

THE DEVELOPEMENT OF OUR
KNOWLEDGE REGARDING THE
FUNCTION OF THE HEART.

— THOMAS FERGUSON —

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The Development of our Knowledge Regarding the Function of the Heart

"All great work is based on work done before, even where the results appear to be different----- All high thought is really continuous"

— Dr. Payne, Harvard Oration
October 12th 1896

It was an axiom of primitive physiology that the blood is the life, and the heart has ever been regarded as typical of things profound. There Aristotle localised the vital principle, and some of his most positive arguments were based partly on his observations as a Psychologist on the connection of emotion with that organ; even today the popular idea tends to regard it as the great source from which spring the deepest of human passions. The Ages have associated the heart alike with the fundamental and the mystic; it is not surprising, therefore, to find that its physiology presents a problem which has attracted the Great Minds of all time. In the ancient thought, it must have been intimately related to the question of the origin of life itself, while the

discoveries of later days only served to whet the scientific appetite. Little by little new facts were elucidated and new theories propounded, and many of the earlier philosophers must have stood on the brink of a great discovery: that they did not actually realise the full fruits of their labours was probably due in large measure to the circumstances of the times, which were not conducive to scientific originality. It is a far cry from Hippocrates to Harvey, but who among us can confidently assert that, even in these later days, we have completely mastered the intricacies of cardiac function? The grosser factors we certainly have determined, but what unfathomed mysteries underlie such terms as "inherent contractility"? These represent but little progress— even Galen could talk glibly of δύναμις συγκινητή.

Such expressions merely cover ignorance, and possibly our whole outlook may be revolutionised by the advent of a deeper physiology.

The ancient Egyptians knew of the existence of arteries and veins, and something of their distribution; but they did not draw any distinction between these two types of vessels, nor did they differentiate between them and such other tubes as the ureter.

Empedocles laid down the principle that "it is the nature of blood to move backwards and forwards" and some two centuries later we find Aristotle lending himself, at times, to this idea of flux and reflux.

Hippocrates thought that veins, like arteries, were distributing vessels, and that their function was to carry vital spirit. In his opinion, the veins took origin in the head; he did not know

that the direction of the blood-flow in them was towards the heart. He described the semilunar valves, but there is no evidence to show that he knew anything of their function. The seat of understanding he placed in the left ventricle, an error which long survived him, and which was destined to complicate considerably subsequent work on the circulation.

"Aristotle", says Crawford, "was the first worker to present anything in the nature of a coherent account of the vascular system, and of the purpose it was destined to serve in the animal economy."¹ The same Author states that Harvey's indebtedness to any but Aristotle was almost negligible, and, while this savours of what Macaulay would have termed *Luce Boswelliana*, the fact undoubtedly remains that the Aristotelian philosophy formed the basis of much subsequent work. That the ideas of Aristotle were deep implanted in the minds of men is amply proved by their revival, in the 16th century, by Vesalpus, and even later, by the contemporaries of Harvey: his statements formed the measure against which his admirers loved to fit subsequent discoveries. For centuries his tenets formed the standards by which aspirants to medical fame were judged: that these standards were not wholly accurate must have had a deleterious effect on scientific progress.

Aristotle had no notion of the flow of blood in a circle, though he believed it supplied nutriment to all parts of the body - like Plato, he regarded the vascular system as the irrigation channel

of the animal. He thought the two sides of the circulation were quite separate; hence he inferred that there were two kinds of blood. He declared the chief bloodvessels to be two in number, "because every animal is bilateral"; he described the pulmonary circulation very accurately, but left a breach of continuity between the pulmonary arterioles and venules in the lung and the systemic homologues in the rest of the body. He had no conception of valvular function. Aristotle located the vital principle in the heart, stating that the heat of metabolism was so vitalised as to afford nutrition and functional activity to the body. He thought that under the heating influence of the heart, the ichor was converted into blood - the material from which the whole body was made; and that this same heat induced expansion of the blood in the heart, and lifted up its muscular containing wall, thus exciting its pulsation. Respiration was made dependent on the same principle, and its purpose was to temper the heat of the heart. To Aristotle the pulsation of the heart was a mere by-product of metabolic changes occurring within its cavities - the heart was a bellows, with diastole the active phase. As has been already indicated, Aristotle's argument that the heart was the centre of sensation and voluntary motion rested partly on his observation, as a Psychologist, of the connection of emotion with the heart, partly also on preconceived ideas, and partly on one fallacious anatomical observation - seeing the chordae tendineae of the heart; he thought they were nerves, and the source of all the

nerves in the body.

But Aristotle was a pioneer, and his work must be viewed in this light. His scope for investigation among human subjects was very limited, yet much of his anatomy was essentially correct. His recognition of the primacy of the heart among the organs of the body was of paramount importance as the starting point for a rational explanation of the circulation. Finally, he was an avowed source of inspiration to Harvey and as such merits our due appreciation.

In Erasistratus is focussed the contribution of the great Alexandrian School to the knowledge of the vascular system, and in his work there is little of the crisp logic of the Hellenes. Erasistratus thought that the veins took origin in the liver, and in his view, the arteries were carriers only of air. He suggested the probability of anastomoses between arteries and ^{veins}, but this was an attempt to bolster up indefensible theories rather than the outcome of any real reasoning. Further Erasistratus described the auriculo-ventricular valves and the chordae tendineae; he pointed out the mode of closure of the valves; and their purpose, though, on account of his firm belief in the idea of the ebb and flow of blood, he ignored their competence. We cannot but think that the name of Erasistratus would have assumed an added importance had the knowledge he possessed been applied in a more unbiased manner; he lacked the initiative to depart from the conventional

Galen was primarily an experimenter; he marks the substitution of fact for dogma. All observers before his time had maintained that the arteries contained only spirit or air. Galen, applying his usual principle of an appeal to Nature, showed that they contained blood. He repeatedly asserted the existence of anastomoses between arteries and veins, though he did not appreciate their fundamental importance. He believed that in the blood there was constant flux and reflux, and that the function of respiration was to regulate heat production in the heart. He took a step forward when he declared that "in the brain high-grade blood engenders animal spirit and so subserves the highest function of the organism"—an early approximation to the true seat of the intellect. With Erasistratus, he held that veins took origin in the liver; he thought that there the chyme was converted into blood. Galen declared that the heart septum was porous: thus allowing blood to filter from one side of the organ to the other; he naively explains that "the pores are seen with difficulty in the dead body, because the heart muscle, being then cold, is stiff, and hard; still reason assures us they are there" He decided that the heart was not muscular, yet located the stimulus to activity in the heart itself—a peculiar travesty on the myogenic doctrine; he attributed to it an "inherent tendency to pulsate," which, after all, nearly summarises our knowledge of the matter in these twentieth century days. The influence of Galen on his successors—especially, at the time of the Renaissance—was tremendous.

His work contains much that is praiseworthy - he insisted on the importance of an accurate Anatomy: he advocated the experimental method as essential to all true scientific progress: he knew that the function of the heart valves was to prevent regurgitation; and he recognised the primacy of the right auricle as the first part to live. But the writings of Galen remained too long the inspiring gospel - the minds of men were held captive and their imaginations enslaved; it was centuries or posterity learned to say, with Henry of Mondville, "God surely did not exhaust all his creative power in making Galen".

There has been much controversy regarding the relative value of work done by "the ardent Anatomists of the Renaissance" Vesalius did not believe that the septum was porous, though he was unable to prove his point: - it was left to Columbus and Servetus to describe the passage of blood from the right ventricle by the pulmonary artery to the lungs, thence back to the heart by the pulmonary veins. So the lesser circulation was being described; but if, about this time, Sarpi had visions of a greater, nothing tangible resulted.

Fabricius discovered and described the valves in veins: he thought their function was "to serve as dams or checks to the flow of blood, so that it would not irrigate too rapidly, and overflow the peripheral vessels to the deprivation of the upper parts of the limbs"

In the sixteenth century, the theories of Aristotle were revived by Vesalpius, while about this time some remarkable properties were ascribed to the heart—it was declared by the Philosophers to be the centre of voice production, and again proclaimed to be the seat of the soul. Still, this was a period of acquisition, characterised by a new depth of accuracy and minute observation, as was only to be expected in the era of such giants as Copernicus, Galileo, and Linacre.

It was under such conditions that Harvey appeared. His more immediate predecessors had cleared up many of the minor points which stood in the way of progress, and men were taking a new interest in the work of the master minds of antiquity. Galen was the fore-runner of Harvey in experiment, just as was Aristotle in observation and generalisation. As Moynihan² has said, Harvey's discovery was due to his application of the experimental method of Archimedes and Galen to a problem of which many factors were already known; and Harvey himself realised and acknowledged his debt to Aristotle, to whom he was wont to refer as his "great leader"

Harvey's discovery was based on his conception of the heart as a muscular pump forcibly propelling blood to the furthest limits of the vascular system—"it is a necessary conclusion that the blood in animals is driven with a kind of circular motion; that it is in ceaseless movement; that this is the action or function

of the heart performed by its pulsation; and that the movements and pulsation of the heart are its sole and only cause.³ Harvey conceived the blood as passing from the arterioles through pores in the tissues, and thence being carried back to the heart by the veins. He did not see the capillaries—the microscope was yet to be.

At the entrance of the vena cava into the right auricle—just where, in later days, Keith located the sinus node, Harvey imagined a sudden expansion of the inflowing blood to take place, under the influence of its own innate heat. Later in life, he transferred the "seat of innate heat" from the heart to the blood; yet his own experiments negatived this idea of the expansion of the blood.—he was well aware that the excised heart may long maintain its pulsations.

Naturally, Harvey's views had a mixed reception. Men had a feeling that, once accepted, so important a discovery must change all the usual conceptions of disease, and as Roche says, "Truth scarce ever yet carried it by vote anywhere at its first appearance". The opposition encountered came chiefly from the more conservative members of the old school, and from the "superior persons" of Disraeli—these "fixed in academic tradition and swathed in formulas". In France the hostility was extremely bitter, and the "Exercitatio Anatomica" was termed "the fiction of an ingenious narrator". In Italy, Caesar Cremoninus, a Professor at Padua, wrote, in opposition, a long book justifying

the views of Aristotle: the general experience was that of Sir William Petty - "I have not met with one man that put an extraordinary value on the book" In the teeth of such criticism, adoption of the Harveian creed implied a very real degree of moral courage. De Back of Amsterdam well depicts the dilemma of contemporary teachers - "Must Hippocrates be left, Galen slighted?" But Harvey's ideas gradually gained ground, and when, some fifty or sixty years later, with the advent of the microscope and its application to medical research, Malpighi and Antony von Leeuwenhoek actually saw the capillaries and the contrary direction of the blood flow in arteries and veins, there was no further room for doubt. The circulation as we know it had been established, and subsequent investigation was to be directed to the elaboration of these fundamental principles.

Modern methods of physical examination came to be applied to cardiology in the 14th and 18th centuries. In 1461, Leopold Auenbrugger, a Viennese physician, introduced chest percussion, while in 1819 R. V. H. Laënnec described his invention of the stethoscope; these innovations made possible a much more accurate investigation of heart function.

As long ago as 1833, Donnell showed that the pulse rate is normally slower in the recumbent posture than in the erect. Wenle in 1841, investigated the question of the innervation of the heart, and Weber in 1845, discovered the inhibitory power of the vagus. Bezold, in 1862, found that the heart's accelerator supply took origin in the spinal system. Meanwhile Stannius had in 1852,

performed his famous "ligature" experiment, and the Medical World had already begun to watch with intense interest the wonderful work of Ludwig.

Garrison quotes Hauser Brunton as saying that "more than to anyone else from the time of Harvey do we owe our present knowledge of the circulation to Carl Ludwig"⁴ In 1844, Ludwig invented the kymograph, in 1848, he described the ganglionic cells in the inter-auricular septum. About 1855, he introduced the idea of perfusion, and Ringer's discovery that saline solution can maintain pulsation in the excised heart greatly widened the scope of experimental Physiology.

In 1866 Ludwig investigated the effects of temperature on cardiac pulsation, and in the same year described the depressor nerve of the heart, and the nerve erigentes of the peripheral vessels. In 1864 he invented the stromuhr, and in 1868 he found that the first systolic heart-sound is not of valvular origin only, but is partly produced by the cardiac muscle. In 1841-3 he discovered the vaso-motor centre in the medulla oblongata, and in 1844, he introduced plethysmography. Even from this mere outline of such of his work as directly concerned heart action, it will be seen that Ludwig's contribution to medicine was invaluable; but his was a much wider sphere, and many of the papers published under the names of his pupils are in reality the work of their master.

In 1869-70 Hauder Brunton began the investigation of the effects of drugs on the heart's action. In 1841 Bowditch introduced the "all or none" theory of cardiac contraction, and in the same year Wronnecker demonstrated that the heart muscle cannot be tetanised.

Waller, in 1889, pointed out the variation of action currents in the living heart, thus opening up a line of research which was to be the basis of much accurate work with the advent of Prof. Einthoven's string galvanometer some twenty years later.

Gaskell in 1886, had worked out the question of vascular innervation, and shown that the nerve supply of the heart is the same in cold- and warm-blooded animals; he had propounded the view that the heart-beat is due to the inherent contractility of its muscle alone, and this myogenic theory was confirmed, in 1893, by the discovery, by His, of the narrow band of muscle, an embryonic rest, which acts as a bridge for contractile impulses, and is now associated with his name. Erlanger in 1895 investigated cardiac rhythm, and in 1904 Keith located the sinus node just below the entrance of the superior vena cava into the right auricle, recognising in it the pacemaker, the point from which originated the normal stimulus to heart contraction; while Yawari in 1908 discovered the atrio-ventricular node in relation to the bundle of His.

At this stage we may consider the present-day attitude towards the question of cardiac function. Engelmann has shown that the function of the heart muscle is a complex one; he enumerates five phases which may be summarised (a) impulse formation (b) irritability (c) conduction (d) contractility and (e) tonicity. The trend of recent thinking in regard to the heart's action is in favour of this myogenic theory of Gaskell and Engelmann. As Barton⁵ points out, a perfect method of estimating cardiac function would be one in which all these five factors could be taken into consideration. But this is Utopian, and cardiology is at present being investigated along two main lines, the methods employed being the instrumental and the functional.

Among the instruments more commonly used may be mentioned the sphygmograph, the sphygmomanometer, the electro-cardiograph, and the polygraph. All these instruments have contributed largely within recent years to our knowledge of both normal and perverted heart function. In his book on cardiac disease, Mackenzie claims for the polygraph - perhaps the most generally useful of the series - that it has not only opened up a new chapter in diseases of the heart, but revolutionised the study and investigation of its physiology. But even the most perfect of these is a potential source of instrumental error, and to all applies in some measure the spirit of Sahi's condemnation of the sphygmomanometer -

The attempt to estimate the condition of the circulation from blood pressure measurements alone is futile - the information derived therefrom is static rather than dynamic"⁶.

The abuse of these mechanical aids has led to a reactionary scramble in the other direction, and to-day the method of investigation which finds most favour is the functional - how much work can the heart do? "The healthiest trend of modern medicine", said Lewis lately, "is to dispense as far as possible with special methods of investigation in dealing with the everyday patient." ⁷ To Rosenbach is generally given the credit of introducing the idea of these functional tests. This method of research, associated mainly with the names of German observers, has been worked out with characteristic Teutonic thoroughness. These tests depend chiefly on the reaction of the heart muscle to various types of exertion, active or passive, and on the response of the heart to reflex stimulation; they are therefore largely parodies on the work of Harvey and Ludwig. They are based on previous experiment and discovery - Graupner's tests, for example, in which blood pressure observations are used as a criterion of cardiac function, is founded on the observation of Masing that normal blood pressure rises during exercise and falls immediately afterwards.⁸

Against these methods we have the fact, emphasised by Herz that the cardiac phenomena produced by exertion tests

are varied by the type of effort attempted, while the influence of psychic effects in interfering with the results must always be remembered.

The heart can no longer be regarded as a thing apart, and we must realise the clear relationship between the circulatory and other systems. Intestine, lungs, endocrine glands, and kidneys - to mention only a few - all influence the action of the heart; the intimacy of this inter-relationship is well borne out by Waldman's recent contribution to the literature of the subject.¹⁰ The high blood pressure of nephritis, or the tachycardia of exophthalmic goitre cannot be regarded as evidences of inherent weakness of the myocardium. They are rather the expression of cardiac adaptability; compensation is typical of the heart's high function.

Our knowledge has advanced, and the steps of our progress have been the discoveries of our predecessors. Aristotle with rare skill figured out large but detached fragments of the picture. Galen widened the view; interested onlookers - Erasistratus, Serapion, Columbus, Fabricius picked up stray pieces and laid them in their places. Harvey mapped out the central theme supplying the key: and from his time less accomplished artists have been trying to complete the unfinished canvas. Much remains to be done - the cry is still for a fuller physiology; may we not yet be able to probe the mystery of "inherent contractility" The expectation that we shall achieve this end is consistent with the march of progress, for, as Harvey himself said, "Mind begets mind, and opinion is the source of opinion".

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