THE

VALVULAR STRUCTURE

OF

THE HEART,

ANATOMICALLY AND PHYSIOLOGICALLY CONSIDERED,

WITH A VIEW TO EXEMPLIFY OR SET FORTH,

BY INSTANCE OR EXAMPLE,

THE

WISDOM, POWER, AND GOODNESS OF GOD,

AS REVEALED AND DECLARED IN

HOLY WRIT.

THE WARNEFORD PRIZE ESSAY,

FOR THE YEAR 1841.

BY

WILLIAM FRENCH CLAY,

OF MAGDALENE COLLEGE, CAMBRIDGE,

AND LATE STUDENT OF THE BIRMINGHAM ROYAL SCHOOL OF MEDICINE AND SURGERY.

"I will praise thee; for I am fearfully and wonderfully made: marvellous are thy works, and that my soul knoweth right well."—*Psalm* cxxxix, 14.

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TO THE

REV. JAMES PRINCE LEE, M.A.,

HEAD MASTER OF THE BIRMINGHAM ROYAL FREE GRAMMAR SCHOOL, AND FORMERLY FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

REV. SIR,

I feel happy in being allowed to dedicate the following pages to you, not only because you preside over that Royal Scholastic Establishment, to whose interests my late Father devoted his best energies during a period of twenty-four years, but also because I am fully convinced that the association of such a name as yours with a "WARNEFORD ESSAY," will prove a far more suitable testimony to the high merits of its munificent founder, than the most laudatory expressions which my gratitude towards that revered individual can adopt.

With every sentiment of cordial respect,

Believe me to remain,

Your obliged and faithful servant,

W. FRENCH CLAY.

Birmingham, July 22, 1842.

ESSAY.

"To combine religious with scientific studies and pursuits" was the great end which the founder of this essay had in view, when, with a beneficence not more pious than patriotic, he instituted an annual prize, for the purpose of promoting the religious as well as the professional advancement of medical students—of making them, in short, good christians as well as able practitioners. It was his wish that the subject should be taken out of some branch of Anatomical, Physiological, or Pathological Science, and that it should be treated, "not only in a professional manner, according to those evidences which Anatomy, Physiology, and Pathology so abundantly supply," but for higher purposes; not with the coldness of mere speculative philosophy, but "always and especially with a view to set forth, by instance or example, the wisdom, power, and goodness of God, as revealed and declared in Holy Writ."

Impressed with a sense of the natural weakness of man's powers, and the narrowness even of his most expanded views, when contemplating the mighty domain of God's mysterious works; and with a deeper conviction of my own inability to furnish resources suitable for an undertaking which involves so much of theological and religious import, I feel that I must look for His aid in whose hands are all the physical and intellectual powers of man, before I enter upon a subject so exalted as the glory of the divine attributes, —comprehending, as they do, an empire no less boundless than that of creation.

But, although sensible that God's ways are above our ways, and His thoughts above our thoughts, even as the heavens are above the earth, I nevertheless perceive that a legitimate field is opened wherein to exercise that desire of knowledge, and those powers of obtaining it, which have been vouchsafed unto me. And how, I would ask, can the mind of man be more nobly or usefully employed, than in the contemplation of the works of "Him in whom we live, move, and have our being," or in humbly admiring His divine attributes? Neither can there be a purer gratification to the reasoning or reflecting faculties of man than to love, venerate, and praise our omnipotent Creator, who is the centre of power, the source of life, as well as the author of things visible and invisible.

It matters not in what part of that vast compage which unites all orders of beings and all objects of nature in one harmonious whole, we prosecute our enquiries—whatever may be the subject of our investigation, we are sure to elicit facts which supply most certain proofs of the universality of GOD's power, wisdom, and goodness! Revelation tells us, that "all things were made by Him, and that without Him was not any thing made that was made,"* and natural reason confirms what the word of GOD proclaims, whilst genuine faith acknowledges that all things declare the glory of their Creator. The animal, and the vegetable, with all the other systems to which we can possibly refer, compel us by their united testimony to assent to St. Paul's declaration, that "the invisible things of Him from the creation of the world are clearly seen, being understood by the things that are made, even His eternal power and Godhead."† Nay, the very heathen readily admitted—

> "Deum namque ire per omnes
> Terrasque tractusque maris cœlumque profundum."‡

But among the works of creation one has been ever held supreme, —the wonderful fabric—man! It may be said to praise with surpassing eloquence the author of its being, and to set forth His attributes of wisdom, benevolence, and power! But if, where all is so entitled to the most devout admiration, one single feature in the general organization of that wonderful fabric—the human system—may be selected for the mind to expatiate upon, I should be disposed to attribute superiority to those valvular provisions which secure the onward flow of the heart's blood, and give continuance and regularity to its pulsations.

The human fabric is so constructed as to require the nourishment of its various organs, and the due maintenance of its vital functions. There is, therefore, abundant provision made to repair the waste and restore the loss occasioned by causes that are ever operating towards debility and exhaustion—"nam omni motu partes solidæ teruntur fluidæ dissipantur corpus debile, macrum, exhaustumque, relicturæ."|| These principles are interwoven with the very texture and framework of the body; we find that materials suitable to such a purpose are elaborated by the digestive process, and, after being taken up by the lacteals, conveyed into and identified with the blood, and submitted in the lungs to the vivifying influence of the atmosphere, are driven through a set of tubes, called arteries, to every part and particle of the body, supplying each with such nutrition and substances as are necessary for its developement, growth, and maintenance, in a healthy condition. This transfer of the nutritious juices is mainly effected in man and the higher orders of animals, by the alternate contraction and dilatation of that fount of life, the muscular organ called the heart, which, acting as a forcing and suction pump, is constantly receiving from the veins and pouring into the arteries a continued stream that circulates throughout the system. A regular supply of the life-sustaining fluid is thus

* John i, 3. † Romans i, 20. ‡ Virg. Georg. iv. 221–2.
|| Gregory's Conspectus Med. cap. i.

conveyed even to the remotest recesses of the body, and that, too, from the earliest periods of life. From the second or third week of conception, even until death puts a period to existence, the vital current continues to flow. Yet this powerful engine, this essential mover of the whole bodily apparatus, could not for a moment fulfil its wondrous destination in the counsels of the Almighty, if certain bodies termed valves had not been most symmetrically adjusted, and most delicately appended to the internal structure of this presiding viscus.

If we extend our contemplations to the mode in which nourishment is diffused over bodies belonging to the lower grades of vital existence, we shall find this part of the vascular system variously modified and admirably adapted to meet the exigences of each individual species. The dissimilar media in which animals exist, require great modifications in this apparatus. If we descend into the lower tribes of animals, such as the Polypi, Asteriæ, &c., (no vessels being present) the current of the nutritious fluids over the body is effected in a manner similar to the motion of sap through the cells of those plants, which possess but a low organization, as the sea weeds. In the medusæ among animals, as in the higher orders of plants, vessels are found to contain as well as circulate the fluids, but without the aid of a heart: this mode of nutrition appears suited to the torpid nature of Zoophytes. In the articulated classes of animals the vessels still remain unprovided with any propelling pulsatory organ, but are furnished with a large dorsal vessel, possessing distinct muscular fibres, and endued with the power of pulsation. This vessel in insects has a remarkable sacculated appearance, and is provided with valves. Globular enlargements of a similar nature occupy the vascular system of the common Earth-worm, (*Lumbricus terrestris*) as also that of the Holothuria.

These appearances point out to us the next step in approximation towards the structure of the human heart. The vascular apparatus of the larger crustacea is still more diffused in ramifications, and still more perfect in form; and, as we proceed to trace this system onwards and upwards through those tribes of this class which possess a still higher degree of organization, we shall find that the influence which the dorsal vessel exerts becomes more confined to and concentrated in its anterior extremity, till in the Decapoda (which includes the lobster and crab) it assumes the appearance of an oval muscular organ, which may legitimately be called heart, and capable, from its powerful contractions, of forcibly propelling the blood into its vessels, which vessels are distinguishable into arteries and veins. The importance of a heart, as the chief agent in the circulation, increases as we ascend still higher in the scale of animals, and in proportion as the vital functions become more and more complex and energetic. The nutrient fluids now require to be diffused with greater rapidity; a further developement in its structure therefore becomes necessary; and so, in order that the blood may be driven with sufficient force to enable it to overcome the greater resistance which is now offered by the greater complexity of the arterial system, we find the heart to consist of two separate cavities, one termed ventricle, the other auricle, which latter (comparatively thin and lax) discharges the blood just received from the veins into the former—and thus the ventricle, being distended at once by the sudden contraction of the auricle, is enabled to close with greater rapidity, and, consequently, exerts a greater pressure on its contents than could possibly be supposed to have been done had only a single auricle existed, into which the veins emptied the blood gradually and with comparative slowness. The heart is thus made to possess extreme importance. It is, therefore, carefully deposited in a bag, called pericardium. It is likewise furnished with valves, whereby many advantages are obtained, and many ill effects prevented. This form of the heart is called " single," which, in some molluscæ, as also in fishes, (whose higher degree of organization and peculiar mode of existence require not only the distribution of blood over the system, but also its exposure to the atmosphere) propels the blood through the lungs, as well as over the body. In the Chelonian reptiles (as, for example, turtles and tortoises) the heart becomes still more complicate, having two auricles, one of which receives the blood that returns arterialized from the lungs; the other, the effete and vitiated blood, after it has completed its circuit of nutrition. This species, however, has but a single ventricle, where the two kinds of blood become mixed, and are again driven by this muscular organ through the lungs and over the body.

The circulatory apparatus, in the Ophidia or serpent tribe, is very similar to that of the Chelonia; there is, however, to be detected an approach towards a double circulation. Then may be discovered the rudiments of a septum in the ventricle. In the Sauria the complexity increases, for each of the auricles, as in the chameleon, possesses a large venous swelling, which assumes the appearance of two additional auricles. In the crocodile there are not only two auricles, but the ventricle is divided into three distinct compartments, which communicate freely with each other. This arrangement is said to direct the current of blood from the lungs, through those vessels which go to supply the head and muscles of the limbs, the other blood being made to traverse the arteries of the viscera. We now arrive at the warm-blooded animals, as birds and the Mammalia, whose frame, functions, and habits of life become still more complex and energetic than those before mentioned. The intermixture of venous and arterial blood now no longer takes place. It may be said that two " single" hearts are provided, under the same roof, one on the right side, for the purpose of propelling the blood through the lungs; the other on the left, to drive the blood received from the lungs over the system at large. Passing onwards through the superior orders of vertebrate animals, we at length arrive at man, in the construction of whose sanguiferous apparatus all those provisions which we have considered in the case of the inferior animals, whether warm or cold blooded, now attain a still more admirable, because more extended developement.

The human heart, like every other viscus of the body, may be treated as a subject of discussion in two ways—ANATOMICALLY and PHYSIOLOGICALLY.

If ANATOMICALLY considered, the heart may be defined to be a hollow muscular organ, of an irregular conical figure, situated obliquely in the thorax, between the anterior and posterior mediastina, overlapped by the lungs, inclining downwards, forwards, outwards, and to the left side in front of the spine, and behind the sternum; it is convex anteriorly, flattened posteriorly, where resting upon the central tendon of the diaphragm, and protected by its proper investing membrane, the pericardium. It presents an anterior and posterior surface, a right and left margin; the apex points downwards, forwards, and to the left, and, when at rest, corresponds to the sixth rib; the base looks upwards and to the right, separated from the spine by the parts contained in the posterior mediastinum. It is subject to a slight degree of change of position from the influence of the parts with which it is in contact. Violent contraction of the diaphragm carries it a little downwards, and it is pressed in the contrary way when the abdominal viscera are forced up by the powerful contraction of the abdominal muscles. It has been seen to sink deeper into the thorax during expiration, but again to approach the thoracic parietes when inspiration was effected. The apex recedes from the inner side of the left wall on the body being bent to the right side; when bent to the opposite one it approaches still more. Two grooves occupy its anterior and posterior surface—one taking a transverse, the other a longitudinal direction; they afford a lodgement for the vessels of the heart, and also indicate the division of it into four separate compartments, two of which have received the name of auricles, the remaining two that of ventricles: the auricles occupy the space *above* the transverse line; the ventricles are situated *below* this line; the veins terminate in the auricles; the arteries arise from the ventricles; on the right are placed an auricle and a ventricle; the same arrangement obtains on the left. The cavities of the same side communicate with each other, valves being interposed, which, when necessary, close this communication; those of opposite ones do not, except during fœtal life,—so that the heart may be considered as being made up of two distinct systems, one on the right side (cor pulmonale), consisting of an auricle and ventricle, for the purpose of driving black blood through the lungs—the other on the left side (cor systemicum), consisting of two analogous cavities, to circulate the fluid received from the lungs, through the arteries of the body.

It now remains to describe each of these cavities; and, in doing so, we shall adhere to their physiological relations, by considering, Firstly, The cor pulmonale, or right cavities of the heart; Secondly, The cor systemicum, or left cavities of this organ. In considering the pulmonic division of the heart, we shall commence with the auricle.

RIGHT AURICLE.

The right auricle rests upon the diaphragm, and occupies the right and anterior parts of the base of the heart; it consists of two parts, one of which is large, and occupies the intervening space between the openings of the two venæ cavæ, and, from its receiving the blood directly from these, has been termed sinus venarum cavarum; the other part is lodged between the right ventricle and origin of the aorta, appearing as a loose appendage to the general cavity, and, from some resemblance it bears to the ear of a dog, the term auricula is used to designate it. The right auricle in the greater part of its extent is free, but, internally, it becomes identified with the left. The lower part thereof *(i. e.)* of the right auricle is identified with its corresponding ventricle; behind are the orifices of the two venæ cavæ. The inner aspect of this cavity presents four surfaces;—a posterior, where the main venous trunks open; an anterior, formed by the auricular appendage, containing numerous muscular bands (musculi pectinati); an external, on which also are a number of muscular bands, similar to those mentioned; an internal, which is nearly smooth, forms the septum, or partition, between the two auricles. The superior vena cava opens at the upper and posterior angle, looking downwards and forwards; the inferior vena cava at the posterior and inferior angle, and is directed upwards and backwards. These openings are circular, that of the inferior being the larger. Around the left edge of the superior, as it enters, there is a band of muscular fibres; another, though less perceptible, is placed around the right posterior margin at the angle of junction with the right edge of the inferior vena cava. This forms what is now called, tuberculum Loweri. On the inner surface, just above the orifice of the inferior vena cava, is seen an oval depression, indicating the situation of an opening, which had existed during fœtal life, called fossa ovalis: it is limited by a prominent ring, annulus fossæ ovalis. The upper anterior margin of this depression being thickened, induced Vieussens to believe that it prevented the blood falling from the superior vena cava into the inferior, which Lower considered might be effected by the tubercle, or projection, which he discovered at the junction of the veins; the position, however, of their orifices, will alone obviate such an occurrence. The upper border of this depression is often found imperfectly united to the septum, which slightly overlaps it; thus obtaining a kind of valvular arrangement sufficient to prevent any communication being effected during the contraction of the auricles. Immediately above the margin of the inferior cava is a crescent-like fold of the lining membrane (valvula nobilis Eustachii), placed vertically, and extending up towards the annulus fossæ ovalis. This valve assumes various appearances in the adult; it is of considerable size in the fœtus, becoming gradually obliterated as age advances, and is, in old persons, almost indistinct. Its posterior surface looks towards the openings of the inferior vena cava, while the anterior corresponds to the cavity of the auricle; its free edge is somewhat concave, and occasionally reticulated. Below this, and between it and the opening into the ventricle, is situate the common orifice of the coronary veins, protected by a peculiar valve, of a semilunar shape, the free and concave margin of which is directed upwards; it is sufficiently broad entirely to close the opening, is occasionally reticulated, and, instead of one valve, there may be two or three, placed behind each other. Both these valves are produced by the lining membrane of the heart being doubled back upon itself; the Eustachian valve also frequently contains, at its fixed margin, some muscular fibres. Numerous small openings (foramina Thebesii) are to be observed in the cavity of the auricle; they are the terminations of minute veins. In the floor of the auricle is the opening into the right ventricle, about an inch in diameter, of an oval figure, on the circumference of which is fixed the base of the tricuspid valve, the remainder resting in the right ventricle.

RIGHT VENTRICLE.

The right ventricle is situated anteriorly, and to the right, extending from the right auricle to the apex of the heart; it is of a triangular figure, the base looking towards the auricles; its walls are considerably thicker than those of the last described cavity, owing to the increased quantity of muscular fibres which become requisite to enable it to propel the blood through the vessels of the lungs, while the auricle merely has to drive the blood received from the veins into the ventricle. The interior of the ventricle is very uneven, numerous depressions and elevations being observable in it: these are owing to the presence of a number of thick fleshy fasciculi, having a rounded appearance, called columnæ carneæ. These may be divided into three distinct sets, some attached at both extremities, while the intervening part is altogether free; others, less prominent, are attached by their extremities—as also by a considerable part of their circumference. The third set consist of several fleshy bundles, prolonged from the apex to the base of the ventricle, where they are connected with the borders and pointed extremities of the tricuspid valve, by means of several tendinous strings, called chordæ tendineæ. Two large openings are placed at the base of the ventricle; the larger is oval when the heart is relaxed, circular when distended, and forms the opening of communication between this cavity and the one before described; the smaller is circular, and situated in front of the former, (towards the left) being about three-quarters of an inch higher. This is the opening into the pulmonary artery; the part of the ventricle, from which this vessel arises, is prolonged upwards, having a smooth and funnel-shaped appearance, whence called by Cruvellier, " Infundibulum." To the circumference of the auriculo-ventricular opening is attached a circular-shaped valve, which soon becomes divided into three several processes, for which reason it has been styled " Tricuspid." The bases of these triangular processes are continuous with each other, while the remaining parts rest in the cavity of the ventricle; one of them corresponds with the septum, another with the anterior wall—while the third, which is the largest, inclines upwards, being interposed between the auricular and pulmonary openings. Their free edges are connected with a number of tendinous chords, the greater of which arise from the third kind of columnæ carneæ, some from the other two, and a few from the smooth part of the septum, particularly from the lower part of the surface, which leads to the infundibulum. They diverge as they pass to their insertion, some dividing and subdividing several times, occasionally crossing each other; the internal division of the valve has its lower margin tied more closely down to the surface of the ventricle than the other two. A valve is again placed at the pulmonary aperture, (though differing from the tricuspid) which consists of three crescent-like pieces of the lining membrane, whose fixed edges are attached to the tendinous ring at the orifice of the artery, while their free edges form two slight curves, owing to the presence of a fibro-cartilaginous tubercle, (corpora sesamoidea) placed near the middle of each. These pieces are convex towards the ventricle, and have their concavities directed towards the vessel, presenting the appearance of three pockets.

Having now described the pulmonic division of the heart, we shall pass on to consider the systemic portion thereof, which consists, like the one described, of an auricle and ventricle,—a valve being interposed.

LEFT AURICLE.

The left auricle is situated at the upper left posterior part of the heart's base. It is quadrilateral, of less capacity than the right, and receives the blood brought from the lungs by the four pulmonary veins which open into the angles of the auricle. This auricle, at its upper part (on the right) is connected with the auricle of the opposite side. At its base it is in conjunction with its corresponding ventricle. From the upper and left extremity the auricular appendage is prolonged, and in its interior presents musculi pectinati, similar to those described as existing in the appendage of the right auricle. The general cavity is smooth; on its inner side is the septum, where may be seen the depressions corresponding to the fossa ovalis. At the lower part of this cavity is the auriculo-ventricular opening, having the base of the vitral malve affixed to its circumference, the apices of which rest in the left ventricle.

LEFT VENTRICLE.

The left ventricle occupies the left half of the body and apex of the heart, one-third of it only being visible on the anterior surface, owing to the obliquity of the septum; it is not so wide, though longer and thicker. The circumference of the base of this ventricle is greater than that of the right, particularly when injected. The interior presents columnæ carneæ, which may be arranged into three sets, similar to those belonging to the right ventricle; they are, however, fewer in number; many of them are likewise less in extent, and are directed, principally, from base to apex. Two large fleshy fasciculi, produced by the combination of smaller ones, (which arise from the anterior and posterior surfaces) may be seen to proceed upwards and terminate in a blunted extremity, from which numerous chordæ tendineæ branch off, and are thence attached to the sides of a large valve called the mitral valve. In the base of the ventricle two openings are to be observed, placed close together. The smaller, situated anteriorly and to the right, is the commencement of the aorta; the larger, placed posteriorly and to the left, is the auriculo-ventricular opening;—these two orifices are separated from each other by a tendinous ring, and from the pulmonary artery by the upper part of the septum-ventriculorum. The origin of the aorta is provided with three semilunar valves, which, in their structure, position, and shape, resemble those placed at the commencement of the pulmonary artery; they are, however, stronger, and have the corpora sesamoidea more developed than those in the pulmonary artery; hence, they are capable of supporting a greater column of blood. To the tendinous ring, around the auriculo-ventricular opening, is attached a valve similar to that of the right side in structure, though differing from it in consisting but of two divisions, which, from some fancied resemblance it bears to a bishop's mitre, has obtained for it the name of mitral valve. The larger process of it looks towards the aortic opening, and is more moveable than the other.

Having now completed a description of the pulmonic and systemic divisions of the heart, we next propose, previous to entering upon a detail of their respective functions, to notice—

1st. The comparative thickness of the several cavities;
2nd. Their relative capacities; and
3rd. Direct the attention to their structure.

I.—First, then, in noticing the comparative thickness of the several cavities. Of the auricles, the left will be found rather the thicker—while, of the ventricles the thickness of the left, when compared with the right, is very considerable. Bouillard's observations determine the average thickness of the parietes of the left ventricle of four healthy hearts to be one and a half lines, while the right was only one line. Laennec, in estimating the relative thickness of the ventricles, considers the left to be to the right, as two to one. Sœmmering is of opinion that they are as three to one. Bouillard found that the average thickness of the base of the right was, in many cases, two and a half lines—while in the left, at the same part, it was seven. According to Bizot, the heart continues increasing in every dimension as age advances; that the heart of a male is, on an average, larger than that of a female, and that the left ventricle continues increasing to the latest period of life.

II.—Of the relative capacities of these cavities, so many and varied have been the statements, that it would, from them, be utterly impossible to arrive at any satisfactory conclusion. The dimensions of the auricles are certainly less than the ventricles; the right auricle is also considered to be larger than the left. The size of the right ventricle is generally found to exceed the dimensions of the left.

III.—We now proceed, in the third place, to examine the structure of the heart. It is composed principally of a muscular substance, which, together with its vessels, nerves, lymphatics, and a tendinous substance, is included between a lining and investing membrane. These will require a separate consideration, and, as the muscular fibres are attached to the tendinous substance, we will give to that material our first consideration. It may be observed that a zone of this tendinous substance surrounds each of the arterial openings, and consists of three lunated parts, level with each other, their convexities looking downwards towards the ventricles, and their concavities upwards—a complete ring being formed by the union of these said lunated parts. The semilunar valves are connected with the inner margin of the upper surface, the middle coat of the artery being attached to the outer, while to the lower part the muscular fibres of the ventricles are affixed. Surrounding each of the auriculo-ventricular openings is also placed a tendinous zone, from the lower surface of which the muscular fibres of the ventricles arise—from the upper those of the auricles. By far the largest part of the heart is composed of muscular fibres, having a very complicate arrangement, particularly in the ventricles. The greater portion of the fibres here is attached, at both extremities, to the tendinous zones; their direction is generally oblique, a few being vertical, but not in their whole extent, the lower fibres acquiring a more circular direction. The outer fibres are longer than those beneath them, and, turning round the apex, proceed upwards below the shorter ones, forming the inner surface of the heart; the lower fibres again overlap those beneath them, enclosing all the shorter ones. Some fibres are common to both ventricles—others belong to each ventricle exclusively; this is more especially so at the base. When the heart is divested of its covering, the outer plane of fibres, which encases both ventricles, will be seen to run downwards in a spiral form on the anterior surface—while on the posterior they are more vertical, and pass from left to right. This arrangement is also found to extend even to the apex. Beneath the outer plane is another layer of fibres, which pass in a direction the reverse of the former: this stratum extends but half the distance of the superficial ones. A third layer runs longitudinally from apex to base, becoming connected with the columnæ carnæ. The muscular fibres found in the auricles are comparatively thin and scattered; they form two layers, differing in their arrangement from those of the ventricles; the superficial fibres connect the two auricles together, while those not superficial have a separate lodgement in each auricle. In the right auricle there are also some circular fibres, which surround the entrance of the superior vena cava: the pulmonary veins in the left auricle are similarly invested. The heart is plentifully supplied with blood by the coronary arteries which encircle it. The blood distributed through these vessels, after furnishing the structure of the heart with its necessary support, is returned to the right auricle by the coronary veins. Its nerves are derived from the nervous system of organic life, and from the par-vagum. The lymphatics accompany the coronary vessels: some open into the thoracic duct, others into the right lymphatic trunk.

MEMBRANES OF THE HEART.

The right cavities of the heart are lined by a membrane, which is continuous with that of the venæ cavæ: in the auricle it closely adheres to the muscular fibres, between which it rests against the serous pericardium, being connected therewith by cellular tissue. Above the inferior vena cava it is folded upon itself, so as to form the Eustachian valve, and, still lower down, that closing the coronary vein is similarly produced. At the circumference of the auriculo-ventricular opening it separates from the muscular structure, and becomes doubled in such a manner as to produce the tricuspid valve; after which it entirely lines the ventricle, where its density becomes considerably diminished. From this cavity it is prolonged into the pulmonary artery, forming, at its entrance, the semilunar valves. The membrane of the left side of the heart is continued from the pulmonary veins into the auricle, which it lines without forming any fold, and then passes into the ventricle through the auriculo-ventricular opening, where it produces the mitral valve. It is afterwards prolonged into the aorta,—forming, as it enters this vessel, the sigmoid valves: it is then continued through all the arteries of the body.

Lastly, the heart is encased in a membranous bag called the pericardium, and which claims a passing notice.

The pericardium consists of two distinct layers—an external, or fibrous—an internal, or serous. The fibrous membrane closely adheres, at its base, to the cordiform tendon of the diaphragm, at which point it is the broadest. Its upper part is prolonged over the primitive vessels, producing for each, except the inferior vena cava, a kind of sheath, which gradually becomes identified with the cellular coat of the vessels. The serous membrane, after lining the fibrous one, is reflected over the heart, together with a portion of the large blood vessels, after the manner of serous membranes in general. The pericardium appears to be the means of restraining any irregularities of action; besides which it secretes and contains a fine halitus or vapour, that lubricates the heart, thereby assisting its healthy and customary motions.

Having thus completed the Anatomy of the Heart, we shall proceed, in the second place, to discuss it PHYSIOLOGICALLY, for the purpose of exhibiting those important functions which belong to the heart's valves, and thereby be better able to " set forth the wisdom, power, and goodness of GOD."

A constant supply of a nutritious fluid, beneficially effected by the atmosphere, and then diffused throughout the bodily system, is an indispensable condition for the continuance of human life: wherefore, the blood collected from the lungs is conveyed in all directions, nourishing the various organs and sustaining their vitality—after which it is returned exhausted and contaminated, that it may be reinforced by the products of digestion. Peculiar chemical changes are then effected in the lungs, which restore vitality to the blood, and render it fit for the purposes of another diffusion. In the former case the blood flows through the right cavities of the heart—in the latter through the left—the rythmic action of which organ gives motion to it. Furthermore, it is essential that the blood, when submitted to the action of the heart, should not move in a retrograde manner; nor can it, in consequence of the intervention of valves, which, like flood-gates, permit the onward passage of the fluid in one direction, but preclude it from flowing back, or regurgitating.

The manner in which valves act may be instanced by the piston valve of the common pump, which, from its construction, is with facility forced up by the fluid which rushes in to fill the empty space, although it cannot return through the same aperture. It is through the interposition of valves in the veins that a due return of the blood to the heart is ensured. They also play an important part in other organs of the body, as the intestines and thoracic duct. Valves generally consist of folds of the lining membrane, so disposed and arranged as to lie close against the side of the cavity, while the contents pass in one direction; but should they have any tendency to take an opposite course, these processes of membrane are forced from the sides and spread out, the fluid insinuating itself between the valve and the wall of the cavity, and thus intercepting the passage.

But to return to our former consideration. The passage of the blood over the body has been divided by Physiologists into the greater and lesser circle: the former or systemic represents its course, from the left ventricle through the arteries of the body, and back by the veins to the right auricle; the lesser, or pulmonic circle, represents its passage from the right ventricle, through the pulmonary arteries, to the lungs, returning by the pulmonary veins to the left auricle. The heart being the principal agent in carrying on this circulation, is therefore essentially a muscular organ; and from the arrangement of its fibres, it is calculated, in the highest degree, to effect that contraction so necessary to propel the blood through its vessels. From the importance also of securing for it the influence of the atmosphere, it is constructed in man, and all warm-blooded animals, with reference to another system, viz., that of respiration; so that it is made up, as was shown, of two distinct hearts under the same roof—one subservient to the pulmonic, the other to the systemic course of the blood. Each of these hearts consists of an auricle and ventricle;—the auricle receives the blood from the veins, and transmits it into the ventricle, the ventricles being the stronger muscular cavities, and therefore appointed to propel the fluid into a single arterial tube. These cavities are alternately contracted and expanded. This state of contraction is termed systole, while the state of expansion is called diastole. The two ventricles contract simultaneously, and the two auricles likewise; but the contractions of the auricles and ventricles do not synchronize, nor do they "alternate in action, at equal intervals, like the motion of a pendulum: but that the time which intervenes between the contraction of the auricle and that of the ventricle is much less than that which elapses from the moment of the contraction of the ventricle to the moment when the auricle again acts."* The contraction of the auricles may be said immediately to precede that of the ventricles.

The systole of the heart takes place with considerable force, the muscular fibres being in a state of active contraction. The diastole is also attended with some degree of vigour, which induced Pecklin, Perrault, and their adherents, to attribute this, together with the systole to an active movement. Bichat, Dumas, and other French Physiologists, maintained the same opinion. Oesterreicher, however, by an ingenious experiment, has recently proved their assumptions to be erroneous; so that the contraction alone is active, the dilatation being altogether passive, inasmuch as it constitutes the moment of repose, when the fibres are relaxed and the blood rushes into the heart's cavities to fill the space, where, otherwise, a vacuum would occur, the valves being so disposed as to allow its entrance.

* See Elements of Physiology, by J. Müller, M.D., translated by W. Baly.

When the ventricles of the heart contract upon their contents, the blood would not only be driven into the arteries, but also forced back again into the auricles, thereby defeating the purposes in view. Hence, it became necessary that some security against this retrograde movement should be provided. Accordingly, we find valves interposed, the construction of which exhibits a most brilliant display of mechanism. The peculiar conformation of the parts between the auricle and ventricle, in this situation, renders the general construction of valves inapplicable,—and, consequently, a different one has been adopted. These valves consist (as was shown while treating our subject anatomically) of two or three processes of the lining membrane, having their fixed edges attached to the circumference of the auriculo-ventricular opening, while their free extremities lie in the cavity of the ventricle. By means of this arrangement they are enabled to fulfil their function, opening a passage to the current in one direction, but are forced from the sides of the cavity so as to close the orifice the instant the ventricle contracts. One thing, however, yet remains, in order to their being complete; for, being affixed around the opening of communication, between the auricle and ventricle, it would appear that the contraction of the latter cavity would cause the fluid to carry the valves up into the auricles, and so permit the blood to flow in a direction the reverse of that which is essential; consequently, we find that such an introversion of the valves is guarded against by a most wondrously wise provision, consisting of little slender ropes, connected, at one extremity, to the sides and points of the valves—while, at the other, they join the fleshy pillars in the cavity of the ventricle. By this means the valves are prevented from going beyond their proper limit, and their motions are duly regulated. Some obscurity exists as to whether they are repelled from the sides of the cavity, the chordæ tendineæ merely limiting their movements, or whether (according to the views of Mayo, Bouillard, and others) they are drawn together by these chordæ, owing to the contraction of the columnæ carneæ, to which they are attached. But, whichever opinion be the more correct, it is certain that these valves were formed for the benevolent purpose of preventing any injurious regurgitation,—for instance, while the ventricles were being contracted for the purpose of forcing their contents into the arteries. Mr. King* has shown what he considers to be " as a safety valve function in the right ventricle of the human heart. Having ascertained that the tricuspid valve, naturally weak and imperfect, closes less and less accurately, according to the increasing degree of the ventricular distention," he is " convinced that, in all cases in which the right ventricle is in any material degree temporarily distended, or permanently dilated, the heart and lungs are relieved by a considerable reflux of the ventricle's contents into the auricle and systemic veins."

In the contrivance, therefore, of these valves, the most gracious forethought has been exercised, for the purpose of guarding against every possible inconvenience; and for this end how refined is the

* See Guy's Hospital Reports, No. IV., 1837.

mechanism! With what exquisite harmony are all its parts adapted to fulfil the object in view! What consummate skill is here! Look at the fleshy ropes pulling close those little gates, and holding them fast while the fluid is beating against them! They, in their turn, preventing a reflux motion of the fluid when the cavity contracts! Now behold them opening to admit a fresh supply! Again they are closed to prevent disaster! Can we gaze upon so magnificent a contrivance without being lost in grateful and adoring wonder? Does not this admirable mechanism, so curious in its several parts, and so well adapted for the function it performs, plainly argue an amazing depth of forethought, as well as goodness? Yea, does it not betoken an infinity of wisdom, as well as power, in its Divine contriver? Curious as these valves undoubtedly are, they are no less important in their office; the heart could no more work without them than a watch without its main spring—in fact, they are as essential to the due performance of the heart's functions as this organ is in carrying on the circulation of the blood. Only let us imagine for a moment the removal of these valves, and the blood, instead of flowing forwards in one continuous stream, would be repulsed at every beat, and—the body not receiving its necessary quantum of stimulus and support—death must be the inevitable consequence.

But to proceed. There are certainly no valves to prevent the blood regurgitating into the veins, upon the contraction of the auricles, because the columns of blood, constantly streaming towards the heart, are sufficient to check any injurious reflux. No impediment, however, is offered to its onward flow into the ventricles, for the valves placed at their entrance allow its influx but check its regurgitation in the manner before stated. When the blood has been ejected by these last-named cavities (ventricles) into the primitive arterial tubes, it would, by the natural contractility of the vessels, and the tendency of the ventricles dilating behind to create a vacuum, have been forced to move in a retrograde direction. It therefore again became necessary to provide against such reflux, by placing, at the commencement of these vessels, a different system of valves, which consist of three pouch-shaped, crescent-like processes of membrane. These valves, when the fluid would retrograde, are caught by it and thrown inwards, obstructing so completely the whole calibre of the artery as to prevent even a single drop of blood passing between them. We find these valves fixed into a zone, forming a contraction in the vessel for the purpose of enabling them to resist the great pressure which the blood must exert at their bases. The margin, also, of each valve is surrounded by a tendinous thickening, which not only materially increases the strength of the valves, but also prevents their adhering to the sides of the vessel (which would defeat the end to be obtained) after the close manner in which they have been applied to these sides, by the sudden rush of the blood from the ventricle. It must be also evident that three semicircular pieces of membrane, which compose these valves, could not so exactly have come together as to close the calibre of the vessel, had they not each been provided with a projection in the middle, which completes the effect of the whole valve.

It has further been ascertained that the position selected for the attachment of these valves, is the exact spot where a fluid similarly driven into a cylinder would be subjected to a contraction, from the difference between the rapidity of the centre and circumference of the current; so that what would elsewhere have opposed the stream, is, in this place, beyond the possibility of such an occurrence. Here, as in the former case, the most marked forethought has been exercised; every inconvenience that might have occurred has been foreseen and provided against; all danger has been skilfully averted; the greatest care, even in points apparently unimportant, has been exercised, in order that this valvular system might be as effectual as could possibly be required. In short, these valves, like the former, are as beautifully and ingeniously contrived and adapted to their especial purposes, as though their Divine architect had had no other work wherewith to occupy his attention.

From this most suitable disposition of valves, the heart may be compared, in its action, to that of a forcing and suction pump, since a portion of blood is thrown into the arteries at every contraction; while, at every dilatation, the same quantity is drawn in from the veins, the valves being thus the means of preventing the fluid from moving but in one direction.

The whole sanguiferous system, from the commencement of the arteries to the insertion of the venous trunks into the heart, is replete with blood, both during the contraction and dilatation of the ventricles; it is also flowing in one continuous stream, since each successive contraction of the ventricles forces on a fresh portion of blood, while, at the same moment, a similar quantity is being poured into the heart by the veins. The pressure which is caused by the blood being driven against the elastic coats of the arteries, at every contraction of the ventricles, is the cause of what has been termed the pulse. This is nearly synchronus with the contraction of the ventricles, being somewhat later than the heart's beat, though the difference as to the time which elapses between the pulse at the heart and that of the arteries is scarcely perceptible. There is another phenomenon which accompanies the heart's action—it is the concussion of its apex, near or between the fifth and sixth ribs. This effect (as some experimenters, among whom are Pigeaux, Stokes, and Burdach, maintain) is produced, during the diastole of the heart, the instant the ventricles are at their maximum of distention, from the contractions of the auricles. " To inform myself," says Müller, " whether, if possible, this view is the correct one, I made some experiments on a goat, whose thorax was opened during life. Professor Albers was present. Our observations did not convince us that the opinion of Stokes and Burdach is the correct one; on the contrary, while the animal lay on its back, we saw distinctly that the heart was elevated at every contraction, and the apex particularly. When the hand was laid on the heart, the shock, during the contraction of the ventricles, was so forcible and instantaneous, that it seemed impossible to attribute the heart's beat, or the impulse against the ribs, to any other cause; while, during the diastole, we felt no shock."* From the concurrent testimony

* See Elements of Physiology, by J. Müller, M.D.; translated by W. Bayly.

of many accurate observers, the correctness of this fact is now fully established—viz., that it is effected during the systole, or contraction of the ventricle. On applying the ear (or a stethoscope) to the chest, two distinct sounds are to be distinguished, succeeded by a corresponding pause; the relation of time between the sounds and pause is, according to Müller, "as one to three, or about one-fourth of the time occupied by the beat and pause together—that is, about one-third of a second." He considers the first sound to correspond with the shock against the chest. Dr. Williams attributes the first sound to the rapid contraction of the auricles and ventricles; the second to the motion of the valves. Dr. Hope considers the first to be synchronous with the systole—the second with the diastole. "This was ascertained," observes Mayo, "by experiments made by Dr. Hope, some of which I witnessed. The first sound is probably caused by the flapping to of the mitral valve, and the protracted vibration of the tendinous chords. The second by the flapping to of the sygmoidal valves. It was found by Dr. Hope that the preventing either valve from closing, by wires passed into the heart, put an end to or impaired the sound attributed to the shutting of the valve."*

We shall now proceed to trace the passage of the blood through the cavities of the heart, and observe how it is influenced by the mechanism we have been attempting to explain.

In doing this we will first notice its passage through the right cavities, and then observe its course through the left cavities. First, then, to speak of its passage through the right, or pulmonic heart.

Supposing for a moment that all the cavities of the heart are perfectly emptied of blood, and that they are filled in succession, the following may be considered as the mechanism of the circulation through the heart. The blood brought back from every part of the body, is poured into the right auricle from the two venæ cavæ and coronary vein. By this means the parietes of the auricle are separated, and it becomes fully distended. The irritation caused by the presence of the blood stimulates the auricle to close upon the contained fluid, which endeavours to escape where the least resistance is offered. There are several openings capable of giving egress to it, viz., the orifices of the venæ cavæ through which it entered, the openings into the ventricle (its proper passage), and the common orifice of the coronary vein. The pressure which the columns of blood exert, offer a great resistance to any retrograde motion through the former; but its onward flow is materially assisted by the forcible dilatation of the ventricle, whose tendency to create a vacuum must necessarily, after the manner of a syringe, draw the blood into its cavity. A variable portion, however, flows back into the veins upon each contraction of the auricle: the undulation thus produced has been called the venous pulse. It is altogether impossible for this to happen in the coronary vein, as its common orifice is wisely furnished with a valve of peculiar structure, which closes the moment the auricle commences its contraction; hence it is

* See Outlines of Physiology, by Herbert Mayo, Esq., F.R.S., p.p. 44, 45.

obvious that the circulation through the coronary vein (so essential to the heart's vitality) would have been greatly impeded but for the interference of this arrangement, while, from the position of the opening into the auricle, it is evident that, upon each contraction of this cavity, some part of its contents would have been forcibly driven into those veins. Here again, therefore, we are bound to trace the exercise of unerring wisdom, and to acknowledge the praise that is due for those provisions which counteract anything that might be injurious! Accordingly the blood is forced by the contraction of the right auricle into the corresponding ventricle, which, now being completely distended, strongly contracts, compressing its contents against the walls of the chamber; and as there are two openings—one by which the fluid had entered, the other which leads into the pulmonary artery—it would appear that this contraction ought to cause a stream to flow through both, at one and the same moment. Its reflux, indeed, would be considerably facilitated, as the auricle is being dilated at the same time. This reflux, however, (which would defeat the end in view) cannot occur, for the divisions of the tricuspid valve are now drawn together, almost completely closing the aperture; and as the tendinous chords, which are attached, prevent them from going further, they are enabled to overcome the resistance offered by the blood, and so impede its flow into the cavity whence it had issued, and as no other opening, except that into the pulmonary artery, exists, the fluid rushes into it by raising the three divisions of the sygmoid valve, placed at the origin of that vessel. It is impossible for the fluid, when once forced into that vessel, to return—as the valves which, during its transit, were pressed closely against the sides of the vessel, are now spread out by the refluent blood; thereby intercepting, with a mechanical exactness, the entrance into the ventricle during the dilatation which follows. Thus, by the wise and merciful interposition of valves, the blood, which by the veins is returned from the body black and effete, is enabled to pursue an uninterrupted course through the right cavities of the heart. Fresh portions of blood are ejected by each successive contraction of the ventricle, and thence flowing through the branches of the pulmonary arteries, the blood passes into the capillaries of the lungs, at which period is effected that important change, which converts venous blood into arterial, and causes what was black to assume a bright scarlet hue.

The capillaries of the lungs consist of innumerable vessels, extremely minute, situated between the terminal branches of the arteries and the primary rootlets of the veins. They are enclosed between the layers of that membrane which forms the air cells, into which the ultimate branches of the bronchi terminate. In fact, the lungs may be looked upon as an organised membrane, having between its layers a complete network composed of these minute vessels, and folded into a number of cells,—by which means a great extent of surface is acquired for a small space. Into these cells, the air, during respiration, rushes,—coming into contact with their parietes, between which the blood is flowing in exquisitely minute currents. The necessary change having been effected, it is thence collected by the pulmonary veins, and emptied into the left auricle, and then commences, secondly—the passage of blood through the left cavities of the heart, where it is influenced by a mechanism similar to that existing in the right. Upon the dilatation of the left auricle, the blood rushes from the four pulmonary veins, so as completely to distend it, when a contraction ensues, causing the greater part to flow into the left ventricle—which at this moment is in the act of dilating—while a smaller quantity flows back into the pulmonary veins. The ventricle being filled by this to its greatest capacity, now forcibly contracts, at which moment the two divisions of the mitral valve are raised—the slender tendinous ropes are brought into play—the opening into the auricle is intercepted—and the blood, unable to return whence it came, is forced into the aorta, by raising the semilunar valves. The blood once in this vessel cannot regurgitate, for these valves are now forced down, thereby completely shutting the entrance into the ventricle. Each contraction of this ventricle forces a fresh portion of blood into the aorta—and this blood, pressing forwards, is now able to find its way through the numerous channels destined to convey life and support, to every extremity, every nook and corner of the body; and, after it has thus furnished every organ with a suitable supply, the residual contaminated fluid is then conveyed back to the heart, by the veins: which veins, commencing from the capillary terminations of the arteries, become reflected back towards the centre of the circulation—the smaller branches joining together, in order to form a larger trunk. These in their turn unite again and again, till at length two main tubes—the venæ cavæ—are the result of their union. Like the rise and progress of some vast river, which at first resembles a rippling stream as it flows through the valley, until by rapid degrees it swells into a mighty torrent, and at length pours its waters into the boundless ocean;—even so, the streams of blood which emanate from the two main venous channels are carried into their grand reservoir, the heart. This blood is again exposed to the air, through the medium of the lungs, and is thence diffused through the body.

This passage of the blood through the heart, is constantly being effected during life; and supposing the mean weight of the blood to be ten pounds, and that the heart contracts on an average seventy-five times in a minute, expelling two ounces thereof at each pulsation, it will follow that all the blood in the body will pass through the heart seventy-five times every hour of our lives! Most suitable, therefore, is the reflection of Paley,* when he exclaims—" consider what an affair this is, when we come to very large animals—the aorta of a whale is larger in the bore than the main pipe of the water works at London bridge; and the water roaring in its passage through this pipe, is inferior in impetus and velocity to the blood gushing from the whale's heart." The force with which this fluid rushes from the human heart is, in proportion to its size, by no means inferior! The valves too, composed as they are of but a thin membrane, are being brought into action at an average of no less than four thousand five hundred times every hour, notwithstanding the

* See Paley's Natural Theology. Chap. x.

great resistance that is being exerted by the blood's pressure, and continuing thus without cessation, during the allotted term of human life. Is there anything which can fill the mind with feelings of a more reverential nature than the thought that this is but one among the vast variety of wonderful processes which are constantly going on within ourselves, and obeying their prescribed law, so long as life is permitted to last. How marvellously unimportant do the noblest works of man appear, when compared with himself, as the work of the Most High. All that ingenuity has contrived, and perseverance has effected—however entitled to our admiration and gratitude—may well be esteemed of no account when placed in contrast with the works of that Divine Artificer, who "hath made of one blood all nations of men,"* and provides for the continuance of mortal existence in the marvellous manner which our subject has led us to observe.

But, to proceed. The impetus which the contraction of the left, or systemic ventricle gives to its contents, is considerably greater than that which the right has the power of producing. An increase in the strength of the former cavity would, of course, be expected; and such is actually the fact, as we found to be the case when considering the anatomical structure of the heart. This is not without some wise end in view, for it will be recollected that the systemic course of the blood is much more extensive than the pulmonic. Dr. Hales instituted several experiments with a view to ascertain the force exerted by the left ventricle; he introduced glass tubes into the arteries of living animals, and observed to what height the blood rose at each beat of the heart; and upon hydrostatic principles, deduced his inferences. He estimated that this cavity in a horse propels the blood with a pressure equal to 113·22 lbs.; "and if," says he, "we suppose that the blood would rise 7½ feet high in a tube fixed to the carotid of a man; and that the internal area of the left ventricle is equal to 15 square inches, these multiplied into 7½ feet, give 1350 cubic inches, which press upon that ventricle when it first begins to contract, a weight equal to 51·5 lbs."†

The frequency of the heart's contraction, varies with the state of the bodily functions, and likewise with the affections of the mind; there being a very material sympathy between itself and them, through the medium of the nerves. The number of its beats gradually diminishes in proportion as age advances. At birth the number of pulsations in a minute is from 130 to 140. During the first year, 115 to 130; at the third year, 90 to 100; at the fourteenth year, 80 to 85; middle age, 70 to 75; and, in very old people, 50 to 65. Its action is increased after food, and still more so, after violent exercise. Sleep, on the contrary, renders it slower. It contracts more frequently in sanguine temperaments, than phlegmatic. It is also quicker in women than men. According to Parrot, its frequency increases in a certain ratio, as we ascend above the level of the sea. With regard to the frequency of its pulsations in different animals, Burdach assigns the following variation, viz:—

* See Acts, xvii. 24, 26.

† Hœmastatics, p. 21, 39.

Horse	36	Cat	100
Ass	50	Ape	105
Sheep	75	Pigeon . . .	130
Frog	77	Hen	140

The heart's motions are involuntary, being altogether beyond controul. Nor do we possess any certain consciousness of its various workings. The cavities contract and propel the blood—the valves are acting and reacting—all the phenomena attendant upon this important organ are carrying out the designs of their All-wise framer, without our being sensibly aware of their respective functions. And here we cannot but admire these provisions of Divine goodness; for, supposing existence had depended upon our keeping the heart in action—suppose it demanded the attention to be constantly directed to it, in order to maintain its pulsations, the whole of life would have been a wearisome course of watching—there would have remained no time for sleep—yea, our existence would have been a burden.

We will next proceed briefly to notice the cause of the heart's contractions; as also the influence which respiration and the nervous system hold over them.

The heart's contractility forms a theory in medical philosophy which did not fail to attract the attention of the ancients; and, like many other points of difficulty, was in those dark ages, made the subject of various hypotheses, which subsequent investigations have discarded. We hear some having resort to chemistry, in order to explain this phenomenon, and telling us that it was produced by a fancied effervescence, arising from an admixture of the old alkaline blood, with the new acid chyle and pancreatic juice. Others again, with Descartes at their head, confidently assert, that steam being generated in the heart, explodes, and so drives the blood over the body.

Leaving, however, these by-gone extravagancies, let us turn to the fact that the heart, like other muscles, contracts when irritated, either mechanically, or by galvanism. The blood constantly flowing through its cavities, is supposed to afford the necessary stimulus.—This supposition is grounded on the fact, that when the rapidity of the blood is increased, the heart's actions are also quickened; but if diminished, its actions are enfeebled. The different cavities also contract in the same order as the blood flows in them; and this is what would, *a priori*, be expected if the blood be regarded as their stimulus. The effect which it appears to have upon the heart, cannot, however, be the sole cause of contractions; for its movements proceed in their regular order, though feebly, when separated from the body, and deprived of blood. To this it has been replied, that the heart now contains a new fluid, the air; but it also continues to contract under an exhausted receiver. Müller conceives the cause to be connected with the organization of the heart, and the mutual action which is effected between the blood or the nerves with the heart's texture, but this is all theoretical, and science has not yet succeeded in accounting for a phenomenon, which, like countless others, still lies beyond the grasp of human intellect.

The influence which respiration appears to have over the heart's action is considerable, for, if the changes which the blood ought there to undergo, be arrested, it would cease to acquire its vivifying influence; the heart, moreover, would become enfeebled, and would speedily cease from its wonted pulsation. If, on the contrary, respiration be supported (for instance after injuries of the brain,) by inflating the lungs, life may be maintained for a much longer period than otherwise would have been the case. Among the recorded experiments put forth by Sir Benjamin Brodie, we read of his having kept up artificial respiration in a decapitated dog, and thereby maintaining the heart's pulsations for a period of two hours and a-half. In cold blooded animals, as frogs, the heart ceases to contract in six hours, while the lungs may be removed, and its movements continue for thirty hours; this is attributed to the greater influence which the brain and spinal marrow are supposed to have over the hearts in this class of animals. Müller seems to think that the stoppage of the heart's action when respiration is arrested, may probably depend upon the changes which follow in the nervous system when it no longer has a supply of red blood.

The effects produced on the heart by mental emotions, acting through the medium of the nerves and other affections of this system, are too well known to need illustration; nevertheless, it has been maintained by some to be independent of nervous power. Sœmmering even went so far as to deny that any branches of the sympathetic nerve were combined with the heart's substance, but merely with the coats of the vessels. Scarpa, however, has proved the contrary, and experiments have shown that contractions can be produced by transmitting galvanism through the nerves. Müller, from the experiments of Legallois, Wilson, Philip, Clift, and many others, made with a view to ascertain how far the brain and spinal marrow influence the motions of the heart, combined with the fact that certain affections of the nervous system, as also nervous syncope, diminish the rapidity, and depress the heart's motions, concludes that they do hold a considerable influence over its actions; First, that through them its contractions may be accelerated or retarded, enfeebled or invigorated. Second, that it continues to contract after the cerebro-spinal system has been removed, and artificial respiration maintained, though at the same time it becomes enfeebled, and finally ceases. Third, that when the heart is removed from the body, and the greater part of its nerves cut away, its contractions still continue for a short time.

We will in the last place briefly consider the developement of the heart, and notice certain peculiarities in the fœtal circulation. Until within the last few years, the nervous system was considered to have a prior existence over the vascular; more recent discoveries, however have reversed that order. It has been demonstrated that the veins which come from the yolk bag in eggs of birds are the first to be developed; and from the analogy which exists between this and the vesicula umbilicalis in the human embryo, it will follow that the veins of the vesicula are also the first to be produced. A vascular connection of an artery and vein is maintained between the vesicula and mesentery, till the second month. To this has been assigned the name of vasa-omphalo-mesenterica; the vein has its origin from the vesicula, and becomes continuous with the mesenteric vein; this is the principle branch of the vena porta, which at this period of fœtal existence, is the chief trunk of the venous system. The vena porta now ascends, and gains a point, where ultimately the heart is to be developed—here it presents a slight dilatation; beyond this, another, and also a third. These correspond to the auricle, ventricle, and bulbus arteriosus. The cavities of the auricle and ventricle are at first single; subsequently, as the work of developement advances, the auricles and ventricles become divided. From the circumference of the auricle, a septum projects inwardly, separating it, though imperfectly, into two chambers. The right ventricle first makes its appearance as a slight swelling, extending from the apex of the heart—the septum shooting inwards from the line marking the boundary of this cavity. On the bulbus arteriosus is a line of demarcation which indicates its separation into two vessels, the aorta and pulmonary artery; these communicate during fœtal life by means of a short branch called ductus arteriosus. The opening by which the auricles communicate, is also maintained till after birth. Another peculiarity to be observed is the large size of the eustachian valve, which at this stage of fœtal life is peculiarly essential.

As soon as the placenta has been formed, and the fœtus commenced receiving its nourishment from the mother, a vein, the umbilical, arises by innumerable radicles from it, and passing upwards enters the abdomen through the umbilical aperture, runs along the longitudinal fissure in the liver, to which it distributes branches, especially to the left lobe; at the transverse fissure, a division takes place —one branch going to anastomose with the vena porta, the other under the name of ductus venosus, empties its contents, together with the hepatic veins, into the ascending vena cava, which pours the blood into the right auricle. Arrived at the heart, it is directed by the eustachian valve, through the foramen ovale, into the left auricle, which then propels it into the left ventricle, from whence it is driven into the aorta—the greater part going to the head and upper extremities, and but a small portion traversing the descending aorta. The fluid returned from the head and upper extremities, is supposed to pass directly through the right auricle into the corresponding ventricle, without mingling with the blood of the inferior cava; the right ventricle then throws it into the pulmonary artery, the greater quantity passing through the ductus arteriosus, and so into the descending aorta, which distributes it to the lower parts of the body. A great portion of this is carried by the umbilical arteries of the placenta. Some of the blood driven by the left ventricle, goes through the lungs, and is returned by the pulmonary veins. The quantity, however, is very slight, as the lungs have not yet been called into requisition. As birth approaches, and the fœtus is about to assume an independent existence, several important changes are being effected. The eustachian valve becomes less; the size of the foramen ovale is diminished, and the blood is driven in larger quantities through the lungs. The eighth day after birth, the foramen ovale becomes, in most cases, closed; the ductus arteriosus is obliterated, and the heart assumes its permanent condition. The successive phases it passes through in arriving at this state, bear considerable relation to the fixed form of this organ in some of the lower animals, showing us what unity of design pervades this part of the vascular system in every gradation of its developement.

We have seen that during fœtal existence, the eustachian valve performed an important part. We observed the communication existing between the auricles, as also between the primitive arterial tubes. These which were specific provisions in that condition of existence, if not obliterated after birth, would be extremely deleterious, as may be seen in those distressing cases where the foramen ovale has not been closed, thereby causing an intermixture of poisonous and arterialized blood ; which, being circulated over the body, produces by its baneful effects a disease called cyanosis, the result of which is a suffering existence and a premature death ;—happily, this is but of rare occurrence. In all other cases, therefore, after the umbilical chord has been dissevered, this opening becomes closed; the ductus arteriosus, which would produce similar effects is also obliterated, and the eustachian valve, which would otherwise impede the passage of blood, becomes sufficiently diminished to enable the heart to perform its newly-acquired function.

This, then, brings to a close the few imperfect observations which have been thrown together with a view to exhibit that divinely constructed mechanism, the heart,—directed, however, more especially to the investigation of those valvular provisions which enable this all-important viscus to carry on its wondrous office in the animal economy ; and although, doubtless, there are numberless particulars which baffle the most vigorous efforts of man's ingenuity, enough of their theory is discernible to convince every honest mind that he who constructed, placed, and upholds these valvular bodies in their proper functions, is supreme in power, wisdom, and goodness. We have in them one of the most exquisite contrivances that imagination can conceive ; a contrivance of all others the most striking. How admirable is their symmetry ! how delicate their construction ! how wise their arrangement ! how well adapted to the prevention of danger and the promotion of bodily comfort ! Surely, everything herein has been well ordered *μέτρῳ καὶ σταθμῷ καὶ ἀριθμῷ*. Where in the whole range of material evidence can any point be adduced, which affords more decided or conclusive proofs of the designing hand of a merciful creator ? We feel assured that so admirable a piece of mechanism can only belong to one who has all wisdom, power, and goodness under his controul; for only He would have so carefully provided against every hurtful contingency, and only He could have called into being a frame-work so elaborate, and fitted it with such exquisite exactness to the various purposes which it has to answer. Who, we would ask, can contemplate the overflowings of Divine benevolence which here, as elsewhere, are so perceptible, without delighting to adopt the apostle's inspired apostrophe,—"Oh ! the depth of the riches both of the wisdom and knowledge of God."— Such a token, moreover, of creative omnipotence, cannot be looked upon even by the most superficial observer, without having his heart uplifted in adoring gratitude to that glorious Being who has thus admirably planned, and thus harmoniously adjusted the whole.

The very valves themselves, although possessing no real voice nor sound, yet with tacit eloquence may be said to set forth Jehovah's praise, declaring as they do the glory and majesty of their Creator; and what more powerful incitement need we have to join in their hallowed chorus of praise, than to behold ourselves the objects of such paternal solicitude,—remembering that the design of these wise provisions is to promote our own safety and welfare. How astounding is the fact, that this fountain of life shall continue dilating and driving forth the blood, day after day, and year after year; and that these frail membranes, these slender strings, should ever be ready to act,—now drawing together the valve, so as to close the entrance,—now throwing it open for the purpose of affording an easy ingress to the vital fluid. Are we not surprised beyond measure that membranes of such remarkable tenuity,—threads of such delicate texture,—should not sometimes, when resisting the force of a fluid which is compressed by a weight, equal to fifty-one pounds and a-half, snap asunder, and so dash us from time to eternity? But the same great and glorious Being who upholds the vast multitude of heavenly bodies in their proper spheres, and guides them in their respective courses, also enables the heart to carry on with untiring efforts its proper function, and the valves to work unwearied or unhurt. Well may we admit that we are fearfully and wonderfully made, when we consider that it is upon the proper working of the valves, and the due adjustment of their little ropes, that our whole vitality is made to depend.

> Obstupeo et memet lœta formidine lustro
> Divini monumentum operis.

Furthermore, from considerations of Divine power, wisdom, and goodness, we may be led to feel and acknowledge the omnipresence and omniscience of the Deity. "There are," says Maculloch, "none from which the universal knowledge and presence of God are so obviously deduced, as His power, wisdom, and goodness; insomuch, that the reader cannot even think of creation, far less contemplate the works around him, without a deep sense of that omnipresence and omniscience." It must be His all-pervading presence which enables the animate and inanimate parts of nature, to move on in perfect harmony; this is it which gives life and motion to the heart; this is it which directs the acting of its valves,—for it would be to argue an imperfection in His nature, to suppose Him absent from any part of His works. To withdraw His presence would be to send back the whole material world to its original chaos. From omnipresence, omniscience necessarily flows; there cannot be a thought which stirs in the whole intellectual world, which is not felt by Him: in fact, reason and revelation assure us that although unseen, He is nevertheless, ever present. "He," continues Maculloch, "who can learn to see creation thus, and thus to feel, must ever also feel the impossibility of escaping the All-seeing eye. Thus will all nature become the temple of the Deity to the heart of man, which it has so often been termed by the poet; not always looking beyond the splendour and interest which this image conferred on his expressions. And not only will he see God in all things, but in all things also, he will find His rule of life written in characters to which he can never shut his eyes; not an object will occur to him in which he will not see the hand of God, and feel that he is under the eye of God; and if he but turn to contemplate the vacancy of the chamber around him, it is to feel that he is in the presence of his maker; surrounded, even to contact, by Him who fills all space."

Now, there is not an atom of the whole corporeal frame which may not be said to teem with attestations of God's divine attributes. There is neither part nor particle of all this glorious fabric, which does not proclaim its divine original, convincing the candid mind that God "is not far from every one of us"—that he careth for us, and delighteth to confer happiness upon all! Does it not tell us that the same is a being of ineffable love, possessing boundless power and wisdom,—that He is the father and preserver of all,—that we are in His hands who is able to do with us "as seemeth best to His godly wisdom." It matters not whether we gaze upon the body's noble exterior, or plunge into its inmost recesses, and there either contemplate the hundreds of arteries which convey the life-sustaining fluid to every portion of the body, or consider the multitudinous veins which absorb as it were, and carry back to their grand reservoir, the residual and contaminated fluid; or whether we fix our attention upon the bony system, so exquisitely moulded to admit of all its various offices, or ponder over the manner in which the muscular, sanguiferous, and nervous systems all co-operate to carry on life; whether we study the structure of the eye, the ear, or the valves of the heart—in each and every of these there will be equal cause for our most unqualified admiration, since each affords the evidence of God's power, wisdom, and goodness: all, too, so well harmonizing with those grand and sacred truths revealed to us by God himself. But, however innumerable are the demonstrations of the Divine wisdom, power, and goodness, deducible from the construction of the human body, they are but as a grain of sand upon the sea shore, when compared with the stupendous pile of the whole universe; for there is not an animal that moves upon the face of the earth, from the gigantic elephant down to the minutest organized body; neither is there a plant or herb among the countless myriads that clothe and beautify its surface, which, if minutely inspected, would not furnish a suitable topic for the soul's admiration to dwell upon. It matters not whether, with rapid survey, we descend into the earth's dark caverns, and there with wondering eye witness its vast heaps of treasure, or dive into the fathomless ocean, swarming as it does with proofs of Divine wisdom and goodness. Every where we are constrained to acknowledge that "there is no end of his greatness;" and, pursuing the thought still further, let us consider that this mighty globe itself is but a particle of an existing immensity;—far above are the heavens glowing with innumerable and far distant worlds, each sustained within its respective orbit; so vast, too, is that immensity, that, were our present earth no longer permitted to remain, no chasm would be produced by its removal. But how can finite ideas comprehend the workings of infinite power and wisdom; prompted as they are by infinite goodness?—"such knowledge is too high, we cannot attain to it." Under such contemplations how complete is the insignificance which encircles man? what a speck does he become in this vast expanse? With David, we are ready to exclaim, "When I consider Thy heavens, the works of Thy fingers, the moon and the stars which Thou hast ordained, what is man that Thou art mindful of him, or the son of man that Thou visitest him?"* How ought we, then, believing (as we are bound to do) the omniscience and omnipresence of Jehovah, beholding, too, the surpassing love and mercy which are manifested in our construction, and still more brightly in our redemption, how ought we, I say, to bow ourselves before him, and to feel as well as to utter the Psalmist's grateful sentiments:—"Bless the LORD, O, my soul! and all that is within me bless His holy name. Bless the LORD, O, my soul! and forget not all His benefits. . . . . . Who redeemeth thy life from destruction, who crowneth thee with loving kindness and tender mercies.†"

That GOD, in his infinite goodness, has endowed us with an existence capable of the most enlarged enjoyment; that His hands have so exquisitely "made us and fashioned us;" and that He has thereby so fully exemplified His divine attributes—are facts, the contemplation of which ought to produce within us the purest aspirations of love and veneration.

Such considerations as these, however, must not be permitted "to float upon the brain as things purely intellectual, unproductive of moral effects, and unaccompanied by practical improvement."‡ We must not rest in a mere cold recognition of the facts, but aim still higher: and when beholding the love, we must obey the word; and when marking the wisdom, we must worship the owner thereof—fearing his power, yet devoting ourselves to his service; and, sensible of our own inability to attain unto this, let us never forget to breathe forth a prayer to that father of mercies who is able and willing to "prevent us in all our doings with his most gracious favour." Indeed the grand aim and object of all philosophic enquiry should be the uplifting of the mind to its Maker—the elevation of the soul to its GOD. Truly, therefore, does Abercrombie assert, that "Philosophy fails of its noblest object, if it does not lead us to GOD. We must," continues he, "seek after purity of character; we must never suppose that there can be anything unphilosophical in the belief, that an influence can be exerted on the mind by Him who framed the wondrous fabric, and we may be assured, that we follow the dictates of the most exalted philosophy, when we commit ourselves to Him as the guide of our youth."||

In conclusion, if our limited capacities are enabled to gather such incontrovertible evidence of wisdom, power, and goodness, from one small portion of His doings, who hath fashioned us with His hand, and redeemed us by His blood,—which evidence, however, does but faintly reflect the resplendent image of those perfections, which

* Psalm viii, 3, 4. † Psalm ciii, 1, 4.

‡ See an admirable Address, delivered at the Birmingham Royal School of Medicine, by the Rev. Vaughan Thomas, B.D.

|| Abercrombie, (Dr.) on the Culture and Discipline of the Mind.

" eye hath not seen, nor ear heard, nor heart imagined,"—how unspeakable must those transports be which shall break in upon the renewed soul, when "this corruptible shall have put on incorruption, and this mortal shall have put on immortality;" when the clouds which now conceal the glorious majesty of our God from mortal vision, shall be for ever rolled away; and when all the ineffable brightness of His heavenly kingdom shall burst in upon our view, enabling us to comprehend the mysteries that now encircle every step of divine procedure, and to trace in the finished work of redemption, a matchless and imperishable monument of the " wisdom, power, and goodness of God."

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eye hath not seen, nor ear heard, nor heart imagined,"—how unspeakable must those transports be which shall break in upon the removed soul, when "this corruption shall have put on incorruption, and this mortal shall have put on immortality;" when the clouds which now conceal the glorious majesty of our God from mortal vision, shall be for ever rolled away; and when all the ineffable brightness of His heavenly kingdom shall burst in upon our view, enabling us to comprehend the mysteries that now encircle every step of His providence, and to trace in the finished work of redemption, a matchless and imperishable monument of the wisdom, power, and goodness of God.