic, a duality—a sterile scholastic and a fertile scientist—rather than a unity; and that his “brilliant success” was accomplished by “almost all kinds of logic.” We can best seek to understand the paradox of Harvey by seeing whether Harvey, in his turn, merely paid lip service to Aristotle who dominated the medieval period or actually utilized him the way one scientist utilizes another.

To show that Harvey was a genuine disciple of Aristotle, four illustrations of how Harvey utilizes and follows Aristotle are presented below. The first summarizes Harvey’s essay on scientific methodology and shows Harvey’s adherence to Aristotle’s *Organon*. The second illustration deals with the great scientific controversy in embryology as to whether animals

¹¹ Thomas Fowler, *Bacon’s Novum Organum*, Edited with Introduction, Notes, etc., 2nd ed. (Oxford, 1889) p. 28.

¹² John Aubrey, *Lives of Eminent Men* (London, 1813), vol. 2, p. 381.

HARVEY: MODERN OR ANCIENT SCIENTIST?

are preformed or epigenetically unfold themselves in development. It shows Harvey decisively siding with Aristotle. The third reviews the actual references Harvey makes to Aristotle in *The Motion of the Heart and Blood* and shows that Aristotle abets rather than hinders Harvey's ultimate demonstration. One of these references points up the need for a modern reader to have a knowledge of Aristotle's works if he is to have an adequate understanding of Aristotle's contribution to Harvey's discovery and demonstration. The final analysis shows that Harvey's demonstration of the true motion of the heart and blood is a classic Aristotelian demonstration, and illustrates that Harvey follows in practice what he adheres to in theory.

AN ESSAY ON THE SCIENTIFIC METHOD

Harvey's essay on the scientific method is the preface to his work, *Anatomical Exercises on the Generation of Animals*, which was published 23 years after the publication of his classic, *The Motion of the Heart and Blood*, when Harvey was 73 years old. It is a product of his later years and reflects the permanency of the position he held. It is not intended as a complete exposition of the scientific method but only as a preface to his work on generation. The preface¹³ consists of 27 paragraphs and has three headings: 'Of the Mode and Order of Acquiring Knowledge'; 'Of the Former, Calling to Mind Aristotle'; and 'Of the Method to be Turned to in the Knowledge of Generation.' The following is a paragraph analysis of this essay.

PREFACE

Anatomical Exercises on the Generation of Animals

A. Introduction

1. Causes of writing (par. 1)
2. Present opinions concerning generation

¹³ Harvey, *Works*, ed. cit., pp. 151-167.

Herbert A. Ratner, M.D.

- a. Of Galen and physicians (par. 2)
- b. Of Aristotle and philosophers (par. 3)
3. Concerning the falsity of these opinions (par. 4)
4. Further exposition of final causes of writing (par. 5)
5. Concerning the method employed
 - a. That it is difficult (par. 6)
 - b. That its difficulty should not be a deterrent (par. 7)
- B. Of the Mode and Order of Acquiring Knowledge (*cognitio*)
 1. That there can be only one road to science (*scientia*) (par. 8)
 2. Explication of the road
 - a. Relation of sense to universals (par. 9)
 - b. As expressed by Seneca and expounded by Harvey (par. 10)
 3. The importance of sense for judgment (par. 11)
 4. Why it was thought fit to present this by way of introduction (par. 12)
- C. Of the Former, Calling to Mind Aristotle
 1. That knowledge (*cognitio*) is not innate but acquired (par. 13)
 2. Whence and how we come to know (par. 14)
 3. Resolution by Aristotle of the difficulty involved (par. 15)
 4. The order of knowledge in any art or science (par. 16)
 5. Conclusions as to the relation of perfect knowledge to sense (par. 17)
 6. Conclusions as restated by Aristotle (par. 18)
 7. Explication of preceding passage from Aristotle (par. 19)
 8. Concluding advice to the reader concerning testimony of the senses (par. 20)
- D. Of the Method to be Turned to in the Knowledge (*cognitio*) of Generation
 1. The method proposed (par. 21)

HARVEY: MODERN OR ANCIENT SCIENTIST?

2. This method compared to that of Fabricius (par. 22)
3. What will be set forth according to the method
 - a. in respect to formal content (par. 23)
 - b. in respect to material content (par. 24 and 25)
4. What will be inferred from that set forth and the difficulties involved (par. 26)
5. Conclusion (par. 27)

Under 'Of the Mode and Order of Acquiring Knowledge' (Section B) Harvey rests his scientific method solidly on Aristotle.

Harvey juxtaposes two key Aristotelian texts which "at first blush may seem contradictory." The one text emphasizes that there is but one road to scientific knowledge, i. e., to the reasoned fact, namely, a syllogistic process by which we move from universals to particulars. He states that we "start from the things which are more knowable and clearer to us and proceed towards those which are clearer and more knowable by nature" (*Physics*, Bk. I, Ch. 1, 184 a 16-18). The second text stresses the inductive and prior knowledge obtained from sense data for "that is more perspicuous to us which is based on induction . . . whence it is advisable from singulars to pass to universals" (*Post. Anal.*, Bk. II, Ch. 13).

In the following section entitled "Of the same matters, according to Aristotle," Harvey elaborates Bk. I, Ch. 1, of the *Posterior Analytics*, which states that all doctrine and intellectual discipline, including the two forms of reasoning, the syllogistic and the inductive, is acquired from antecedent knowledge, none of which is innate. He then uses a passage from Aristotle to explicate this antecedent knowledge, which arises in sense, is retained by memory, and which, when repeated, results in experience, from which in turn is derived the beginnings of art and science. He again quotes a more "elegant" passage of Aristotle to the same effect (*Metaphysics*, Bk. I, Ch. 1).

Harvey goes on to say that "By this Aristotle plainly tells us that no one can truly be entitled prudent or truly knowl-

Herbert A. Ratner, M.D.

edgeable (*scientem vere*), who does not of his own proper experience, i. e., from repeated memory, frequent perception by sense, and diligent observation, know that a thing is so in fact. Without these, indeed, we only imagine or believe, and such knowledge (*scientia*) is rather to be accounted as belonging to others than to us." Harvey concludes this section with a passage from one of Aristotle's research works:

That the generation of bees takes place in this way appears both from reason and from those things that are seen to occur in their kind. Still all the incidents have not yet been sufficiently examined. And when the investigation shall be complete, then will sense be rather to be trusted than reason; reason, however, will also deserve credit, if the things demonstrated accord with the things that are perceived by sense (*Gen. An.*, Bk. III, Ch. 10, 760 b 28-33).

EPIGENESIS VS. PREFORMATION

A textbook in a required biological course in a leading university in the United States makes reference to the "preformationists" of approximately 300 years ago who thought that the "embryo was preformed in miniature in the microscopic spermatozoon and had but to unfold as the rosebud into the rose" and to the "ovicists," who "postulated a preformed embryo in the egg that needed only a slight stimulus to make it grow and develop." In contrast the authors cite the modern scientist who through "the employment of the scientific method of repeated and careful observations and deductions has made it clear to us that the embryo is not preformed in its final form. . ." but that "the various parts of the new individual are gradually formed and undergo a tremendous modification from their first appearance up to their final state."¹⁴

¹⁴ *Syllabus, Introductory General Course in the Biological Sciences*, edited by Merle C. Coulter. Seventh edition. (University of Chicago, 1937), p. 104.

These same authors could have equally and more accurately written: Over 2300 years ago, Aristotle, by employing the scientific method of repeated careful observation as his basis for inference, made it clear to anybody and everybody who would read, that the preformationist account of embryological development was impossible and the epigenetic account necessary. He asked, "How, then, does it [the embryo] make the other parts?"; he answered, "Either all the parts, as heart, lung, liver, eyes and all the rest, come into being *together* or in *succession* . . ." "That the former is not the fact is plain even to the sense, for some of the parts are clearly visible as already existing in the embryo while others are not; that it is not because of their being too small that they are not visible is clear, for the lung is of greater size than the heart, and yet appears later than the heart in the original development" (734 a 17 ff.). William Harvey, 2000 years later, who did read, came out with experimental confirmation and enrichment of the same view. He states in his *Generation of Animals*:

Now it appears clearly from my research that the generation of the chick from the egg is the result of epigenesis (Exercise 45). And first, since it is certain that the chick is produced by epigenesis, i. e. the addition of parts successively, we shall investigate what part may be observed before any of the rest are erected, and what may be observed in this mode of generation. What Aristotle says of generation . . . is confirmed and made manifest by all that passes in the egg, viz. that all the parts are not made simultaneously, but ordered one after the other, and that there first exists a genital particle, by the power of which as from a principle, all the other parts proceed (Exercise 51).

Curiously enough, however, the preformationist theory came into prominence again—curiously, because it did so just following the discovery of the microscope and the aberrations that passed for facts that resulted thereof. But the epigenetic theory has since been restored and given great richness of detail in support.

It can be seen that Harvey in following Aristotle reaffirmed a truth that was lost during the late Renaissance, but rediscovered in modern times. That it was one of Harvey's prime objects in writing *The Generation of Animals* to defend and establish the opinion already held by Aristotle has been expressed by Thomas H. Huxley.¹⁵

REFERENCES TO ARISTOTLE

In *The Motion of the Heart and Blood*, which is more a demonstrative work than a descriptive one, 22 references to Aristotle are made. In only one instance does Harvey clearly disagree with Aristotle. In this instance Harvey writes, "Hence, since the veins are the conduits and vessels that transport the blood, they are of two kinds, the vasa and the aorta; and this not by reason of sides (as in Aristotle), but office (*officio*), and not, as is commonly said, by constitution, for in many animals, as I have said, the vein does not differ from the artery in the thickness of its tunic, but is distinct by duties (*munere*) and use (*usu*)."¹⁶ It should be noted that the disagreement is not based on Aristotle's anatomical observations, which D'Arcy W. Thompson states to be "remarkable for its wealth of detail [and] for its great accuracy in many particulars . . . , "but rather on physiological considerations, viz. on its office, duty and use."¹⁷

In another reference Harvey discusses an anatomical observation which "probably led Aristotle to consider this ven-

¹⁵ Thomas H. Huxley, "Evolution in Biology," in *Darwiniana Essays* (New York, 1898), p. 193.

¹⁶ Harvey, *Works*, ed. cit., ch. 8, p. 47. The English translations of Harvey appearing in this article are mostly adapted from the Willis translation following consultation with the original Latin. Where possible key Latin terms which have English equivalents are substituted. The Latin text consulted is the edition of Bernardus Albinus (Johannes van Kerckhem, 1737).

¹⁷ Aristotle, *History of Animals*, Translated by D'Arcy W. Thompson (Oxford, 1910). 513 a 35, fn. 3.

trickle double, divided transversely."¹⁸ Other than these, the remaining references to Aristotle are utilized to help Harvey make or confirm a particular point.

Of particular interest is the reference to Aristotle where Harvey enunciates the possibility of "a motion, as it were, in a circle . . . which motion we may be allowed to call circular, in the same way as Aristotle says that the air and the rain emulate the circular motion of the superior bodies; for the moist earth, warmed by the sun, evaporates; the vapors drawn upwards are condensed, and descending in the form of rain, moisten the earth again; and by this arrangement are generations of living things produced; and in like manner too are tempests and meteors engendered by the circular motion, and by the approach and recession of the sun."¹⁹

In connection with this passage, a recent translator and a scientist of renown, who is now President of the American Association for the Advancement of Science, is able to observe only that "Harvey seems never to have heard of [the] studies [of] Copernicus, J. Kepler, and G. Galilei [which] had overthrown the Ptolemaic theory of the circular motion of the stars in the heavenly spheres . . ."²⁰

But to think of this reference as a poetic metaphor to which scientific error can be attached rather than as a striking evocation of Aristotle's analysis of locomotion misses the precision for the poetry in the analogy.

Here one has to know certain passages from Aristotle's works, *Post. Anal.*, Bk. II, Ch. 12, *Physics*, Bk. VIII, Ch. 8 & 9, *Gen. and Cor.*, Bk. II, Ch. 11, *Meteorology*, Bk. II, Ch. 4, among others. Aristotle divides natural locomotion into circular and rectilinear. Only circular motion can be single and continuous. When Harvey concludes in Ch. 14 that "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

¹⁸ Harvey, *Works*, ed. cit., ch. 17, p. 79.

¹⁹ *Ibid.*, ch. 8, p. 46

²⁰ Chauncey D. Leake, *op. cit.*, ch. 8, p. 70, fn. 1.

(*perpetuo*) motion . . ." he is talking in a strict Aristotelian framework.

Harvey, in the development of this conclusion, had to combat in his own mind the prevailing physiological concept that blood was produced from nutriment in a central organ, and was moved peripherally to be totally consumed by the body. That Harvey refers to Aristotle's concept of circular motion in his exposition, which is in the order of demonstration, suggests the critical role that Aristotle's concept had in the order of discovery.

THE DEMONSTRATION OF THE MOTION OF THE HEART AND BLOOD

Harvey makes it clear throughout his work that his "new views of the motion and use of the heart and the circulation of the blood"²¹ are the result of the application of both sense and reason. In his dedication to the learned physicians he states that "for nine years or more [he has] confirmed these views by ocular demonstrations [and] manifested them by reasons and arguments, freed from the objections of the most learned and skillful anatomists." In Ch. 14 entitled 'The Conclusion of the Demonstration of the Circulation of the Blood' where he concludes that the blood is impelled to the whole body by the pulse of the ventricles, he states that this is "confirmed by reason and ocular experiment," and that one must "necessarily conclude" that the motion of the blood is circular. In the final words of the concluding chapter of his book, the chapter which confirms the motion and the circulation of the blood through an anatomical analysis of the heart, Harvey concludes that "All these phenomenon and many others observed in dissecting, if rightly weighed, seem clearly to illumine and fully confirm the truth contended throughout these pages . . . it would be difficult to explain in any other way for what cause all is constructed and arranged as we have seen it to be."

²¹ Harvey, *Works*, ed. cit., Dedication to Learned Physicians, p. 5.

HARVEY: MODERN OR ANCIENT SCIENTIST?

Notwithstanding, the modern scientist with his disproportionate worship of observation manages for the most part to ignore the role played by reason, thereby missing what is so magnificent in this classic work. The carefully organized nature of Harvey's demonstration can be detected by scrutinizing Harvey's table of contents, which, because it is a contraction, mirrors the logical structure of the masterpiece in bold outline. The following represents a structural analysis of the table:

ANALYSIS OF HARVEY'S TABLE OF CONTENTS²² OF AN ANATOMICAL EXERCISE ON THE MOTION OF THE HEART AND BLOOD

Part 1. Prefatory

- A. Dedicatory: extrinsic to work,
 - 1. To the King: to civil authority,
 - 2. To Learned Physicians: to peers who respect truth.
- B. Introductory: intrinsic to work,
 - 1. 'Introduction': establishes the need for the work; dated to the belief of scientists of that period.
 - 2. 'The Causes Moving the Author to Write' (Ch. 1): establishes the difficulty of the work; timeless, as the truths obtained from nature are permanent and belong to posterity.

Part 2. Motion of the Cardiovascular System (Ch. 2-7)

- A. Motion of the Containing Parts
 - 1. 'Motion of the heart through dissection of living animals.' (Ch. 2)
 - 2. 'Motion of the arteries through dissection of living

²² Words enclosed in single quotation marks are those used by Harvey as chapter headings. Other quotations have individual reference numbers.

Herbert A. Ratner, M.D.

- animals.' (Ch. 3)
- 3. 'Motion of the heart and auricles through dissection of living animals.' (Ch. 4)
- 4. 'Motion, action and function of the heart.' (Ch. 5)
- B. Motion of the Contained Parts from Right to Left Ventricle
 - 1. 'Ways by which blood passes from right ventricle to left.' (Ch. 6)
 - 2. 'That the blood pass through the lung from right ventricle to left.' (Ch. 7)

Part 3. Circular Motion of the Contained Part (Ch. 8-17)

- A. The Thesis and Demonstration (Ch. 8-14)
 - 1. Preliminary statement of the thesis: "Of the abundance of blood passing through the heart out of the veins into the arteries and of the circular motion of the blood." (Ch. 8)
 - 2. The three suppositions necessary for the demonstration.
 - a. 'The first supposition': "the blood is incessantly transmitted by the pulse of the heart out of the vena cava into the arteries in such abundance that it cannot be supplied from the ingesta, and in such wise that the whole mass must very quickly pass through the heart."²³
 - (1) 'circulation of blood confirmed from it.' (Ch. 9)
 - (2) 'is freed from objections and further confirmed by experiments.' (Ch. 10)
 - b. 'The second supposition': "the blood under the influence of the arterial pulse enters and is impelled in a continuous, equable, and incessant stream through every part and member of the body, in much greater abundance than were suf-

²³ Harvey, *Works, ed. cit.*, ch. 9, p. 48.

ficient for nutrition, or than the whole mass of ingesta could supply"²⁴

(1) 'is confirmed.' (Ch. 11)

(2) 'circulation of blood confirmed from it.' (Ch. 12)

c. 'The third supposition': "the veins in like manner return this blood perpetually to the heart from all members of the body"²⁵

(1) 'confirmed and that there is a circulation of blood from it.' (Ch. 13)

3. 'The conclusion of the demonstration concerning the circulation of the blood.' (Ch. 14)

B. Confirmation of Conclusion that the Blood Circulates (Ch. 15-17)

1. 'The circulation of the blood is confirmed by likely reasons.' (Ch. 15)

2. 'The circulation of the blood is proved from consequences.' (Ch. 16)

3. 'Motion and circulation of the blood is confirmed by those things that appear in the heart and which are clear from anatomical dissections.' (Ch. 17)

In the Introduction (Part I, B, 1) Harvey paves the way for his new theory by showing that the existing theory is unsatisfactory. He states in the opening paragraph that "In discussing the motion, pulse, action, use and utility of the heart and arteries, we should first consider what others have said on these matters, and what the common and traditional viewpoint is. Then by anatomical dissection, multiplied experience, diligent and accurate observation, we may confirm what is rightly stated, but what is false make right." Harvey then carefully examines the beliefs of his contemporaries in a series of seventeen dialectical propositions and replies. He concludes, "From these and many other considerations it is

²⁴ *Ibid.*

²⁵ *Ibid.*

plain that what has been said on the motion and use of the heart and arteries must seem obscure, inconsistent, or impossible to the thoughtful student. It will therefore be proper to investigate the matter more closely, to study the motion of the heart and arteries not only in man but in all animals possessing a heart, and to search out and find the truth by frequent vivisections and by constant ocular inspection."

This doxographic approach is distinctly Aristotelian,²⁶ and establishes that one should not lean on man as the final authority.²⁷ In Ch. 1, he indicates that nature, despite the diffi-

²⁶ It is part of Aristotle's methodology to examine dialectically existing opinion before proceeding to the scientific investigation of things. Examples of this procedure are found in *Physics*, Bk. 1, ch. 2; *Generation and Corruption*, Bk. 1, ch. 1; *The Soul*, Bk. 1, ch. 2, and elsewhere. The following passage from *On the Heavens* states some of the reasons for the procedure: "Let us start with a review of the theories of other thinkers; for the proofs of a theory are difficulties for the contrary theory. Besides, those who have first heard the pleas of our adversaries will be more likely to credit the assertions which we are going to make. We shall be less open to the charge of procuring judgment by default" (Bk. 1, ch. 10, 279 b 6-11). "We may convince ourselves not only by the arguments already set forth but also by a consideration of the views of those who differ from us . . . If our view is a possible one . . . and [what] they assert is impossible, this fact will be a great weight in convincing us . . ." (Bk. 2, ch. 1, 283 b 30-a). All translations from Aristotle are from the Oxford edition of his works.

²⁷ The true Aristotelian tradition may be gathered from the following statements: "We had perhaps better consider the universal good and discuss thoroughly what is meant by it, although such an inquiry is made an uphill one by the fact that the Forms have been introduced by friends of our own. Yet it would perhaps be thought to be better, indeed to be our duty, for the sake of maintaining the truth even to destroy what touches us closely, especially as we are philosophers or lovers of wisdom; for, while both are dear, piety requires us to honour truth above our friends." (Aristotle, *Nicomachean Ethics*, Bk. 1, ch. 6, 1096a 11-16).

"He who believes Aristotle to be a god ought to believe that he never made a mistake. But whoever thinks him to have been a man must admit that he was as liable to make mistakes as the rest of us." (St. Albert the Great, *Physicorum lib. VIII*, tr. I, cap. 14, ed. Borgnet, III, p. 553).

"Unless a man holds truth dearer than friends, he will be ready to pro-

culty of extracting answers from her, is the final authority.²⁸

In subsequent chapters Harvey begins to record his reading of the book of nature. In Chapters 2-5, he reports what she says about the heart and arteries. By obtaining the true attributes of these critical components of the cardiovascular system, their motion, pulse and action, he will be in a position

nounce false judgments and to bear false witness for the sake of friends. But that is immoral. All men ought to hold truth dearer than friends, because all men have the use of reason. But this duty is particularly binding on all philosophers because they profess to teach wisdom, and wisdom is nothing else than the knowledge of truth . . . Truth is, indeed, divine for it is found fundamentally and primarily in God. That is why Aristotle insists on the sacredness of the duty of holding truth dearer than friends . . . Plato is of the same opinion. For, once, when setting aside a theory of his master, Socrates, he declares that truth must be our supreme concern. And elsewhere, he declares: Socrates is, indeed, a friend of mine, but truth is a greater friend. And in a third text, he declares that one may make little of Socrates, but one must make much of truth." (St. Thomas Aquinas, *In I Ethic.*, lect. 6, nn. 76, 78).

²⁸ This is another expression of the true Aristotelian position. "God, like a good teacher, has taken care to compose most excellent writings that we may be instructed in all perfection. 'All that is written,' says the Apostle, 'is written for our instruction.' And these writings are in two books: the book of the creation and the book of the Holy Scriptures. In the former are so many creatures, so many excellent writings that deliver the truth without falsehood. Wherefore Aristotle, when asked whence it was that he had his admirable learning, replied: 'From things, which do not know how to lie.'" (St. Thomas, *Sermo 5 in Dom. II de adventu*, ed. Vives, *Opera Omnia*, XXIX, p. 194).

William Harvey, who, on the one hand, makes clear that "the authority of Aristotle has always such weight with me that I never think of differing from him inconsiderately" (Harvey, *Anatomical Exercises on the Generation of Animals*, Ex. 11, ed. cit., p. 207), also states that "Whoever, therefore, sets himself to opposition to the circulation, because [he] regards it as in some sort criminal to call in question disciplines that have descended through a long succession of ages, and carry the authority of the ancients; to all these I reply: that the facts manifest by the senses wait upon no opinions, and that the works of nature bow to no antiquity; for indeed there is nothing either more ancient or of higher authority than nature." (*Second Exercise to John Riolan*, ed. cit., p. 123).

subsequently to elucidate their use and utility. "For if none of the true attributes of things have been omitted in the historical survey" states Harvey's mentor Aristotle, "we should be able to discover the proof and demonstrate everything which admitted of proof, and to make that clear, whose nature does not admit of truth." Aristotle emphasizes in this same passage that "in each science the principles which are peculiar are the most numerous. Consequently it is the business of experience to give the principles which belong to each subject. I mean for example that astronomical experience supplies the principles of astronomical science: for once the phenomena were adequately apprehended, the demonstrations of astronomy were discovered. Similarly with any other art or science. Consequently, if the attributes of the things are apprehended, our business will then be to exhibit readily the demonstrations."²⁹

Again Aristotle emphasizes that "each set of principles we must try to investigate in the natural way, and we must take pains to state them definitely, since they have a great influence on what follows. For the beginning is thought to be more than half of the whole, and many of the questions we ask are cleared up by it."³⁰

Harvey, of course, as an Aristotelian, does not limit himself to man. To get at the heart of the matter and of man he must be interested in the hearts of other animals. His aim is to get at the true nature of the heart. His interest is not descriptive. He is not interested in this heart or that with the variations in numbers of chambers or differing associations with lung or gills, but in the heart universally considered, prescinding from the variations that are found in nature. He refers to cold blooded animals as well as to warm blooded: toads, snakes, frogs, snails, shellfish and fish. In all it has been estimated that he worked with about 80 species of animals.³¹

²⁹ *Prior Analytics*, Bk. 1, ch. 30, 46 a 18-27.

³⁰ *Nicomachean Ethics*, Bk. 1, ch. 7, 1098 b 4-9.

³¹ William Harvey, *Prelectiones*, ed. cit., Introduction by a Committee

That this is a methodological approach and not simply the insatiable curiosity of a field biologist is made clear from the quote from Aristotle that appears on the title page of *Preelectiones*, from the fifth of the canons which Harvey lists for his own guidance at the beginning of his lectures, and from a passage from Harvey that appears in *De Motu*.

The Aristotle quotation states, "The fact is that the inner parts of man are to a very great extent uncertain and unknown, and the consequence is that we must have recourse to a consideration of the inner parts of other animals which in any way resembles that of man."³²

The fifth canon emphasizes that one should systematically study other animals "according to the Socratic rule" for this will permit one to refute and correct errors in natural philosophy, and to discover the use, action and dignity of things, and thereby obtain for anatomy knowledge of the causes of the parts, the ends, their necessity and use. The Harvey passage is as follows:

Since the intimate connection of the heart with the lungs, which is apparent in the human subject, has been the probable occasion of the errors that have been committed on this point, they plainly do amiss who speak and demonstrate the parts of animals generally (as all anatomists commonly do) from the dissections of man alone, and at that dead. They obviously act no otherwise than he, who, having studied the form of a single republic, should set about a general discipline of polity; or who, having taken cognizance of a single farm, should imagine that he has scientific knowledge of agriculture; or who, on one particular proposition attempts to syllogize the universal. Had anatomists only been as conversant with the dissection of the lower animals as they are with that of the human body, the matters that have hitherto kept them in a perplexity of doubt would in my opinion, have met them freed from every kind of difficulty.³³

of the Royal College of Physicians of London, p. vi.

³² Aristotle, *The History of Animals*, Bk. I, ch. 16, 494 b 21-24.

³³ Harvey, *Works*, *op. cit.*, ch. 6, p. 35.

It should be seen here that in his dedication to comparative anatomy, to Socrates' and Aristotle's rule, Harvey differs from the modern scientist. The latter directs this branch of biology primarily to taxonomy or to the elucidation of evolutionary history. The Socratic rule, on the contrary, is directed at eliciting an essential definition through the use of the inductive method. Socrates, according to Aristotle, was interested in what a thing is, its essence, as the starting point for syllogizing. "Two things may be fairly ascribed to Socrates," says Aristotle, "inductive arguments and universal definitions, both of which are concerned with the starting point of science."³⁴

To understand the use and the goal of Grecian and Harvian comparative biology, two things should be understood. First, that one has to seek out and know the many. Secondly, that knowledge of the many which one has to seek out is the "one in the many"—that which is common to the many, that commonality which most fully accounts for why the thing is as it is.

To know the *many*, however, does not automatically result in an answer. Modern science suffers from a plethora of the *many*, because of the variety and the high output of sense observations from our laboratories. The modern scientist is in the position of Meno, who, in answer to Socrates' question, What is virtue?, responds that "Every age, every condition of life, young or old, male or female, bond or free, has a different virtue: there are virtues numberless, and no lack of definitions for them . . ."³⁵ The modern scientist in the absence of the Harvian answer would respond similarly to the question, What is a heart?, that every species of animal has a different heart: there are numberless hearts and numberless definitions. But Harvey, following Socrates, prescind from the many and seeks what the heart is "in the universal . . . whole and sound,

³⁴ Aristotle, *Metaphysics*, Bk. M, ch. 4, 1078 b 18-30.

³⁵ Plato, *Meno*, 71 E-72 A (Jowett translation.)

and not broken into a number of pieces."³⁶ Harvey also follows Aristotle, who formally discusses the method of obtaining definitions in his *Posterior Analytics* which, as part of the *Organon*, was part of Harvey's formal training in logic and scientific methodology.

Unlike the modern whose notion of causality is limited primarily to the material and efficient causes, Harvey further follows Socrates and Aristotle in seeking the fuller explanation that comes with the additional knowledge of the formal and final causes.

Socrates in his last days recollects his rejection of this ancient error of modern scientists when, as a young man, he, "with a prodigious desire to know that department of philosophy which is called the investigation of nature: to know the causes of things, and why a thing is"³⁷ registers his disappointment after being directed to Anaxagoras who, forsaking any principle of order, tried to explain everything by "having recourse to air, ether, and water and other eccentricities."³⁸

Aristotle as a scientist's scientist³⁹ and philosopher's philosopher fully and formally develops this Socratic position in Book I of the *Parts of Animals*. He, too, as if writing against the enthusiastic follower of Harvey, who reads but does not understand him, talks about "the ancient writers, who first philosophized about Nature as having busied themselves" with "the material principle and material cause."⁴⁰ Aristotle explains, on the contrary, that

if men and animals and their several parts are natural phenomena, then the natural philosopher must take into con-

³⁶ *Ibid.*, 77 A.

³⁷ Plato, *Phædo*, 96 B.

³⁸ *Ibid.*, 98 C.

³⁹ Charles Darwin, *Life and Letters*, Letter to Ogle, 1882, vol. 3, p. 252: "From quotations I had seen I had a high notion of Aristotle's merits, but I had not the most remote notion what a wonderful man he was. Linnæus and Cuvier have been my two gods, though in very different ways, but they were mere schoolboys to old Aristotle."

⁴⁰ Aristotle, *Parts of Animals*, Bk. I, ch. 1, 640 b 5.

sideration not merely the ultimate substances of which they are made but also . . . the homogeneous and heterogeneous parts; and must examine how each of these comes to be what it is, and in virtue of what force. For to say what are the ultimate substances out of which animal is formed, to state, for instance, that it is made of fire or earth, is no more sufficient than would be a similar account in the case of a couch or the like . . . For a couch is . . . such and such a matter with this or that form; so that its shape and structure must be included in our description. For the formal nature is of greater importance than the material nature.⁴¹

Aristotle finally concludes that

It is plain, then, that the teaching of the old physiologists is inadequate, and that the true method is to state what the definitive characters are that distinguish the animal as a whole; to explain what it is both in substance and in form, and to deal after the same fashion with its several organs; in fact, to proceed in exactly the same way as we should do, were we giving a complete description of a couch.⁴²

We can see then that Harvey as an Aristotelian is interested in function as well as action, in ends as well as means—the teleological as well as the mechanical. We shall also see that Harvey respects the differentiation as well as the interrelationship of what has to be known for a full understanding of the causes. Part of the modern difficulty in understanding Harvey stems from a failure to appreciate Harvey's sensitivity to language, and our insensitivity to the sharply delineated concepts which his terminology precisely communicates—concepts and terms which are the culmination of a long logical and biological tradition.

The conceptual difficulty can best be seen from the Leake translation. In the table of contents: the Latin words *dissectione*, in three instances, and *experimentis* are both translated into *experiment*; *dissectio*, in another instance, is translated into *inves-*

⁴¹ *Ibid.*, 640 b 15-29.

⁴² *Ibid.*, 641 a 14-18.

tigation; *confirmato* is translated into both *established* and *proved*; *probatur* is translated into *supported*; and *suppositio* is translated into *consideration* and *proposition*. The first sentence of the Introduction of this translation begins, "In discussing the movements and functions of the heart and arteries, we should first consider . . .". The original Latin, however, instead of *movement* and *functions*, has *motu, pulsu, actione, usu, utilitatibus*.

We can now return more specifically to the manner in which Harvey arrived at his revolutionary conclusions concerning the motion of the heart and blood. If one turns to the table of contents above, he will note that whereas the word *dissection* is characteristically found in the chapter headings on the motion of the heart and arteries (part 2 A), the word *supposition* is characteristically found in the section on the circulation of the blood (part 3A). Dissection, of course, pertains to sense; supposition, to reason. One may correctly infer from this that, when it comes to the circulation of the blood, the demonstration is logical, not ocular. The absence of magnifying instruments of sufficient strength at the time made it impossible to observe either the circulation of the blood or the continuity of the cardiovascular system. It is not implied here, however, that the ocular, even if possible, could approach or match the certitude of the logical demonstration.⁴³

Circulation, as such, is not mentioned in the body of the work until Chapter 8, where it is introduced in the form of a short review of the argument developed subsequently. Since the conclusion that the circulation of the blood is the end result of a long reasoning process, the chief function of Har-

⁴³ It should not be forgotten that the observations of Swammerdam of the perfectly formed butterfly in the cocoon in 1669, and a those of Leeuwenhoek of the complete outline of both maternal and paternal individuals in the microscopic spermatozoa in 1677, led to the complete replacement of Harvey's theory of epigenesis by the preformation theory, which lent itself to a mechanical explanation of nature, and which was to dominate biological thinking through the first half of the eighteenth century.

vey's preceding chapters is to contribute premises which are true, primary, immediate, better known than, prior to, and the cause of the conclusions which follow from them.⁴⁴ In other words, it is necessary to establish the motion, pulse, and action of the heart and arteries, and the relationship of the lungs to the heart and the blood to the lungs first. This calls for the most exacting type of sense observations, their verification by collated findings, and care in the inferences drawn from them. It is through such knowledge that Harvey is in a position to ask questions leading to the initial idea and final demonstration that the blood circulates.

The first part of Harvey's treatise establishes, contrary to the beliefs at the time, that the heart and the arteries in the living animal always contain blood: that the proper motion of the heart is contraction, not expansion; that its action is pump-like, not bellow-like, and that it forcibly expels blood in one direction; that contraction, not expansion—systole, not diastole—corresponds to the pulse on the chest wall; that the arterial pulse, which in arterial diastole corresponds to cardiac systole, not cardiac diastole; that cardiac systole is the cause of the arterial pulse via the motion it transmits through the blood; and that blood from the right ventricle gets to the left ventricle through the lungs.

Since "the one action of the heart is the transfusion and propulsion of the blood by mediation of the arteries to the extremities of the body,"⁴⁵ the question arises as to where the heart gets the blood which is the subject of its action. The genesis of the belief and the hypothesis that blood circulates is as follows:

And sooth to say, when I surveyed in various disquisitions by how much abundance blood might be lost from cutting arteries, in dissections and induced experiments in the living; then the symmetry and magnitude of the vessels that

⁴⁴ Aristotle, *Posterior Analytics*, Bk. I, ch. I, 71 b 16-22.

⁴⁵ Harvey, *Works*, *op. cit.*, ch. 5, p. 32.

enter and leave the ventricles of the heart (for nature doing nothing groundlessly, would never have given them such proportionate magnitudes groundlessly), then the ingenious and attentive fitting together of the valves and fibers, and the rest of the heart's fabric and many other things besides, I frequently and seriously bethought me, and long revolved in my mind, by how much abundance blood was transmitted, and the like, in how short a time its transmission might be effected, and not finding it possible that this could be supplied by the juices of the ingested aliment without the veins on the one hand becoming drained, and the arteries on the other hand getting ruptured through the excessive charge of blood, unless the blood should somehow find its way from the arteries into the veins, and so return to the right ventricle of the heart; I began to think whether there might not be a motion as it were, in a circle.⁴⁶

Chapter 9 contains the principal demonstration of the circulation:

A fluid of limited quantity kept in perpetual motion		
in one direction	is	moved circularly.
And the blood	is	such a fluid.
Therefore the blood	is	moved circularly.

In this syllogism according to the Aristotelian logic employed by Harvey the middle term is the material cause (i. e. limited quantity of fluid), and the demonstration is "one through the material cause." The major premise is a general physical theorem proved by Aristotle in Books VII and VIII of the *Physics*, where he shows that perpetual motion of any system must be circular in character. The minor premise is a definition of the blood derived from Harvey's careful studies recorded in his earlier chapters.

Harvey's conclusion is, as he admonishes a critic on a later occasion, "demonstrative and true, and follows of necessity, if

⁴⁶ *Ibid.*, ch. 8, pp. 45-46.

the premises be true."⁴⁷ Therefore he adds that any criticism of his conclusion cannot be in the area of argument and logic, but in the area of observation and experiment which supplies the premises. Harvey insists here that "our senses ought to assure us whether such things be false or true and not our reason, ocular testimony and not contemplation."⁴⁸ That Harvey has learned well from Aristotle, who was the father both of biology and logic, is evident from Harvey's recognition of and respect for the proper spheres of sense and reason.

The degree to which Harvey's demonstration is Aristotelian should be noted further. First, it is an example of the relationship of a less general science, biology, to a more general and fundamental science, physics, to which it is subalternate: a particular biological fact is illuminated by a universal physical theorem to yield a new biological fact. Secondly, it is an example of the dictum that demonstrations in science are made through a definition expressing an essential characteristic. Thirdly, contrary to modern thinking, Harvey's demonstration does not depend on mathematical measurements but on physical proportions, i. e., the proportion of one quantity to another on the basis of physical comparison rather than on mathematical principles. In stating that Chapter 9 is "the first instance of the quantitative method in physiology" and that it "introduced the most important method of reasoning in science,"⁴⁹ Leake misses Harvey's fidelity to Aristotle's method and its reward. Kilgour, in a recent and careful analysis of Harvey's use of the quantitative method, concludes that certainly "Harvey was not concerned with accurate measurement" and that his estimations were consciously indifferent to precision, the essence of the mathematical procedure. He adds, "Apparently, quantitative evidence was not important in leading Harvey to develop the idea of the circulation because there

⁴⁷ Harvey, *Second Exercise to John Riolan*, ed. cit., p. 133.

⁴⁸ *Ibid.*

⁴⁹ Chauncey D. Leake, *op. cit.*, ch. 9, p. 74, fn. 1.

is no quantitation in his Lumleian Lecture notes of 1616.⁵⁰ The computations Harvey supplies, therefore, may be better viewed as communicating to the reader—in the manner in which a sensible model makes a theory vivid to the reader—the physical reality of the disproportion between the amount of ingesta and the flow of blood through the heart.⁵¹

Finally, it would be amiss not to recognize that the demonstration of the circulation of the blood is just an Aristotelian step in the elucidation of the nature of the heart, the prime component of the cardiovascular system. The ultimate purpose of Harvey's treatise is to define the heart upon which the motion of the blood is dependent.

One of the most remarkable chapters in this work of Harvey's is the 17th and final chapter. From all the fields opened up by the establishment of circulation—physiology, pathology, symptomatology and therapeutics—he selects his topic: to relate the various particulars that present themselves in the anatomical study of the fabric of the heart and arteries to their several uses and causes, "for I shall meet with many things which receive light from the truth I have been contending for, and which, in turn, render it more obvious. And indeed I would have it confirmed (*firmitatem*) and beautified (*exornatam*) by anatomical arguments above all others."⁶²

This chapter is primarily an elaboration of the formal cause of the heart through the re-examination of the heart and

⁵⁰ Frederick C. Kilgour, "William Harvey's Use of the Quantitative Method," *Yale Journal of Biology and Medicine*, XXVI (1954), 417-18.

⁵¹ Some of the thoughts appearing in this article were first presented and in part developed at a summer institute for scientists and philosophers conducted by The Albert Magnus Lyceum for Natural Science at River Forest, Illinois, July 1952. A report of this institute is to be found in the publication, entitled, *Science in Synthesis: A dialectical approach to the integration of the physical and natural sciences*, by W. Kane, O. P.; J. D. Corcoran, O. P.; B. M. Ashley, O. P.; and R. H. Nogar, O. P. (The Aquinas Library, Dominican College of St. Thomas Aquinas: River Forest, Illinois, 1953). See pp. 93-108.

⁶² Harvey, *Works*, *op. cit.*, ch. 16, p. 74.

the vessels—structurally, comparatively, embryologically and functionally—in the light of the final cause, viz. the circulation of the blood. His final statement which closes his treatise is: "it would be difficult to explain in any other way for what cause all is constructed and arranged as we have seen it to be."

He establishes what a heart is in his characterization of the heart *per se* as the left ventricle, viz. that ventricle "distinguished by use not position, the one namely that distributes blood to the body at large, not the lungs alone. "In doing so he establishes the connection of the final and formal causes.

This chapter completes the definition of the heart for Harvey, which definition may be expressed in syllogistic form as follows:

An organ which must supply the body with a steady flow of a fluid whose quantity is proportionately small	is	an organ which is so constructed as to be able to produce a circular motion of that fluid.
And the heart	has	this very function.

Therefore the heart is:

1. An organ which has a pulsating "left" ventricle with a non-regurgitating valvular inlet and outlet and whatever additional cardiac parts that conform to the needs of the species (the *formal cause*: the anatomical structure described teleologically and in detail, i. e., in its relationship to its motion, pulse, action, use and utilities, e. g., the arrangement of the fibres in the walls, the valves, the braces of the heart; "the actions and uses of the heart may be understood from the constitution of its muscular fibers and the fabric of its moveable parts"⁵³),
2. and is composed of muscular tissue and other tissue components necessary to the parts (the *material cause*),
3. for the sake of circulating the blood (the *final cause* or function)

⁵³ *Ibid.*, ch. 17, p. 82.

4. by contraction (the *efficient cause* of circulation).⁵⁴

Naturally, the final and efficient causes are proximate causes

⁵⁴ That the last chapter is an integral and important part of Harvey's classic is not the common position. Leake presents a typical viewpoint when he states that "The last three chapters add little to the significance of the demonstration" (Chauncey D. Leake, *op. cit.*, Translator's Preface, p. x). But here it seems that Leake has a limited appreciation of the purpose of the work as explicitly stated by Harvey, and of the true scientific nature of the anatomical exercise employed by Harvey. As to the purpose of the work it should first be recalled that the title of this classic makes clear that it is an anatomical exercise, and that it concerns the motion of the heart as well as the motion of the blood. Secondly, that the opening statement of the *Introduction* states that Harvey is discussing "the motion, pulse, action, use and utility of the heart and arteries," and of Chapter 1 that his purpose is to discover "the motions, use and utility of the heart." That Leake does not appreciate the comprehensiveness of the anatomical exercise is reflected in his translation, in which he reduces *action, use and utility to function* in the *Introduction*, and *use and utility to function* in Chapter 1.

If we turn to the anatomical works of Fabricius, who was Harvey's teacher, we find the following exposition of the anatomical exercise: "to treat first the dissection or description of each organ, then its action, and finally its utilities, and in this way present our entire knowledge of the organs as comprised in these three divisions." He adds that he has followed "this path the more willingly because those distinguished pioneers, Aristotle and Galen, have blazed the trail and, so to speak, carried the torch before me on the way." (Fabricius, *De Visione, voce, auditu*, Preface, translated by Howard B. Adelman, *The Embryological Treatises of Hieronymus Fabricius of Aquapendente*, Cornell University Press, 1942, p. 82). Fabricius classifies the biological works of Aristotle and Galen in these three divisions and states that "The third part, indeed, which discusses the utilities of the whole, as well as of the parts of an organ, corresponds to the four books of Aristotle's *De partibus animalium* [and] to that great work of Galen's, *De usu partium* . . ." (*ibid.*, p. 83).

When we turn to Aristotle's explication of the third part of the anatomical exercise he states that "In the first place we must look at the constituent parts of animals. For it is in a way relative to these parts, first and foremost, that animals in their entirety differ from one another: either in the fact that some have this or that, while they have not that or this; or by peculiarities of position or arrangement; or by the differences that have been previously mentioned, depending upon diversity of form, or

and are not intended as complete in any sense. In this context Harvey's Aristotelian answer to his critic Riolan is pertinent:

excess or defect in this or that particular, or analogy, or on contrasts of the accidental qualities. "For, according to Aristotle "to do this [pass on to the discussion of the causes] when the investigation of the details is complete is the proper and natural method, and that whereby the subjects and the premises of our argument will afterwards be rendered plain." (Aristotle, *The History of Animals*, Bk. 1, ch. 6, 491 b 10-19).

Galen's position is quoted by Fabricius: "A practical knowledge of the nature of each of the members is gained from dissection together with a thorough understanding of its actions and utilities." Galen further adds, in the quotation from Fabricius: "Moreover, lest anyone unwisely neglects these aspects or be thoughtless enough to say that they are not of great consequence, I can truly say this: They are of so much importance, that whoever has learned them thoroughly must unhesitatingly confess that he has learned and comprehended the whole subject of anatomy, which, in my opinion, is nothing but the true and solid foundation of all medicine and the absolute and perfect end of natural philosophy." (Fabricius, *op. cit.*, p. 83).

Galen's statement is clearly in anticipation of criticisms such as Leake's. That Leake has this position is in great part explained by the fact that contemporary physicians and doctorates of anatomy have been raised on Gray's *Anatomy* which is entitled *Anatomy, Descriptive and Surgical* and which is intended for "Students of Surgery rather than for the Scientific Anatomist." (Henry Gray, *Anatomy, Descriptive and Surgical*, A New Edition Thoroughly Revised by American Authorities from the Thirteenth English Edition (Lea Brothers, 1896) Preface to the Thirteenth English Edition, p. 8). It can be seen that Gray's *Anatomy* is a practical work ordered to surgery and which only relates the first division of the traditional notion of anatomy, namely description, to surgery.

An understanding of Harvey's procedure then, may be summarized in the words of Fabricius: "Now in the second part of this treatise, I must discuss action, since, as Galen everywhere testifies, it is not permissible to arrive at the third section, which describes the usefulness (*utilitates*) of the parts, before the actions of the organs are understood. For the utilities of an organ always have reference to action, and depend upon the action which proceeds from the homogeneous parts of it. For this reason, in every organ there is always provided one part which is the principal instrument of its action, that is, a part from which the action proceeds, while the other parts of the organ are related to the action as useful assistants." Fabricius then exemplifies the above distinctions with

“To those who repudiate the circulation because they neither see the efficient nor final cause of it, and who exclaim, *Cui bono?* I have yet to reply, having hitherto taken no note of the ground of objection which they take up. And first I own I am of opinion that our first duty is to inquire whether the thing be or not, before asking wherefore it is (*propter quid*)? for from the facts and circumstances which meet us in the circulation admitted, established, the use and utilities of its institution are especially to be sought.”⁵⁵

Notwithstanding, Harvey makes clear “the principal use and end of the circulation: it is that for which the blood is sent on its perpetual course, and to exert its influence continually in its circuit, to wit, that all parts dependent on the primary innate heat may be retained alive, in their state of

the eye, in which the crystalline lens has the principal utility, and the other parts of the eye, the cornea, the iris and the rest, are structures useful for the eye’s action through the secondary utilities they have for either improving or protecting vision, and concludes: “It is now clear from the foregoing that utility is always related to activity, whether the usefulness of the organ is sought from its action or from other things either consequential or accidental; nor can you inquire into the usefulness of any organ unless its action is first known.” (Fabricius, *The Formed Fetus*, Part 2, The Action and Usefulness (*utilitas*) of the parts of the fetus, ch. 1, Adelman translation, ed. cit., p. 276).

Harvey’s last chapter, which is entitled “The motion and circulation of the blood is confirmed by those things that appear in the heart and are clear from anatomical dissections,” can now be seen as an integral part of the anatomical exercise. In the preceding chapters Harvey has established the proper action of the heart, as well as its use, the circulation of the blood. This now permits him to look at the heart so as to determine formally its utilities, i.e., its abilities to serve, in the light of its actions and use. By determining that the formal cause of the heart—its utilities—has a one to one correspondence with its action—the efficient cause of blood circulation—and with its use, the final cause, namely, the circulation of the blood, Harvey can now reflectively confirm the circulation. In this remarkable chapter Harvey identifies the principal utility with the muscular left ventricle and the secondary utilities with valves, braces, etc.

⁵⁵ Harvey, *Second Exercise to John Riolan*, ed. cit., pp. 122–123.

vital and vegetative being, and apt to perform their duties; whilst to use the language of physiologists, they are sustained and actuated by the inflowing heat and vital spirits.”⁵⁶

The modern reader, of course, will have to understand that it would take some time, and the modern development of the science of chemistry, before this point could have been made in terms of oxygen instead of vital spirits, or amino acids, glucose, and fatty acids instead of natural spirits. In the meantime he can have the reassurance from Harvey that “There is, in fact, no occasion for searching after spirits foreign to, or distinct from, the blood”:⁵⁷ for “the blood and spirits constitute one body (like—whey and butter in milk, or heat in hot water . . .).”⁵⁸

It should be stressed that Harvey in elucidating the formal cause of the heart, as well as the formal cause of the arteries and veins, has obtained the efficient cause of circulation and the basis for a *propter quid* demonstration. This is the import of his last chapter and his concluding statement quoted above.

CONCLUSION

Although Harvey’s discovery of the circulation of the blood was truly revolutionary, its establishment was strictly traditional. Ironically, the greatest opposition to his work came from the traditionalists. What accounts for the paradox?

Most scholastics of the fifteenth and sixteenth centuries so admired Aristotle that they ended up slaves to his conclusions and caricaturists, rather than disciples, of the methods by which he arrived at them. As a result they were very unproductive in the natural sciences.

Modern biologists trace their lineage back to three seventeenth century scientists who revolted from these Aris-

⁵⁶ Harvey, *First Exercise to John Riolan*, ed. cit., p. 98.

⁵⁷ Harvey, *Anatomical Exercises on the Generation of Animals*, Ex. 51, ed. cit., p. 502.

⁵⁸ Harvey, *The Motion of the Heart and Blood*, Introduction, ed. cit., p. 12.

totalians: Francis Bacon, René Descartes⁵⁹ and William Harvey. What each of these three did was to free himself from the shortcomings of his contemporaries by a daring innovation. The innovation of Descartes was philosophical. He allowed his philosophical genius to carry him to the extreme of founding a completely new philosophy. The innovation of Bacon was pseudo-philosophical. His lack of philosophical genius carried him to the extreme of founding a new methodology of investigation. Descartes paved the way for a whole series of modern errors; and Bacon caused the disappearance of methodology in those who became his followers. But the innovation of Harvey lay in the diligence of his investigation of the Aristotelian premises and the profundity of his penetration of Aristotle's method. From this novelty—fidelity to the tradition—has come his permanent contribution to modern

⁵⁹ Descartes was one contemporary who had no difficulty accepting Harvey's conclusion. "I need only mention in reply what has been written by a physician in England, who has the honour of having broken the ice on the subject (that the blood's) course amounts precisely to a perpetual motion." (René Descartes, *A Discourse on Method of Rightly Conducting the Reason and Seeking Truth in the Sciences, Everyman's Library*, p. 41). He accepted Harvey's conclusion without difficulty because it fit in with his mechanistic and mathematized method. His method, however, did not protect him from misunderstanding Harvey's demonstration and almost everything that Descartes further said about the motions of the heart and blood was in error. (*Ibid.*, pp. 37-43).

Harvey, of course, was fully cognizant of Descartes's failure and makes this clear in the following passage: ". . . the ingenious and acute Descartes (whose honourable mention of my name demands acknowledgments,) and others . . . in my opinion do not observe correctly . . . Descartes does not perceive how much the relaxation and subsidence of the heart and arteries differ from their distention or diastole; and that the cause of the distention, relaxation, and constriction, is not one and the same; as contrary effects so they must have contrary causes; as different movements they must have different motors; just as all anatomists know that flexion and extension of an extremity are accomplished by opposite antagonistic muscles, and contrary or diverse motions are necessarily performed by contrary and diverse organs instituted by nature for the purpose" (Harvey, *Second Exercise to John Riolan, ed. cit.*, pp. 139-140).

science. It made him both an authentic representative of the past and an authentic representative for the future, and establishes him as a model for an age that slights sense, as well as for an age that slights reason.