however including Mr. Arbuthnot Lane—are inclined to jog along in the old-fashioned way. You have a fine big pathological building but there seemed to be very few workers in it." It may be of some interest to say a few words here about Dr. Douglas, who was the grandfather of Mr. Lewis Douglas, lately American Ambassador to Great Britain.

He was the son of a Scots doctor who after qualifying in Edinburgh and London migrated to Canada where he became the leading surgeon. He was unfortunate enough to get into difficulties over some mining properties at an age when he could hardly hope to extricate himself from his commitments, and his son, Dr. James Douglas, therefore made himself responsible for them, threw up the professorship of chemistry which he then held and went into business, becoming one of the richest men in the States. He spent £250,000 on the Memorial Hospital, New York and, in addition to this, vast sums in other directions. This was the largest sum spent on cancer research up to that time and it should really have come to Guy's.

Leonardo da Vinci, and the Movement of the Heart

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In October 1517 Cardinal Luis of Aragon, with his Secretary, paid a visit to Leonardo da Vinci in his house in one of the outlying parts of Amboise. Here they were shown various pictures, and the Secretary notes of the visit:

"This gentleman has written of anatomy with such detail showing by illustration the limbs, muscles, nerves, veins, ligaments, intestines, and whatsoever else there is to discuss in the bodies of men and women, in a way that has never yet been done by anyone else. All this we have seen with our own eyes; and he said that he had dissected more than thirty bodies both of men and women, of all ages. He has also written of the nature of water, of diverse machines and of other matters which he has set down in an infinite number of volumes all in the vulgar tongue, which if they should be published will be profitable and very enjoyable" (MacCurdy, 1938, quotation).

The "infinite number of volumes" referred to were taken by Francesco Melzi who treasured them to the end of his life, that is to say for fifty years until 1570, in his villa at Vaprio near Milan.

The anatomical manuscripts through Pompeo Leoni found their way to Spain. The next we hear of them is their discovery at Windsor when Mr. Dalton, the King's Librarian, informed William Hunter, who in 1784 requested permission to examine them. He comments:

"I expected to see little more than such designs in anatomy as might be useful to a painter in his own profession. But I saw, and indeed with astonishment, that Leonardo had been a general and a deep student. When I consider what pains he has taken upon every part of the body, the superiority of his universal genius, his particular excellence in mechanics and hydraulics, and the attention with which such a man would examine and see objects which he was to draw, I am fully persuaded that Leonardo was the best anatomist at that time in the world."

Though William Hunter hoped to publish engravings of these anatomical figures, he died before this was accomplished, and not until 1916 was such a publication completed.

Leonardo's known manuscripts consist of over 5,000 pages, the largest part of which is on mechanics. There are some 190 pages on anatomy of which about 50 or 1% of the whole are on the heart.

Leonardo's approach to anatomy was essentially that of an illustrator. As comparison with the anatomical figures of his day makes clear, he was the first to make naturalistic representation of the organs of the body, including many of the heart.

With regard to physiology his approach was governed by three main lines of thought. First, he accepted the fundamental Galenic principles but stripped them as far as he could of all their occultism. Secondly he substituted for the occult powers of Galen four mechanical powers:

"Force with material movement and weight with percussion, are the four accidental powers in which all works of mortals have their being and their end" (Arundel MSS. No. 263, 151).

"I have drawn up the rules of the four powers of nature without which nothing through her can give local movement to these animals" (Quaderni d'Anatomia **1**, 1).

Leonardo considered that it is on the basis of friction produced by these powers, that heat, the basis of life, emerges. He devoted much study to the phenomenon of friction with heat production, in solids and liquids. The relationship of heat to life is made clear in his statement:

"Where there is life there is heat; where there is vital heat there is movement of the watery humours" (Codice Atlantico, 80).

In Leonardo's view the essential function of the heart was to produce the heat of the body. This it did by friction of the blood inside it, which was thrown from auricles to ventricles, rather like milk in a churn.

The third great principle of Leonardo's physiology was the application of the analogy between macrocosm and microcosm.

"Man has been called by the ancients a lesser world, and indeed, the term is rightly applied, seeing that man is compounded of earth, water, air and fire, this body of the earth is the same. And as man has within himself bones as a stay and framework for the flesh, so the world has the rocks which are the supports of the earth; and as man has within him a pool of blood wherein the lungs as he breathes expand and contract, so the body of the earth has its ocean, which also rises and falls every six hours with the breathing of the world. As from the said pool of blood proceed the veins which spread their branches through the human body, in just the same way the ocean fills the body of the earth with an infinite number of veins of water" (MS. A. 54).

A subject to which Leonardo gave great attention was the number of ventricles of the heart. According to Galen, and accepted by Avicenna and Mondino, the heart consisted of two ventricles into which the vena cava and arteria venalis (i.e. the pulmonary veins) opened by dilated mouths. Small auricular appendages were recognized, and thought to accommodate superfluous blood and air. Leonardo himself attached great importance to the discovery that, as he said:

"The heart has four ventricles, that is to say two upper ones, called auricles of the heart, and below them two lower ones called the right and left ventricle" (Quaderni d'Anatomia **2,** 17).

He writes extensively on such problems as:

"Why the auricles on the ventricles of the heart were made" (Quaderni d'Anatomia **2,** 3); "whether nature could make the right ventricle larger and abandon the upper ventricle or not" (Quaderni d'Anatomia **1,** 4). He discusses the Galenic contention that there are only two ventricles under the heading "reply to the adversary against the number of ventricles, saying there are two and not four". And he devotes a whole page of manuscript proving "how the upper ventricles are not one and the same with the lower" (Quaderni d'Anatomia **1,** 3).

Corresponding with this discussion are drawings which show how his appreciation of the anatomy of the auricles, or atria, developed, culminating in the illustration shown in Fig. 1. This was drawn probably about the year 1513 towards the end of his life.

Much of Leonardo's discussion is devoted to the subject of the function of the newly discovered auricles or upper ventricles. This he considers to consist of contraction, throwing the blood into the lower ventricles, and dilatation as they receive the blood thrown back into them from contraction of the lower ventricles on each side. In this way, the blood was heated

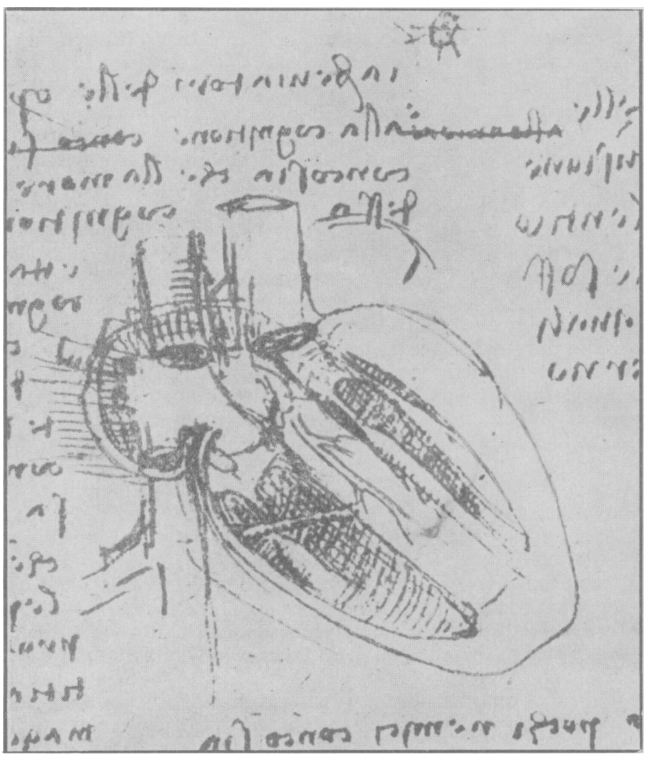

FIG. 1.—Dissection of the heart displaying the right atrium, right ventricle with moderator band, the anterior descending branch of the coronary artery, and the left ventricle, with papillary muscles and cordæ tendinæ attached to the aortic cusp of the mitral valve (Quaderni d'Anatomia **2,** 14).

before its distribution through the vessels, both arteries and veins, to the organs and tissues of the body.

Though Galen and his successors had considered the heart to consist of a special tissue, Leonardo came to the conclusion that the heart was a muscle, saying:

"The heart is a principal muscle in respect of force" (MS. G. 1), and he goes on to look for its nerve supply and examine its blood vessels as for any other muscle.

In illustrating the structure of the left and right ventricles he used an inflation technique to bring into relief the papillary muscles, trabeculæ carnæ and moderator band.

"Before you open the heart inflate the ventricles of the heart, beginning from the aorta, and then tie them up and consider its quantity. Then do similarly with the right ventricle and right auricle; and thus you will see the shape of that which was created to dilate and contract itself and to revolve the blood" (Quaderni d'Anatomia **4,** 13).

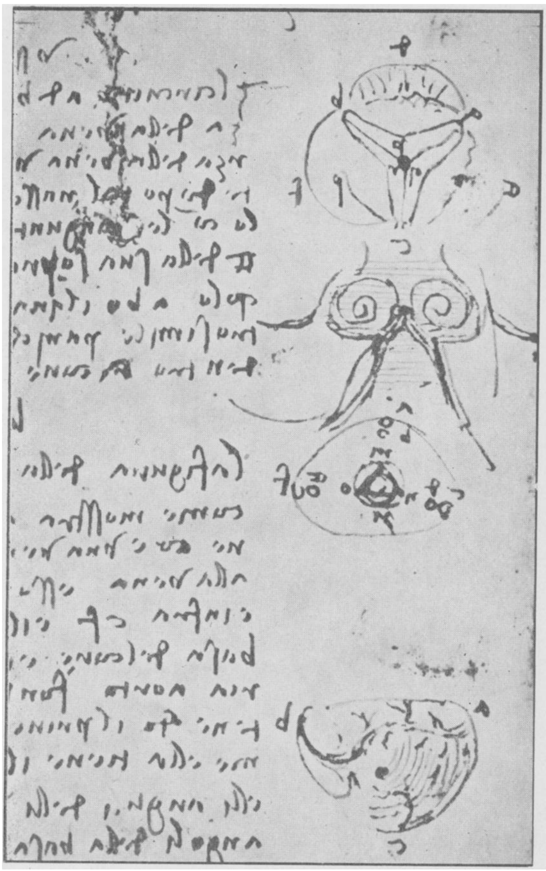

FIG. 2.—Diagrammatic sketches of the aortic valve, showing its triangular shape and the eddies of blood which effect closure of the cusps (Quaderni d'Anatomia **4,** 14).

The papillary muscles, particularly in the left ventricle, are repeatedly drawn. Leonardo considered that their contraction caused shortening and widening of the heart in diastole; at the same time the cordæ tendinæ drew down the valve cusps to permit the inflow of blood from the auricles.

In a well-known experiment in which he observed the peasants of Tuscany killing pigs by driving a borer or "spillo" into the heart, he noted the movement of the handle corresponding to systole and diastole of the pig's heart. Though he observed correctly from these movements that the heart shortens in systole he failed to follow up these observations and still continued to believe that the cardiac impulse was produced by narrowing and lengthening of the heart—as was the Galenic tradition.

In his studies of the valves of the heart, Leonardo devoted most attention to the tricuspid and aortic valves which are repeatedly drawn open and closed. His conception of the function of the heart valves was that "always the valves of the heart, on the shutting of the heart, give passage to a quantity of blood first before they shut from within outwards" (Quaderni d'Anatomia **2,** 4). In the case of both the tricuspid and mitral valves he considered that this shutting was "perfect".

Galenic physiology considered that the mitral valve, having only two cusps, was imperfect. Air was supposed to be sucked from the lungs along the arteria venalis (pulmonary veins) directly into the left ventricle on diastole. Leonardo, as a result of his dissections of the bronchi and pulmonary vessels, as well as the experiment of inflating the lungs with bellows without producing any such passage of air, concluded that no air entered the left ventricle. His descriptions of the movements of the mitral and aortic valves confirm that he appreciated that blood and blood alone was concerned in their movements.

In his study of the aortic valve he made the experimental approach of constructing a model by pouring wax into a bull's aorta. He makes a glass cast of the aorta and describes "the form of the glass, to see in the glass, what the blood does in the heart when it shuts the openings of the heart" (Quaderni d'Anatomia **2,** 6).

Approaching the subject of the currents of blood in the aorta, he used the analogy of water spouting out of a pipe. Noting that the orifice of the aorta was triangular he observed that there were three laterally deviating currents of blood which impinged on the walls of the aorta entering the hollows, or sinuses, later named after Valsalva, and that these streams of blood returned towards the centre making impact on the valve cusps from below and from the side, closing them together in a vertical plane (Fig. 2).

"The heart is a vessel made of thick muscle, vivified and nourished by artery and vein as are other muscles"—was the point of view from which he dissected the coronary arteries, which are clearly shown arising from the aorta (Fig. 3) and followed out in detail through all their main branches, accompanied by the veins.

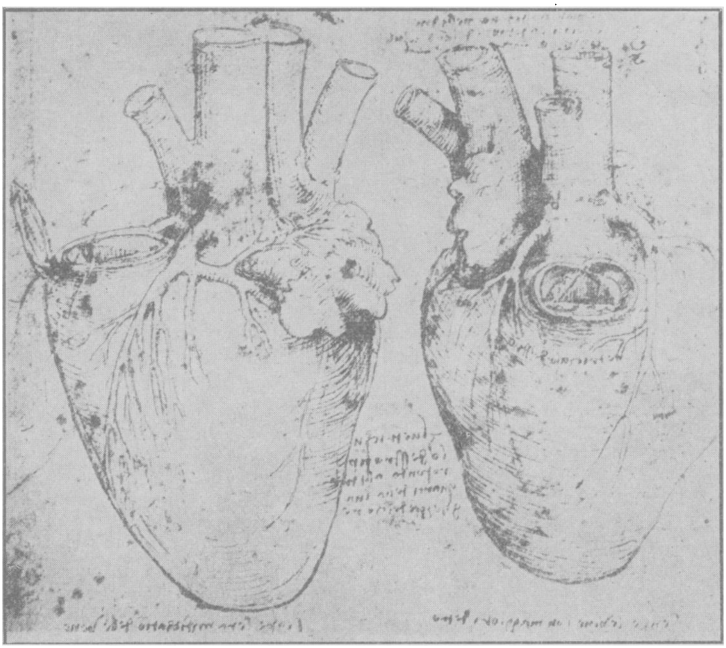

FIG. 3.—The origin of the coronary arteries and their course in relation to the pulmonary artery in a bullock's heart (Quaderni d'Anatomia **2,** 3).

The blood vessels of the body were dissected and illustrated by Leonardo in such a manner as to suggest that he followed Avicenna's Canon with conscientious accuracy.

During the course of his dissections, Leonardo came across the condition of arteriosclerosis and asks "why the vessels in the old acquire great length and those which used to be straight become bent, and the coat thickens so much as to close up and stop the movement of the blood, and from this arises the death of the old" (Dell' Anatomia Fogli B.10).

He suggests in answer to this question that the vessel wall swells as a result of absorbing increased nourishment from the blood.

Another pathological feature he noted was a hole in the atrial septum in the region of the foramen ovale. He writes "I have found from a, left ventricle, to b, right ventricle a perforated cavity from a to b, which I note here to see whether it is the same in the other auricles of other hearts" (Quaderni d'Anatomia **2,** 11).

Leonardo attempted to substitute the four powers of "force", "material movement", "weight" and "percussion" for the occult forces so freely invoked by Galen to account for the movement of the heart and blood. There is no doubt, however, that he accepted the Galenic pattern of movement of the blood towards the periphery where it was consumed by the organs and tissues. This movement was accomplished according to Leonardo by three factors, heat being the most important, moving blood in the same way as fire carries smoke up a chimney, against gravity. The heart beat was of importance, and "natural gravity" played a role. Blood (cooled at the periphery) returned to the heart and superfluous blood, according to his idea, was excreted into the bowel, forming part of the fæces. He was thus a long way from the conception of the circulation as Harvey demonstrated it.

This failure has rather obscured the real advances that he made. As an illustrator of cardiac anatomy his drawings bear, with credit, comparison with any until recent years. He himself, judging from the amount of attention devoted to them, was most interested in his discovery of the auricles, or atria, as "upper ventricles" of the heart, and his investigation into the movements of the blood in eddies through the aortic valve.

For his achievements Leonardo surely merits a greater place in the history of cardiology than has up to the present been allowed him.

The illustrations are reproduced by gracious permission of H.M. the King.

The author hopes to produce a full account of Leonardo da Vinci's work on the heart in book form.

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[*January* 3, 1951]

The Lifework of William Harvey and Modern Medical Progress

By H. P. BAYON, M.D.

An essay to commemorate the tercentenary of the publication of *Exercitationes de Generatione Animalium*, London, 1651.

THE biography of William Harvey (1578–1657) has been so frequently examined in books and articles, and his opinions so often discussed in many orations that it might be assumed that no matter of any relevance has been overlooked. Still, it must be conceded that, beginning in his lifetime, an unfortunate controversy about the priority of the recognition of the circulation of the blood and similar non-essentials has been continued with great vigour, if not acrimony, whilst the cardinal significance of the methods he consistently practised and the doctrines he propounded have been misunderstood, if not ignored.

To-day, three centuries after his lifetime, we are in a position to appraise the influence of his writings, as a whole, on succeeding generations; more particularly we can decide whether his example inspired any researches or produced any results of medical significance. It will be of interest to try and ascertain how and to what extent Harvey succeeded in leading others to undertake those experimental researches to which we owe much of the contemporary scientific achievement and the triumphs of present-day biological medicine. It will not be denied that our diagnosis is more accurate, our therapy much more effective, our prognosis and prevention assured to a greater degree than they were in the days of Molière (1622–73).

It is intended to show that this progress is the direct outcome of the methods so successfully advocated and practised by William Harvey.

A few examples taken at random will illustrate the prevalent opinion shortly after the death of Harvey—and possibly even later—on the question of whether he played any part in furthering medical progress. Fontenelle (1657–1757) in his *Dialogue des Morts* (Paris, 1683) made Erasistratus say that whatever might be the real course of the blood-stream, mankind would continue to die. Or Sir John Floyer (1649–1734) who in the Preface to his book on the Pulse-watch stated: "Dr. Harvey gave the first credit if not the first rise of the opinion about the Circulation of the Blood, which was expected to bring in great and general innovations into the whole practice of physic, but it had no such effect" (London, 1707–10). Then William Hunter (1718–73) in *Two introductory lectures etc.* (1784), p. 47—in comparing the merits of Harvey with those of Christopher Columbus and Copernicus—wrote that the achievements of Harvey must rank comparatively low, because so much had been discovered by others, that little remained for Harvey but to dress it up into a system. These criticisms were related to the action of the heart and the circulation of the blood, but even more severe observations were those of Jan Swammerdam (1637–80) who in his *Historia insectorum generalis* (1699) asserted that Harvey, in studying the generation of animals, had, in his senile decrepitude, incoherently mixed truth and error, accuracy and falsity.