THE

AORTIC SYSTEM,

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 1839,

BY EDWARD SMITH,

STUDENT OF THE BIRMINGHAM ROYAL SCHOOL OF MEDICINE AND SURGERY.

VENERARE DEUM.

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TO THE

REV. SAMUEL WILSON WARNEFORD, LL.D.

RECTOR OF BOURTON ON THE HILL,

THIS PRIZE ESSAY ON THE AORTIC SYSTEM,

INTENDED,

ACCORDING TO THE CONDITIONS OF THE FOUNDER,

TO PROVE BY THE

MINUTE DEMONSTRATIONS OF ANATOMY AND PHYSIOLOGY,

THE AGREEMENT

BETWEEN WHAT IS REVEALED IN THE WORD, AND

ATTESTED BY THE WORKS OF GOD,

RESPECTING THE DIVINE ATTRIBUTES,

IS DEDICATED WITH THE GREATEST RESPECT,

BY HIS VERY HUMBLE SERVANT,

EDWARD SMITH.

Birmingham, July 1, 1840.

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The reader is respectfully requested to make, with the pen, the following

CORRECTIONS.

Page 2	4 lines from the bottom		for " still shewing to us," read we still see.
7	4	... ...	for " æsophagus," read œsophagus.
19	26	... ... top	for " Richrand," read Richerand.
32	26	... ...	for " bulbus," read bulbous.
44	4	... ...	for " verticle" read ventricle.
—	28	... ...	for " lamella," read lamellæ.
46	2	... ...	for " coagulam read coagulum.
51	11	... ...	for " hœmatin," read hæmatin.
—	26	... ...	for " Michael," read Michaelis.
55	24	... ...	for " on the blood passing," read the blood on passing.
62	Marginal Note	... ...	for " apparati," read apparatus.
89	15	... ...	for " is," read it.
91	18	... ...	for " fabic," read fabric.
91	25	... ...	for " life of the read life " of the

ESSAY.

PART I.

In whatever direction we turn, for the purpose of investigating the productions of nature, we must, at once, be struck with the beauty, sublimity, and grandeur, which every object around us presents to our view. Whether our attention be directed to "the heavens above," or "the earth beneath," or "the waters under the earth," multitudes of objects are pressed upon our notice, demanding our highest admiration. On surveying the heavens we shall find a never-ending source of delight and gratitude, when we behold the magnificent luminary that rules the day, giving life and animation to all created nature, rewarding, by his genial influence, the toil and care of the honest husbandman, and stimulating the seed placed in the ground by his exertions to germinate and spring forth; then nursing the tender plant until it arrives at a state of maturity, and finally fitting it to provide for the continuation of its species, and for the wants of the animal creation. How does the warmth of grateful feeling pervade the breast towards the Great Creator, when we behold the lesser luminary that rules the night, throwing the silvered rays of her borrowed light on the world which we inhabit, enhancing the heavenly delight we feel whilst contemplating, in calm and solemn stillness, the varied scenery of hill and dale, the quiet ripple of the murmuring stream, or the mighty rush of the stemless torrent, leaping, with headlong bound, from crag to crag!

Introductory remarks.

If we continue our investigations, and contemplate the starry multitude glittering in the heavens, the same extatic feeling will occupy the mind; some presenting their little complement of light, and then becoming lost to our senses; whilst others, with a steady constant glare, appear like so many guardian angels to guide the night-worn traveller to his wished for home. This scene is perhaps more delightful to a contemplative mind, capable of properly estimating the pleasures to be derived from a consideration of the works of the Almighty, than even when the sun, in noontide splendour, pours vitality on every object within his reach.

If next we turn our attention to the objects by which we are every day surrounded, can we see nothing to tell us, in language not to be controverted, "the hand that made us is Divine!" If we pass into the fields, and examine the beautiful mechanism of each gay floweret, the finely wrought tints presented by their petals, each colour having a distinct and definite position, and not, as in the works of human hands, terminating abruptly in each other, but "shade unperceived, each softening into shade," must demonstrate, at once, to every candid mind, the power and wisdom of a great first cause. But our admiration need not stop here; if we attend to the harmonious sounds which, at every step, salute the ear, and ascertain the source whence they proceed; if we examine the colours of the feathery coat, each little appendage having its own peculiar tint, the assemblage of which forms one of the most beautiful of created objects, we shall again see something to excite our wonder and surprise. Lastly, if we pry into the secrets of the "great deep," and examine the treasures contained therein, made as it were, of one living mass of organised beings, moving along with an almost inconceivable rapidity, scarcely presenting themselves to our notice ere they have disappeared, varying in size from the gigantic whale, formed of an immense mass of organised materials, down to the minute animalcula, thousands of which might sport in a single drop of their native element, still shewing to us the same Almighty hand. Thus, to use the language of David, when speaking of the Omnipresence of the Deity, "If I ascend up into heaven thou art there, if I make
Ps. 139—8, 9, 10. my bed in hell, behold thou art there,—if I take the wings of

the morning, and dwell in the uttermost parts of the sea, even there shall thy hand lead me, and thy right hand shall hold me."

But, of all created beings, God's favourite creature man, stands pre-eminently first; and it will be our object in the following pages, to point out some of the more prominent features, in a beautiful portion of his fabric, viz., the Aortic System.

SECTION I.

ANATOMICAL STRUCTURE.

The heart is a hollow muscle, irregularly pyramidal in shape, situated obliquely in the cavity of the thorax, its direction being downwards, forwards, and to the left side, in the middle mediastinum, betwixt the lungs, resting upon the central tendon of the diaphragm. The greater portion is on the right side of the median line, behind the second portion of the sternum, having its apex corresponding to the bony extremity of the sixth rib, and the highest point indicated by the pulmonary artery. It is enclosed in a fibro-serous bag, called the pericardium, which passes some way upon the primary vessels, having its inner layer (which is analogous to serous membranes) reflected upon the whole of the external surface of the heart, and like other serous membranes, forming a shut sac. The space situated betwixt the layer of the serous membrane, covering the heart, and that portion lining the inner surface of the fibrous pericardium, is filled by a fine vapour or halitus during life; but, after death, this is condensed into a fluid, called the liquor pericardii, the quantity of which is probably augmented by transudation. The lower part of this envelope, where it corresponds to the flat surface of the heart, is intimately connected with the cen-

The Heart.

Situation

Pericardium

tral tendon of the Diaphragm, from which it is exceedingly difficult to separate it.

Division of the Heart

The heart is divided into four cavities; two superior, termed Auricles, and two inferior, termed Ventricles. The Auricles are separated from each other by the Septum Auricularum, in which may be observed a depression, corresponding to the foramen ovale in the fœtus. In these cavities the veins terminate, the venæ cavæ in the right auricle, and the pulmonary veins in the left. The ventricles are separated by the septum ventriculorum. From the right the pulmonary artery proceeds, and from the left the aorta. As the left ventricle is the only part of the heart essentially connected with our subject, we shall confine our remarks to that cavity.

Left Ventricle.

Owing to the obliquity of the septum ventriculorum, only one-third of the left ventricle is visible on the anterior surface of the heart, the remaining portion being placed posteriorly. The walls of this cavity are about five or six lines in thickness at the base, and three lines at the apex. The columnæ carneæ are much thicker than on the right side; but in other respects resemble them. They are for the most part, directed from the base to the apex. The irregularities, owing to their numerous interstices, are particularly observable at the summit, and along the posterior wall, whilst the anterior is comparatively smooth.

Valves.

Two fleshy fasiculi are particularly observable in this cavity, arising by smaller bundles, the one from the anterior, the other from the posterior surface, passing upwards, and terminating by stunted points, from which numerous tendinous threads, the chordæ tendineæ, proceed to be attached to the apex of the valve. At the upper and forepart on the right side, is the point of connexion with the Aorta, which point is indicated by a tendinous ring, to which are attached three festoons of the lining membrane, having betwixt the layers a number of muscular fibres, called the sigmoid or semi-lunar valves. In the centre of each valve is a small corpuscule, the corpus aurantii. These valves are precisely the same in structure and situation as those defending the pulmonary artery. The left auriculo-ventricular opening, like the right, is defended by a valve, having in this situation only two divisions, and called the mitral valve. The bases are attached to the tendinous ring, being there continuous with each other. The apices pass downwards and become connected with the chordæ tendineæ. This cavity, like the other portions of the heart, is lined by a smooth, polished membrane, somewhat resembling serous membranes, and passes into the primary vessels. Between this membrane and the pericardium is situated the proper muscular tissue of the heart; but as the description of this would belong to an essay on the heart itself, rather than on the aortic system, we shall not enter upon it here. We may however say, that the heart is abundantly supplied with blood by the coronary arteries, derived from the aorta, and with nerves from the cardiac plexus of the great sympathetic. We shall now proceed at once to treat of the Aorta. LiningMembrane.

The Aorta arises from the upper part of the left ventricle of the heart, in front, and on the right side of the left auriculo ventricular opening, and behind the pulmonary artery. It is connected to the heart in the following manner; externally by the serous membrane covering the heart, and being prolonged some way upon the primary vessels; internally, by the lining membrane of the heart passing into the aorta; and intermediately by the middle or proper coat of the Aorta, the fibres of which are not continuous with the muscular fibres of the heart, there existing a distinct line of separation. From this point the middle coat of the Aorta passes in three semi-circular portions, their convexities looking towards the ventricle. These cover the sinuses of Morgagni, so as to render them sufficiently strong to resist any dilatation, when the blood is forcibly pressed into them, during the contraction of the Aorta. In the angle resulting from any two of these semi-circular portions, the fibrous structure is of course wanting, and at that point, the strength of the artery must be diminished, but it is still sufficiently strong to prevent rupture. Aorta—its origin. Connection with the heart.

The lining membrane of the heart, whilst passing over the line marking the point of its connexion with the Aorta, forms three semi-circular folds, between the layers of which are placed a number of muscular fibres. These are termed the semi-lunar valves of the Aorta, and are placed immediately beneath the three dilatations, the sinuses of Morgagni raising up a complete barrier to any fluid having a retrogade course.

The Aortic opening when viewed from the ventricle, is of a triangular shape, and much less in size than the calibre of the artery, where it forms the sinuses of Morgagni. The Aorta first passes upwards, forwards, and to the right side, as far as the upper edge of the cartilage of the second rib; then horizontally backwards to the left side, crossing the second dorsal vertebra; lastly, it passes downwards, lying on the bodies of the vertebræ, gradually becoming more anterior, until it reaches the body of the fourth or fifth lumbar vertebra, when it divides into right and left common iliacs. That part situated between its origin, and where it lies on the third dorsal vertebra, constitutes what is termed the arch. To facilitate the description of the very important relations which it bears to the surrounding parts, it is customary to divide it into three portions; the ascending, transverse, and descending. The ascending portion, about two inches and a quarter in length, commences at the point of origin of the Aorta, (which may be shewn by passing a probe directly backwards from the upper border of fourth costal cartilage, on the left side, at its point of junction with the sternum,) and terminates at the upper edge of the cartilage of the second rib, when it changes its direction,so as to form the transverse portion. In this course it describes a curve,which is convex upwards, forwards, and to the right side, the greater part being contained in the pericardium. At its commencement it has in front, below, the pulmonary artery which afterwards gains its right side; above, the sternum, from which it is separated by the pericardium and cellular tissue, being only a quarter of an inch from that bone, when distended; this, however, differs according to age, it being not so near in early life as in

Course.

Arch,and its divisions.

The Ascending portions.

old age. On the left side it is in relation with the superior vena cava, and posteriorly with the right branch of the pulmonary artery and right bronchus. This part of the artery is usually much enlarged without disease, and has hence received the name of Great Sinus of the Aorta.

The transverse portion commences at the point described as the termination of the ascending portion, and terminates on the left side of the second dorsal vertebra, where the artery makes a second turn to form the descending portion. This part lies behind the junction of the first and second portions of the sternum, separated from it in part by the left brachio-cephalic vein. The right extremity is situated much more anteriorly than the left, it being placed near the sternum, whilst the left is in relation with the body of the second dorsal vertebra. It lies upon the trachea, a little above its bifurcation; along its upper border runs the left brachio-cephalic vein, part of which is in relation with its anterior surface. On the left side the par vagum crosses it; and around its angles, formed by its junction with the ascending and descending portions, the recurrent branch of the par vagum winds. Its termination is connected to the pulmonary artery by the remains of the ductus arteriosus, the canal being obliterated. Transverse portion.

The descending portion commences at the termination of the last-mentioned part, and terminates opposite the third dorsal vertebra, which in the old subject is often indented by the pressure made upon it, from the constant dilatations of that artery, causing absorption of the bone. In this course it passes downwards and backwards within the posterior mediastinum, betwixt the left lung and vertebral column, accompanied by the descending vena cava, par vagum, æsophagus, thoracic duct, and vena azygos; the æsophagus and thoracic duct lying on its right side, and rather in front. The concavity of the arch thus described, looks downwards and to the left side, winding Descending portion. Direction of the concavity of Arch, and parts within it. around the root of the left lung. The following are the parts contained within it, in the order in which they appear, passing from before backwards: the pulmonary artery, left bronchus, part of left auricle, æsophagus, thoracic duct, recurrent branch of the par vagum, and bronchial glands. The remaining part of the Aorta is divided into two portions, superior, and inferior; that part situate above the diaphragm, is called the thoracic Aorta, that below it, the abdominal Aorta. All the portions of the Aorta now described, are merely separated by their relations to the surrounding parts; there existing no distinct or visible line of demarcation betwixt them.

Course of the Aorta below the Arch. The Aorta lies at first on the left side of the third dorsal vertebra, but on passing downwards gradually comes forward, so as to be near the median line on reaching the twelfth dorsal vertebra. From this point to its division, it gradually inclines again to the left side; thus forming a lateral convexity and concavity, the convexity looking towards the right side, the concavity towards the left. It also forms a concavity in the thorax, and a convexity in the abdomen, corresponding to the position of the vertebræ. Thoracic Aorta. The thoracic Aorta is separated from the bodies of the vertebræ only by cellular tissue, the origin of intercostal arteries, and the left intercostal veins as they pass to join the vena azygos. It is covered in its whole extent, by the pleura, left bronchial tube, left pulmonary artery, left root of lungs, left auricle of the heart, and the pericardium. The æsophagus and par vagum which accompany it, bear different relations to it, according to the portion examined; superiorly they are on the right side; in the middle of the posterior mediastinum they cross it, in consequence of the Aorta bending from left to right, whilst the æsophagus passes from right to left; below they are placed on the left side, on a plane anterior to it. It is also accompanied by the splanchnic nerves, (derived from the sympathetic) which lie on either side of it, the left one frequently accompanying it through the Aortic opening in the diaphragm.

The vena cava lies on the right side, separated from it by the vena azygos and thoracic duct.

The opening in the diaphragm, through which the Aorta passes, (hence termed the Aortic opening,) is a tendinous passage, situated between the central and left leaflet of the central tendon, and between the crura of the diaphragm. It is more particularly closed in by a number of tendinous fibres, forming the insertion of the crura, passing forwards and upwards along the side of that opening, and meeting at its upper border, where they decussate, leaving between them an elliptical opening, the œsophageal opening, and finally terminating in the central tendon. The Aortic opening also gives passage, frequently, to the thoracic duct, vena azygos, and splanchnic nerves, and is much larger than the Aorta. Aortic opening in the Diaphragm.

The Abdominal Aorta is shorter than the Thoracic, and terminates opposite the fourth or fifth lumbar vertebra. It is covered by the following parts passing from above, downwards, and from before, backwards: the stomach and little omentum, behind these the branches of the cœliac axis and solar plexus; below and opposite the second lumbar vertebra, the vena porta (formed by the junction of the superior mesenteric and splenic veins) passing across the lumbar vertebræ to reach the transverse fissure of the liver; in front of this are placed the mesenteric vessels, and still more anteriorly, the pancreas. Below these, the duodenum crosses it, separated from it by the left renal vein, when that vein does not pass behind the Aorta; below this, the transverse mesocolon, and root of mesentery, and from this point to its division, by one layer of the small intestines. Superiorly the semi-lunar ganglia are also placed on either side, and below this the continuation of the solar plexus, here called the Aortic plexus. On the right side is the descending vena cava, which also partially covers it, and the thoracic duct, lying superiorly between the artery and vein, and inferiorly behind the arterial trunk. Abdominal Aorta.

Branches. We shall now proceed to consider the principal branches derived from this artery, not however giving a minute description of the numerous routes which they take to their several terminations, but only a general view of their distribution, which appears more compatible with the purpose of this essay.

The branches, for the most part, pass off at an angle more or less acute, and, in some instances, at right angles; as the intercostal and lumbar arteries. They are also usually given off near to the organs to which they are destined; but there is an apparent exception to this in the spermatic arteries, which take a long tortuous course in the male, through the inguinal canal to the testes, and in the female, between the layers of the broad ligaments to the ovaries; but, it must be remembered, that both the testes and ovaria were originally placed upon the psoæ muscles, so that it is not a real exception. The number of divisions of an artery from its commencement to its final termination seldom, if ever, exceeds eighteen or twenty.

Coronary arteries. Right. The first branches given off are the coronary arteries, two in number, arising immediately above the origin of the Aorta, that of the right side directly above the floating edge of one of the semi-lunar valves ,appearing between the pulmonary artery and right auricle, and running in a very tortuous manner to the right side in the groove between the right auricle and ventricle; it then divides into three branches; one continuing in the original course of that vessel, and by its inosculations with the left coronary artery, forms a distinct arterial zone around the heart, between the auricles and ventricles; the other branches are distributed to the anterior and posterior walls of the heart. The Left. left has a similar origin, and appears between the pulmonary artery and left auricle, taking a similar course to the left side of the heart, and dividing into two branches; one passing to assist in the formation of the arterial zone before spoken of, the other distributed to the parietes of the heart. These form frequent anastomoses with each other, and by them the heart is abundantly supplied with blood. From these a number of smaller branches proceed, distributed to the coats of the primary vessels, constituting the vasa vasorum; these are reflected on the pericardium, and communicate with the phrenic and internal mammary arteries.

From the transverse portion of the arch, three large trunks are given off; the arteria innominata, left carotid, and left subclavian, which, from the obliquity of the course of the transverse portion of the arch, lie on different planes to each other, the arteria innominata being situated most anteriorly, then the left carotid, and lastly the subclavian.

The arteria innominata is the shortest but largest trunk; it arises from the angle formed by the junction of the transverse with the ascending portion; passes upwards and to the right side, to the extent of an inch or an inch and half, in the first intercostal space, behind the sterno clavicular articulation of the right side, and divides into its terminal branches, the right subclavian and right carotid arteries. It lies first on the trachea, and at its division it is opposite, but at a considerable distance from the longus colli; anteriorly, it has the first portion of the sternum separated from it by the vena innominata sinistra, sterno hyoid and sterno thyroid muscles, and cellular tissue,and at its termination by the origin of the sterno cleido mastoideus muscle. Arteria Innominata.

The right carotid artery, resulting from the division of the arteria innominata, passes upwards into the neck. It takes a direction upwards and outwards, as far as the upper border of the os hyoides, where it divides into internal and external carotid. It lies on the longus colli and rectus capitis anticus muscles, sympathetic nerve and its cervical ganglia, the inferior thyroideal artery and recurrent laryngeal nerve. It is covered in its lower half by the integuments, superficial fascia, platysma myoides,ascending branches of cervical plexus of nerves, deep cervical fascia, sterno cleido mastoideus,sterno hyoideus and sterno thyroideus muscles, crossed about its middle by the omohyoideus, and lastly the descendens noni nerve. In its upper half it is superficial, merely covered by the integuments, super- Right Carotid artery.

ficial fascia, platysma myoides, superficial cervical nerves, descending branches from facial nerve, deep cervical fascia, and descendens noni nerve. It is enclosed in a sheath of condensed cellular tissue, with the par vagum and internal jugular vein, the nerve lying betwixt and behind the vessels; on its outer side is placed the vein, on the inner side the larynx, trachea, œsophagus, and thyroid body. In its course it gives off no branches. It divides into the internal and external carotids, which are distributed to the head and neck; the one to the external, the other to the internal parts. They form frequent and very important anastomoses with each other, and with the branches of the subclavian artery.

Right Subclavian Artery.

The right subclavian, like the last described artery, arises from the bifurcation of the arteria innominata, behind the sterno clavicular articulation. It passes upwards and outwards to the inner border of the scalenus anticus muscle, then behind that muscle, and lastly downwards and outwards beneath the clavicle and subclavius muscle, terminating at the lower body of first rib in the axillary. In this course it describes an arch, the convexity looking upwards, the concavity downwards. That portion of the artery internal to the scalenus anticus muscle, is covered by the integuments and superficial parts, deep cervical fascia, sterno cleido mastoideus, sterno hyoideus, and sterno thyroideus muscles, cellular tissue, a number of veins, and a strong fascia stretching from the arteria innominata to the scalenus anticus muscle; also by the par vagum, branches of inferior cervical ganglion of sympathetic, the phrenic nerve, the internal jugular and vertebral veins. This part lies upon the recurrent laryngeal nerve, cellular tissue, and lymphatic glands, separating it from the vertebræ and longus colli muscle, also the sympathetic nerve and pleura. In that part of its course where it passes behind the scalenus anticus muscle, it is covered by the superficial parts, deep cervical fascia, sterno cleido mastoideus muscle, subclavian vein, phrenic nerve, and scalenus anticus muscle It lies upon the pleura, and scalenus medius muscle, and is accompanied by the brachial plexus of nerves. Externally to the scalenus anticus muscle, it is covered by the superficial parts, deep cervical fascia, clavicle, cellular membrane, and external jugular vein. It lies upon the scalenus medius muscle, and superior surfaçe of the first rib, which is grooved to receive it. It is accompanied by the subclavian vein, which is internal and anterior,also by the brachial plexus of nerves which is external and superior. From this artery several important branches are given off, to be distributed to the brain, head, neck, the muscles about the shoulder, and some intercostal spaces. One of its branches, viz., the internally mammary, is very important; it runs along the inner surface of the cartilages of the ribs, giving off branches, communicating with the intercostal branches of the thoracic Aorta, coronary arteries, phrenic, and lumbar arteries, supplying the draphragm ; the continued trunk then ramifies in the substance of the rectus abdominis muscle, where it communicates with the epigastric artery, a branch of the external iliac. It is principally by this artery that blood is conveyed to the lower extremity, when the external iliac artery is tied. In consequence of the free inosculations of the branches of the subclavian artery, (particularly the vertebral and deep cervical) with the branches of the internal and external carotids, a sufficient supply of blood is carried to the head, when a ligature is applied around the common carotids. Some of its branches inosculating with those of the axillary, as the transversalis colli and transversalis humeri, carry on the circulation to the arm, when its proper vessel is obliterated.

The subclavian artery having terminated at the lower border of the first rib in the axillary, that vessel continues its course down the arm, and, at the lower border of the conjoined tendons of the latissimus dorsi and teres major muscles, takes the name of brachial. This vessel also passes down the arm to the bend of the elbow, where opposite to the insertion of the brachialis anticus muscle, it divides into the radial and ulnar arteries. These proceed along the fore-arm, giving off branches to supply that part, and in the palm of the hand form two arches, inosculating with each other, and distributing branches to the hand and fingers. Around the elbow there is a beautiful arterial anastomosis,

Axillary artery.

Brachial artery.

Radial and Ulnar arteries.

formed by the recurrent branches of the radial, ulnar and interossei arteries, with the superior and inferior profunda arteries and ramus anastomoticus magnus, branches of the brachial.

Left Carotid artery.

The left carotid artery, the next in order arising from the arch of the Aorta, passes nearly directly upwards, inclined however a little outwards, resting upon the trachea, œsophagus, and thoracic duct. It then enters the neck, where its description would be precisely the same as that of the right carotid artery and it is, therefore, unnecessary to repeat it. In its course within the thorax, it is covered by the sternum, left vena innominata, and part of the thymus gland. The par vagum, on this side, passes down parellel with it, giving off its recurrent branch on reaching the arch of the Aorta.

Left Subclavian artery.

The left subclavian, the last branch arising from the arch of the Aorta, commences opposite the second dorsal vertebra, passes upwards as high as the inner margin of the first rib, from which point its course is similar to that of the right subclavian. It lies upon the vertebræ, longus colli, and inferior cervical ganglion of sympathetic nerve; it has on the left side, the œsophagus, and anteriorly, the superficial parts, the sternum, first rib, clavicle, left jugular vein, left vena innominata, thoracic duct, par vagum, left carotid artery, left lung and pleura.

Branches from Thoracic Aorta.

The branches from the thoracic Aorta are comparatively small and insignificant. They may be divided into four sets, irregular in their number, in their origin, and mode of distribution: first, the bronchial arteries; which are usually two or three in number, accompanying the divisions of the bronchi, and distributed to the substance of the lungs, being their proper nutritious arteries; secondly, the œsophageal arteries; usually five or six in number, distributed to the structure of the œsophagus, and communicating with branches from the abdominal Aorta, particularly the superior division of the coronary arteries of the stomach; thirdly, the pericardiac branches; a few small vessels distributed to the peri-

Bronchial Arteries.

Œsophageal Arteries.

Pericardia Arteries.

cardium, communicating with the coronary arteries; fourthly, the intercostal arteries; which pass into each intercostal space between the intercostal muscles, to which they are distributed, communicating with the intercostal branches of the subclavian artery, internal mammary, thoracic branches of axillary, and the phrenic and lumbar branches of the abdominal Aorta. Intercostal Arteries.

The branches derived from the abdominal Aorta are numerous, large, and very important. They are usually divided into pairs and impairs. The pairs are, first, the phrenic arteries; distributed for the most part to the diaphragm, communicating with the lumbar, intercostal, and internal mammary arteries, which form a vascular zone around the central tendon; secondly, the renal capsular arteries; which are very small in the adult, but, in the fœtus are of considerable size, being larger than the renal, and are distributed to the renal capsules, situated above the kidneys; thirdly, the renal arteries; of considerable size, distributed to the kidneys; fourthly, the spermatic; which are longer and more tortuous in the male, and are distributed to the testes, having previously traversed the inguinal canal. In the female they are distributed to the ovaries, and upper parts of the uterus, inosculating with the proper uterine arteries, derived from the internal iliac; lastly, the lumbar arteries; four or five pairs passing outwards, lying upon the intervertebral substance. Each then divides into two branches, distributed to the parietes of the abdomen and bodies of the vertebræ, communicating above, with the intercostals, and phrenic arteries; below, with the circumflexus ilii. Branches from the Abdominal Aorta. Phrenic Artery. Renal Capsular Arteries. Renal Spermatic Arteries. Lumbar Arteries.

The impairs are, first, the cœliac axis, about half an inch in length, having on each side the semi-lunar ganglia, and surrounded by the solar plexus. It immediately divides into three branches; the coronary, hepatic, and splenic, distributed, as their names imply, to the stomach, liver, and spleen; secondly, the superior mesenteric; arising directly below the cœliac axis; it passes downwards, and to the left side, getting between the layers of the mesentery, and divides into branches, which, Cœliac Axis. Superior Mesenteric Artery.

by their inosculations with each other, form a series of arches, from the last and smallest of which, branches are given off distributed to the coats of the small intestines. Branches are also given off to the cœcum, ascending and transverse portions of

Inferior Mesenteric Artery.

the colon; thirdly, the inferior mesenteric artery, which passes downwards and to the left side, covered by the peritoneum, and divides into branches, which also form arches by their inosculations, distributed to the sigmoid flexure of the colon, the descending colon and rectum; fourthly and lastly, the

Sacro Median Artery.

arteria sacro media; a small branch commencing at the point of division of the Aorta, running downwards along the anterior surface of the centre of the sacrum, and communicating with branches from the internal iliac artery.

A very free series of inosculations exist between the different branches derived from the abdominal Aorta; all the vessels distributed to the chylopoetic viscerá being as it were, one continuous chain of vascular canals, by reason of their various communications. They also communicate with the thoracic Aorta, by branches from the coronary arteries passing to the œsophagus, and communicating with the proper œsophageal arteries, also by the phrenic and lumbar arteries uniting with the intercostals; with the subclavian by its internal mammary branch, and spinal branches of the vertebral artery; with the external iliac artery by its epigastric and circumflex branches; with the internal iliac by the sacro median artery,spermatic, and lumbar arteries; and with the femoral, by its superficial branches uniting with the lumbar arteries.

Division of the Abdominal Aorta.

The abdominal Aorta having divided into the right and left common iliacs, each of these arteries passes outwards, and opposite the ilio-sacral articulation, divides into internal and

Internal Iliac.

external iliac. The internal iliac passes downwards into the pelvis and gives off branches, some of which are distributed to the parts contained within it, whilst others pass out of that cavity through the anterior and posterior openings, and are distributed to the anterior and posterior parts of the thigh. The external iliac runs along the margin of the pelvis, accompanied by its corresponding vein; it then passes beneath pourparts ligament, and receives the name of femoral. This artery gives off two branches; first, the epigastric, which is the most important, and has been previously mentioned; secondly, the circumflexus ilii, running along the margin of the ileum, and distributed to the muscles in that region. The femoral artery passing down the anterior part of the thigh, distributes branches to the parts in its course; it then passes through a triangular tendinous ring in the adductor magnus muscle, and enters the popliteal space, receiving the name of popliteal artery. It here gives off a number of articular branches distributed to the joint, and around which an important anastomosis is placed, formed by the vessels inosculating with the recurrent branch of the anterior tibial, ramus anastomoticus magnus, and terminal branches of the profunda femoris. The artery at the lower border of the popliteus muscle divides into the anterior and posterior tibial, which pass down the leg, distributing branches as they proceed until they reach the foot; the anterior then passes on the dorsum of the foot, giving off branches which form arches, and one branch to communicate with the posterior tibial, which had passed into the palm of the foot, and formed an arch, from which branches were distributed to the toes.

External Iliac Artery.

Femoral Artery.

Popliteal Artery.

Anterior and Posterior Tibial Arteries.

Around the ankle joint a considerable system of anastomosis is again formed by the branches from the anterior and posterior tibial, peroneal, dorsalis pedis, and plantar arteries.

Another very important series of anastomosing vessels exist between the internal iliac and femoral arteries. This is more particularly the case with the obturator, gluteal, and ischiadic branches of the former, with the circumflex and perforating branches of the latter, and it is chiefly by means of these that the circulation is carried on to the lower extremity when the iliac or femoral arteries become obliterated by disease, or manual interference

What has been previously stated respecting the distribution of the branches of this primary trunk, will be sufficient when the several parts are found as they exist in the majority of cases; but, probably, in no system of the body are there so many varieties, or, in other words, exceptions, as there are in the vascular system. In some instances we have a superabundance of parts, in others remarkable diminutions. Thus, besides the number of vessels described as arising from the arch of the Aorta, there is frequently found another, which, from its position and destination, has been called the middle thyroideal. The left vertebral and right subclavian also occasionally arise from it. Sometimes there is only one coronary artery, at others three. In some cases the Aorta has divided into two primary trunks, the one passing to the head and upper extremities, the other pursuing the original course of the vessel. In others, it has divided into three trunks; two forming the subclavians, and the third, the descending Aorta. In another case, the Aorta having divided into two branches, they became reunited to form the descending Aorta. These, as will afterwards be shewn, resemble the mode of division of the primary vessels in some of the lower animals, from which, in connexion with other circumstances, some have imagined man to have proceeded, through different gradations, from the lowest tribe of animals, until he reached the station he holds, as the most perfect of the animal creation. The brachio-cephalic artery has been known to give off both carotids, the left one passing across the trachea, rendering the operation of laryngotomy or tracheotomy highly dangerous, the continued trunk forming the subclavian. Indeed, the varieties in the circulating system, which have from time to time been observed, are very numerous, and the subject soon will be, and even now is, a very interesting one to curious minds.

Varieties in the Vascular System.

The final termination of arteries constituting the capillary system, will be considered, in conjuction with the circulation in them, in another part of this essay.

We shall now treat of the structure of the blood vessels. Every arterial trunk is composed of three tunics; the external one, or tunica cellulosa; the inner one, or tunica intima; and an intermediate one, or tunica propria. Structure of the Blood Vessels.

The internal tunic is supposed, by Bichat, to be the membrane lining the whole of the passages through which red blood circulates; as the left side of the heart, the pulmonary veins, and the Aorta with its branches. It is smooth and resembles the serous membranes in having a uniform texture. It is transparent and of a homogeneous nature, not having, according to Bichat, any appearance of fibres, vessels, or other traces of organization. It adheres very slightly to the middle coat, not being connected by the intervention of cellular tissue. It may be readily separated from it, but always requires the aid of dissection—boiling water, maceration, or putrefaction, not being sufficient of themselves to procure the division. It is remarkable for its great brittleness, breaking and lacerating from very slight causes, and it is the membrane which is divided on the application of a ligature around an artery. This membrane is supposed to form the parietes of those vessels, in which the middle coat cannot be demonstrated. In the left ventricle it is evidently thinner, and more capable of extension than in the right, a fact we shall afterwards see, of great moment. Tunica Intima.

The middle coat is of a dun yellow colour, dry, hard, compact, and highly elastic, and contains about half its weight of water, (according to Richrand) which, when driven off by heat, leaves a yellow horny substance, brittle and transparent. This, when placed in water, greedily absorbs it, and is restored to its pristine state. It greatly resists maceration, heat scarcely curls it, and boiling water, although it removes a portion of the gelatin, does not destroy its elasticity. Acids and alkalies do not render it transparent, but, if macerated in them for some days, its texture becomes affected. It is very similar to the ligamenta subflava of the arches of the vertebræ, and the ligamentum nuchæ and ligamentum patellæ, the only point of Tunica propria.

difference being in the mode of distribution of the fibres. It may be readily separated into several layers, from which some anatomists are disposed to consider it as consisting of numerous lamellæ. This membrane is very obvious in the larger branches, but in those of very small calibre its demonstration is difficult. In the arteries of the brain it is particularly thin. It is to this membrane that the vessels owe their strength, and the power they possess of retaining their figure after removal from the body, and of being emptied after death. Like the internal membrane, it is sometimes found of a deep red colour, which is owing to the red particles of the blood passing into its substance by transudation, and, after a certain period of maceration gradually disappears. This coat is evidently formed by a number of fibres arranged in a circular manner (none in a longitudinal one) around the vessel, no single fibre encircling it, but in the main entirely surrounding it. These fibres are not connected by cellular tissue. Whether the fibres are muscular or not, is a question which is, or rather has been, a cause of much discussion amongst physiologists, both sides being advocated by able men of this and other countries, and supported by arguments which each party considered conclusive. Yet, notwithstanding this, the matter is not, at the present day, finally settled. As this question is somewhat connected with the enquiry, whether the arteries are contractile or not, perhaps it will be better to defer the investigation until we arrive at that subject.

Tunica Cellulosa.

The external coat is usually considered as composed of condensed cellular tissue, forming a nidus or bed, in which the nutrient vessels of the arteries may ramify, and through which the arteries are connected with the surrounding parts. It is intimately and essentially connected with the middle tunic, any detachment, even the slightest, giving rise to inflammation and sloughing of the part, followed by death, rupture, and consequent discharge of its contents. Beclard considers it to be composed of a fibro-cellular substance, which may be divided into two layers. It is not present in the cerebral arteries, and in most parts of the thorax and abdomen, its place being supplied by the pericardium, pleura, and peritoneum; but even here there appears to be a fine layer of cellular tissue. The existence of longitudinal fibres, in this membrane, was advocated until the time of Morgagni, who doubted or denied their existence. Haller, Bichat, and Meckel also confirmed his opinion.

The arterial tissues are very plentifully supplied with blood, by vessels termed from their office, vasa vasorum. These small vessels are usually given off from some neighbouring trunk, and ramify in the external coat. The Aorta receives blood from the coronary arteries, the bronchial, œsophageal, internal mammary, phrenic, spermatic, and lumbar arteries. They are also very liberally supplied with nerves; almost every artery of considerable size being accompanied by a plexus of branches from that system, particularly in the abdomen. The arch of the Aorta is also surrounded by branches, from the cardiac plexus. Bichat considered that the arteries invariably derive their nervous energy from the ganglionic system; an opinion which does not appear to have been formed from correct investigation, as numerous instances occur where they are accompanied by branches from the cerebro spinal axis.

Vasa Vasorum.

Nerves.

SECTION II.

PHYSIOLOGY.

Having now completed the anatomical portion of this essay, we shall next proceed to give some account of the physiology or uses of the different parts previously described, proceeding in the same order, viz., first, the heart,—secondly, the arteries.

The use of the heart is, on the one hand, to attract the blood by virtue of a suction power which it possesses, to be spoken of

Physiology of the Heart. Its use.

hereafter; and, on the other, to propel or assist in propelling the blood through every part of the system. This last part of its office is performed by the contraction of its fibres; and, before proceeding further, it will be necessary to give a brief sketch of the circulation.

Circulation. That something like a circulation of the blood did exist was known to the ancients; but how this occurred, and the course the blood pursued, was to them a perfect mystery. In endeavouring to explain what they really knew nothing of, some of the most fanciful and ridiculous theories were propounded, each receiving credit and support, according to the peculiar taste of the individual, or to the sway which the opinions of the propagater chanced to have over the minds of the credulous multitude. It was left for our celebrated countryman, Harvey, to demonstrate to the world this hitherto impenetrable secret; a discovery which has rendered his name immortal, and will cause it to descend to our successors, enrolled in the annals of fame, as long as time shall endure; a discovery, also, which has rendered (and will still continue to render) the greatest benefits to humanity. But, notwithstanding the great advantage thus rendered to mankind, perhaps none ever met with more determined and decided opposition; and it was not till his sun was setting magnificently below a western horizon, nor till the "silver cord was loosed," and the "golden bowl was broken," that it was duly and sufficiently appreciated. The first appearance of this discovery was in a small work spoken of by Aikin, "as the most admirable example of a series of arguments, deduced from observation and experience, that ever appeared on any subject."

The course of the circulation, thus first unfolded by Harvey, is as follows: the blood being collected from all parts of the body by the venæ cavæ, is brought, in conjunction with that from the heart itself, into the right auricle; this cavity then contracting, it is forced into the right ventricle, and from thence by the power exerted by the ventricle, into the pulmonary artery; regurgitation from the pulmonary artery into the right ventricle is prevented by the semi-lunar valves, and from the right ventricle into the right auricle by the tricuspid valve; a certain amount of regurgitation does take place from the right auricle into the venæ cavæ, but, owing to the column of blood in these parts, and the muscular fibres around their orifices, no injury results; this regurgitation frequently causes a kind of pulse in the jugular veins of old persons, and in some diseases of the heart. The blood having entered the pulmonary artery it is carried onwards, along its divisions, to the lungs, where it enters a beautiful network on the inner side of the air cells of this organ, and is exposed to the action of air. It is then removed by the capillary terminations of the pulmonary veins, and transmitted along them to the left auricle; from thence into the left ventricle, and finally into the Aorta, to be distributed to every part of the system; regurgitation from the Aorta into the left ventricle being prevented by the sigmoid valves; and form the left ventricle into the left auricle by the mitral valve. The blood having entered the capillary terminations of the arteries, distributes the flood of life to every part, and furnishes the numerous and necessary secretions; it is then collected by the capillary terminations of the veins, and passes through their numerous channels, until it is at length brought, by the venæ cavæ, to the point whence we set out.

Divisions of the Circulation.

It will be observed that the blood passes through two distinct circulations; one to the lungs and again to the heart, the other to the remaining part of the system; the first, is called the pulmonic, the second, the systemic circulation. The heart, it will also be observed, is divided into two parts; the one for the reception of the blood brought by venous canals, the other for the transmission of that fluid, by the arteries, to every part of the system. There is also another division, the one half for the reception of venous or dark blood, and the other for arterial or red blood, the former occupying the right, the latter the left side of the heart.

Proofs of the Circulation.

It may now be proper to mention some of the proofs of the circulation. Firstly, on opening the chest of a living animal, and exposing the heart, alternate contractions and dilatations are distinctly perceptible, occurring with great regularity. Secondly, the experiment of Morgagni, applying the microscope to the web of a frog's foot, demonstrating the pulsations of the arteries, the passage of the blood through the arteries into the veins, and the return of the blood through the venous trunks. Thirdly, the fact of no retrograde motion existing is demonstrated by the position and action of the valves. Fourthly, the possibility of the passage of the blood into the arteries, from the ventricle, as demonstrated by dissection; no obstacle being placed to oppose the current in that direction. Fifthly, the course of the blood in the arteries and veins may be proved by puncturing those vessels, and applying a ligature to the part; in an artery, the blood will be found to flow in a direction from the heart, in a vein, towards the heart.

General view of the Heart as an agent of Circulation.

Having now described the course of the circulation, it becomes necessary to state the means by which the constant motion of the blood is effected. The heart is composed, as we have seen, of four cavities; two auricles, of which the size of the right, as compared with the left, is (according to Haller) as seven to five; two ventricles, which, from the experiments of Sabatier, are of nearly equal dimensions. These cavities differ in the strength of their parietes, those of the ventricles being much the more powerful, and of these the left is the strongest; which, according to a law of Providence, that every instrument is precisely adapted to its peculiar function, must necessarily be the case. The auricles also differ in muscular power, the right one being the weakest, only one-third (according to Haller) of the strength of the left auricle. These cavities do not, as was warmly maintained by some physiologists, succeed each other in their period of contraction, but the two auricles contract at the same moment, which contraction, as was abundantly shewn by the experiments of Drs. Hope and Williams, is immediately followed by the simultaneous contraction of the ventricles.

Difference in the power of the parietes of the Cavities.

Relative and absolute period of Contraction.

There is, however, another power besides the contractions of the heart, that is supposed very materially to assist the circulatory movement; viz., the vacuum that would be formed did the blood not rush in on the dilatation of a cavity after previous contraction. This vacuum is supposed to act like a vortex, drawing everything into the cavity within its reach, as far as the dimensions of that cavity will admit. Thus, the heart may be compared to a suction and forcing pump.

Suction power of the Heart.

The amount of blood supposed to be thrown into the Aorta by each contraction of the left ventricle, is, on the average, about two ounces. It is also calculated that about thirty-three pounds of blood are contained in the vessels, and that the heart contracts about seventy-five times in the minute. These calculations are of course subject to great variation; but as the adult age, usual size, and healthy state, appear to have been taken as the standard, probably they are as correct as the circumstances will allow. Proceeding, therefore, upon the correctness of these data, the whole mass of blood must pass through the body once every three minutes and a half, or seventeen times every hour; the different portions of the blood requiring different periods to complete their course, according to the length of their journey, and the obstacles they are subjected to.

Quantity of blood ejected at each contraction—quantity in the body—and the time required for its complete circulation.

The cause of the pulsation, which we feel on applying the hand over the cardiac region, has received different explanations; it however appears now to be decided, neither to be owing to dilatation of the cavities of the heart, as supposed by Corrigan, Stokes, and others; nor to the straitning of the arch of the Aorta, as conceived by Hunter; but, as contended by Müller; that all the parts of the heart contract towards the central point of the auriculo-ventricular openings, by virtue of which, the apex is struck against the inner surface of the ribs. The number of pulsations of the heart in the minute, when not affected by disease, (for in disease every variety occurs) differs materially according to the age of the subject, sex, temperament, climate and habit; but of all these, the first is the most

Cause of the pulsation of the Heart.

Circumstances modifying the frequency of the pulsations of the heart.

important. At birth they are from 150 to 130; at one year old, 130 to 115; at two years old, from 115 to 100; at three years old, from 100 to 95; at seven years of age, from 95 to 85; at puberty, 80; at adult age, 70 to 75; and in old age, 50 to 60. The female sex, persons of sanguine temperament, or those living in hot climates, and of industrious habits, have the pulse quicker than those of an opposite character. The action of the heart is slower during sleep, is increased after a meal, and in proportion to the height above the level of the sea. At an ascent of 2,600 yards, the pulse is 90; at 3,900 yards, 100 in the minute. There is a remarkable difference in the action of the heart in animals; according to Müller, in fishes the pulsations in the minute are from 20 to 24; in frogs 60, in birds 100 to 140, in rabbits 120, in cats 110, in dogs 95, in sheep 75, and in hares 40.

Frequency in Animals.

Force of the left ventricle

The amount of force required by the left ventricle to propel its contents onwards through the arterial system, was a question, that in by-gone days, excited much attention, and learned men, as might be expected, from the nature of the undertaking, obtained very different results from their experiments. Borelli, by calculating the power of muscles from their weight, arrived at the extravagant, and certainly erroneous conclusion, that it exercised a power equal to 180,000 pounds; Keill, on the other hand, seeing the error into which Borelli had fallen, by a set of experiments, quite as remarkable for their ingenuity as the complication of their character, was led to believe the actual force to be five ounces and a half. From the great difference of opinion thus formed by men of as nearly equal celebrity and intellectual attainments as may be, we may, without much fear of error, say, that the matter is one of extreme difficulty, one not at the present time decided, and probably never will admit of certain and correct conclusions being derived from it. We must not, however, forget to mention the experiments and the conclusions deduced from them by the celebrated Hales. He attempted the solution of this difficult problem by inserting tubes into the Aorta soon after its commencement, and ascertaining the height to which the blood was impelled in them; he then compared the result with the dimensions of the cavity whence it was projected, taking also into the account, the time, and dimensions of the vessel. By this means he arrived at the conclusion, that the amount of force was equal to about 50lbs. This is probably much nearer the truth than either of the preceding conclusions; but, from circumstances not attended to in the calculations of these data, it is, to say the least, probable, that the result is not correct, and we must leave this, like many other subjects connected with physiology, for future generations to analyse.

We shall now proceed to shew the cause of the contractibility or constant motion of the heart, which has also been a subject of much discussion, and consequent difference of opinion. The ancients supposed it to be owing to a kind of ethereal or subtile spirit, what, they chose not to say. Sylvius ascribed it to the supposed effervescence occurring within the heart by the mixture of the different kinds of blood, one being possessed of acid, and another of alkaline properties; an idea equally visionary and absurd. Senac attributed it, with much greater apparent propriety, to the fact of the cavities being distended to a certain point, by the blood poured into them; this distension exciting the organ to contract, and consequently causing an expulsion of its contents. The exciting cause of contraction being thus removed, the blood again rushes into the cavity, and again excites it to contract. Müller however is disposed to adopt the following theory; during the contraction of the heart, the blood is forced out of the nutritious vessels of that organ; but, when the contraction ceases, these vessels, by virtue of their elasticity, become refilled, which is the cause of a fresh contraction. He, however, admits that this theory is open to the same objections as the preceding one, viz., that contraction does go on, though feebly, when the heart is emptied of its blood. (This theory cannot, by any means, be received with implicit confidence, when we remember that the heart of the turkey, according to Mr. Langston Parker, has been known to contract, at intervals, nearly

Cause of the Contractility of the Heart.

regular, for twelve hours, when removed from the body and placed in water.) Therefore, according to Muller, the cause of motion exists in the organisation of the heart, and in the constant mutual action going on between the blood and the capillaries, or the cardiac nerves with the heart. The nature of the cause is not, at the present time, clearly understood, shewing that it is much easier to find a blemish in a given theory, than to frame one in which no defect exists. The act of respiration has very considerable influence over the action of the heart, probably more so than that of the nervous system. Thus, if any impediment be given to the passage of the air into the lungs, the action of the heart becomes more and more feeble, the blood still continuing to flow through the vessels, but deprived of its arterial character, and, after a certain time, the action of the heart, and consequently the circulation, ceases. But if the brain or medulla oblongata be injured, and artificial respiration used, the animal will live some considerable time. In cold-blooded animals however, the lungs may be tied, and yet the action of the heart continues for twelve hours, whilst, if the cerebro-spinal axis be injured, it dies in six hours, shewing that either respiration has less influence on the heart, or that nervous energy is more essential for the continuance of its functions. The cause of the staying of the circulation, in these cases, is nôt precisely understood; Goodwin referred it to the presence of dark blood in the left ventricle, and Bichat to the absence of red blood in the coronary arteries. It is not owing to collapse of the lungs, because the arterial circulation is not disturbed; but the relative proportion of nervous energy and stimulant effect (if any) of the blood, cannot be certainly and satisfactorily determined. Respecting the effect of the nervous influence on the action of the heart, it is well known that any passion or emotion of the mind very materially influences it, either to accelerate or retard; and, in some cases, the latter effect is so great, that the action of the heart is absolutely suspended for a time; and cases are not rare, where a complete stoppage to the circulation has resulted, from sudden and violent emotions. Notwithstanding this, some have denied, *in toto*, that the nervous system has any influence whatever, over the action of the heart. Haller conceived that it was owing to innate muscular contractility, because the contractions occurred in their wonted order when the heart was removed from the body; and further, that irritation of the cardiac nerves does not produce convulsive action, as irritation of the nerves supplying other muscular structures does. This opinion was strengthened by the researches of Behrend and Sœmmering, who endeavoured to prove that the cardiac nerves are not distributed to the muscular structure of the heart—only to the coats of the cardiac vessels. They also maintained that the galvanic pile does not produce contraction in this, as it does in other muscular organs. These researches have, however, been found to be inaccurate from the more recent observations of Scarpa, who demonstrated the distribution of nerves to the cardiac structure; and also by Humbolt, Fowler, and Wedemeyer, who succeeded in producing contraction, or rather, a series of contractions, (as occurs in all involuntary muscles) by galvanism.

Cause of Contraction of the different parts in their order.

The cause of the phenomenon distinguishing this muscle from every other,—the contraction of the different parts in their proper order, is not known; and must, like many other subjects of which we are perfectly ignorant, be referred to the nervous system, but to which portion of that system is not so well decided. All agree that the sympathetic nerve has considerable influence over the heart; whether the cerebro-spinal system has any, or to what extent, is not determined. The principal experimenters on this point are Legallois, Wilson Phillip, Dr. Marshall Hall, Clift, and Flowrence. From a number of experiments performed by Legallois, he concluded that the sympathetic nerve was intimately connected with the spinal cord, and that the nervous power of the heart was derived from the spinal cord; not from any single part, but from the whole. He also states that the destruction of the spinal cord only so far influences the action of the heart, as to prevent its throwing the blood to the whole system; but it can throw it to a certain distance, the amount of which depends upon the extent of the injury inflicted on the medulla spinalis. Wilson Phillip, on the other hand, came to the conclusion that the action of the heart is essentially independent both of the brain and spinal cord, but that it is intimately connected with them by means of its nerves, and that the brain and spine have a considerable share in the sympathetic affections of the sympathetic nerve and heart. Cleft saw the heart beat eleven hours after the destruction of the spinal cord. Flowrence, from his experiments on fishes, considers that the action of the heart is principally dependent upon the integrity of the medulla oblongata, causing respiration to be properly performed. Dr. Marshall Hall has, however, seen the circulation carried on after the destruction of the medulla oblongata. From these and other experiments Müller draws the following conclusions: first, that the heart's action is much influenced by the brain and spine; secondly, that its action continues for some time after the simple removal of the brain and spinal cord from the body, these movements being feeble and terminating after no long time; thirdly, that when the heart is removed from the body, its contractions still continue for a certain period.

Particular description of the agents of the Circulation. The Heart.

We now proceed to speak more particularly of the efficient agents in the circulation of the blood. These are two; the heart, and arteries. The blood, as we have elsewhere seen, having been carried to the heart from all parts of the system, and thence transmitted to the lungs to undergo certain changes, is again returned to the heart, into its left ventricle. This cavity contracting, forces the blood into the Aorta, which, by the fresh impulse given by it to the blood previously contained within that vessel, is forced onwards along the course of the vascular system into the terminal ramifications, and, as we shall presently see, some consider it to be impelled even through the capillaries themselves. The relative forces exerted by the heart and arteries on the blood, will, of course, depend upon the opinion formed respecting the contractility or non-contractility of the arterial parieties, some maintaining that the heart is the sole cause of the circulation, whilst others assert, that the arteries, possessing a contractile power, very materially assist in the propulsion of the blood onwards. As we cannot decide this point until we have treated of the arteries, we will now proceed to give some of the arguments in favour of, and against, their contractile agency.

The great difference of opinion respecting their agency is on two points; first, are they muscular; secondly, are they contractile; for we cannot for a moment admit, that they are tubes intended simply to form as canals for the circulating fluid. We shall first treat of their muscularity. The arguments, on this subject, are few, and they appear tolerably conclusive. They are the following; first, the arterial tissue is hard, compact, dry, and highly elastic, containing about half its weight of water. Secondly, the power of muscular action never exists in the mammalia more than three quarters of an hour (according to Müller) after death, whilst, in the arterial tissue, it remains some days. Thirdly, according to Hodgkins, the fibres of the arterial tissue do not present, under the microscope, the transverse lines observable on the fibres of muscular tissue. Fourthly, muscular fibre is composed of a substance bearing all the characters of fibrine, which is certainly not the case in the arterial tissue. These arguments, founded on certain essential differences of structure, are the most powerful, and, if we give credit to them, I think every unbiassed mind must admit, that the middle tissue of arteries is not composed of a substance having the characters of muscular fibre. It must not, however, be forgotten that Richerand has demonstrated the presence of true muscular fibres in the parietes of the Aorta of the elephant, and from the great light that has been thrown upon the minute structures of the human body, by referring to analagous parts in the lower animals, it probably may, at some future time, be demonstrated, that the same exists in man; but until then, we must adopt the above conclusion.

Are Arteries Muscular?

But, although we have admitted this part of our subject, it does not appear to be necessary to give up, with it, the opinion that the arteries are contractile, because, in their structure, they do not resemble muscular fibre. That would be making an inference not legitimately deducible, for we do not know that muscular fibre is the only substance possessing a contractile power. It is true we cannot say it is not, but I think we shall be able to bring forward a number of facts, not to be disposed of satisfactorily without that admission. On the side for

Contractility

the contractile power of the arteries, we have the names of Haller, Whyte, Senac, Hunter, Phillip, Thompson, Hasting, Verschein, Sir C. Bell, and Bostock; on the opposite side those of Bichat, Berzelius, Magendie, Spallanzani, and Müller. These latter physiologists maintain, that the arteries are not stimulated to contraction by galvanism, and that irritation of other kinds, mechanical and chemical, has the same effect. These statements are unequivocally denied by others, as Phillip, Thompson, and Hastings. Phillip placed the web of a frog's foot under a microscope, and distinctly saw the capillaries contract upon the application of certain stimuli; and Dr. Thompson, in his treatise on inflammation, expressly states the same fact. Müller endeavours to overturn this experiment, by supposing that the irritation does not produce contraction of the proper tissue, but owing to a chemical action on the organic structure, a kind of corrigation takes place.

Another fact derived from analogy,may perhaps furnish us with a useful argument, viz., that the venæ cavæ in fishes, according to Nysten and Wedemeyer, have been seen to shew distinct signs of muscular contraction; and Flowres has also seen regular contractions in the large veins of the abdomen. The distinct contractions of the bulbus aortæ in fishes, and amphibia, have also been adduced in favour of contractility. This part is, however, considered by the opposite party to belong entirely to the heart; in some instances the contractions occurring only at the point of junction with the heart, and in those having a branchial circulation it forms a part of the heart itself. The fact of the circulation in animals occurring without hearts, as in the dorsal vessels of insects; the principal vessel of the annelides, as in the leech; and in acephalous monsters, in which the heart is generally wanting; are also considered as powerful arguments. These Müller endeavours to nullify by considering these vessels as elongated hearts. We have also arguments derived from pathological observation; viz., the increased or diminished action which, under certain circumstances, occurs in certain vessels. In inflammation of any part, as the finger or conjunctiva, the vascular action has, by almost every medical man, been observed to be more or less excited, (in the latter instance red blood passing into vessels usually transmitting a colourless fluid,) that excitement being perfectly independent of the heart. The same in some neuralgic affections, as of the face; the carotid artery of one side may be observed to labour more violently than that of the opposite. In paralytic limbs the circulation is much less frequent than in the healthy parts. How can these be satisfactorily explained, except we admit an independent action in the vessels? Müller has, however, endeavoured to explain the first by denying the fact altogether, but it has been observed by too many pathologists, and occurs too frequently, to admit of so sweeping an explanation. The second fact he accounts for, by supposing that in inflamed parts there is an accumulation of blood in the capillaries, and an impeded circulation through them, giving rise to a more violent action; an explanation which contains an admission of the fact of the arteries possessing a local action independent of the heart. His answer to the third argument is, that the mutual vital reaction between the blood and the solids being diminished, they become lax, shrivelled, and imperfectly nourished.

Dr. Hall adduced the fact of the oscillations occurring in the Aorta, when tied, as owing to muscular contractility. This, by the opposite party, is also denied. The fact of arteries having the power to contract their calibre to the quantity of their contents, as shewn by the experiments of Hunter, is adduced by him as an argument for arterial contraction.

From the above, and many other arguments, which have from time to time been brought forwards, it appears that we must still adhere to the doctrine of arterial contractility, though we do not say that contraction is owing to muscular fibre. This

The parts where the contractile power is greatest, as opposed to elasticity.

contractility is more apparent in the smaller arteries than in the larger trunks, in which latter the elastic power is more perceptible. This elastic power is very materially modified and, impaired, by the presence of ossific depositions, which give a tendency to apoplexy, gangrene of parts, and other affections depending upon defective circulation. Contractility, according to Hunter, Bell, and others, cannot be shewn after the death of the animal, whilst the elastic property remains some days.

Obstacles to the blood.

The following are the chief obstacles opposed to the circulation of the blood through the vessels. First, the friction of its particles against the sides of the vessels, and particularly in the capillaries. Secondly, the capacity of the branches of the Aorta being greater than the Aortic trunk, by reason of which, according to an existing law in hydraulics, the circulation must become slower. Thirdly, the arteries passing off at obtuse angles has also been mentioned, but Weber remarks, "that the acuteness or obtuseness of an angle influences the rapidity of a fluid only when when it meets with so little resistance in its progress, that the amount of the impulse which it receives cannot give a determinate direction to its course; but that when the resistance it experiences is so great that each impulse is lost in overcoming it, the angle, at which the branch of the tube is given off, no longer has this effect." From what has been previously stated respecting the force necessary to give the proper impulse to the mass of blood in the vessels, it appears to be too great for us to believe in the heart being the sole motor cause of the circulation.

The arteries are always full of blood, and when the ventricles contract, the force exerted on the blood in the Aorta, by the projected quantity, causes that artery to dilate, and at the same time, to elongate to a considerable extent. The artery then contracts, propelling the blood more forcibly onwards after the ventricle has ceased to act. The phenomenon we observe, termed the pulse, is owing to the dilatation of the arteries, and in those near the heart it is synchronous with the contraction of

The cause of the pulse.

the ventricle; but, in parts more distant from the centre of circulation, it occurs from one-sixth to one-seventh of a second (according to Weber) after its contraction. This delay is accounted for by him on the supposition, that the arteries admitting of extension both in length and width, the impulse given to the blood by the heart distends first, merely the arteries nearest this organ. These again contract, and cause the distension of the adjoining portion of the arterial system; which, in its turn contracts, and proceeds in the same manner to the terminal branches. By this means a certain interval elapses before the dilatations of the terminal ramifications can occur.

The force with which the blood is propelled has given rise to a number of ingenious experiments, particularly by Hales and Poiseuille. Hales introduced a glass tube into different vessels, and ascertained the height to which the blood rose in them. In the crural artery of the horse it rose to eight or nine feet; in the temporal artery of a sheep, six feet and a half; in the carotid artery of a dog, from four to six feet; in the jugular vein of the horse, from twelve to twenty-one inches only; in the sheep, five inches and half; in the dog from four to eight inches and a half. Poiseuille ascertained it by using a tube containing a quantity of mercury. He noted the height to which the mercury was raised by the current, and, calculating the force on hydrostatic principles, found that in the larger vessels, as the carotid and Aorta, it was the same, the difference in size not making a difference in the required force. The height of the column was the same in all the arteries of the same animal. In the Aorta of the mare, the force was equal to eleven pounds nine ounces avoirdupois; in the radial artery, four drachms. This force was found to be increased during respiration, by Haller, Magendie, and Poiseuille; every effort at expiration, by contracting the chest, causing pressure to be exerted upon the vessels, and a consequent increase of force on the blood contained therein.

The force necessary to propel the blood onwards.

The capillaries are a series of exceedingly minute vessels, terminating the arteries, and with which they are continuous;

Capillaries.

and by them the blood is conveyed into very minute veins, which, by their frequent anastomoses, form a net work, and when well injected presents a beautiful object for microscopic examination. During life they may be seen, by the aid of a magnifying power, in any transparent part, as the web of a frog's foot. The point at which the arteries terminate, and the veins commence, cannot be determined with anything like precision, in consequence of the gradual transition from the one to the other. There is a peculiarity in the net work of the capillaries, the vessels not decreasing and increasing in size like the arteries and veins, but are, in every part, of the same dimensions. This, according to Bichat, is sufficient to constitute them a peculiar set of vessels, distinct from arteries and veins; but this opinion is not generally received at the present day. Their size is proportionate to that of the red particles of the blood, varying from 1-1,000 to 1-5,000th part of an inch in diameter, the median size being from 1-1,850 to 1-3,700. The size of the capillaries of the brain, according to Müller, is 1-4,700; in the kidney, 1-2,500 to 1-1,592; in the skin, 1-1,149th part of an inch. These are proportions obtained from injected preparations, and it must be remembered that, in the natural state, they are not so distended, therefore their diameter must be considered as less than the above statement indicates. They are larger in the young than in the old subject, accommodating themselves to the size of the globules of the blood which are then larger.

Peculiarity of the Capillaries.

Size.

Position.

All the different elementary tissues, glandular, ducts, muscular fibre, and nervous fibrils, are surrounded and connected by a set of capillary vessels. In the kidney they run in the interstices and on the surface of the urinary ducts, and in the cortical portion there are peculiar glomeruli of blood vessels, in the midst of a capillary net work. With regard to the form of these vessels they are pretty regular, only differing in the size of the meshes, or in their being elongated or not. In the muscles and nerves they are elongated in the direction of the primitive fibrillæ. According to Sœmmering, the mode of ramification in the small intestines resembles a tree not in leaf; in

Mode of ramification

the placenta, a tuft; in the spleen, a sprinkling brush; in the muscles, a bunch of twigs; in the tongue, a hair pencil; in the testicle and choroid plexus, a lock of hair; and in the schneiderian membrane, a trellis work; illustrations as remarkable for the ingenuity displayed in their selection, shewing the different forms in which the capillary vessels occur, as for their general truth and correctness. At the extremity of each of the villi forming the tufts in the placenta, a minute arterial branch may be distinctly seen to terminate in an equally minute vein. In the medullary portion of the kidney, minute arteries and veins may be seen running between the tubuli uriniferi, and eventually giving off branches forming the capillary network surrounding the opening of the urinary ducts. The parts in which the network of the capillary vessels are the closest, are the lungs and choroid membrane. In the iris and corpus ciliare they are somewhat larger. They are also very close in the mucous membrane of the liver, kidney, and cutis vera. In the lungs, the interspaces are smaller than the vessels, but, in the kidney, the diameter of the injected capillaries, compared with that of the interstices, are as one to three or four. In the brain, the capillaries are very minute, and not so numerous as in some other parts, so that the blood must pass through into the veins more quickly than in other organs. In bones, cartilage, ligament, and tendon, there are but few capillaries, comparatively, the difference in appearance being very great at the point where the muscular fibre terminates in the tendinous. Rudolphi states, that the serous membranes do not possess vessels,—that they are placed in the subjacent cellular tissue; but, in consequence of some injections of the peritoneum by Bleuland and Schroeder-vander-kolk, this opinion must be received with caution.

Relative size of the vessels and meshes.

Haller conceived that arteries terminated in five ways; first, by opening on the surface of membranes; secondly, in lymphatics; thirdly, in secreting canals; fourthly, in adipose matter; and fifthly, in veins. This opinion is however hypothetical, not supported by anatomical evidence, and cannot, in the present state

Termination of the Capillaries.

of science, be admitted. Minute anatomy demonstrates to us, that the capillaries are merely a minute series of vessels, intervening between the extremities of the arteries and the commencement of the veins, and that they are continuous with both; and further, that these vessels do not give off branches. It is therefore impossible for us, with these facts before our eyes, established by the authority of some of the greatest men of the past and present day, to admit that the capillaries terminate by open mouths.

Serous vessels.

A class of vessels have been described connected with the capillaries, and forming a part of the same system, called serous vessels; from their not admitting the red particles of the blood. These have not been demonstrated, but they probably exist; as in the cornea, vitreous body, and capsule of the crystalline lens; but in these parts their presence is doubtful, and rests at the present time, for the most part, on theory.

Sides of the capillaries.

Do the capillaries possess membranous sides? is a question long asked, and one that has obtained attention; but, owing to the difficulty of obtaining the information, and to the frequent occurrence of circumstances modifying the results of the experiments, it is not decided. Wedemeyer, Wolff, Hunter, Doellinger, and Meyer, maintain that they do not; whilst evidence of as high a character, from Leeuwenhoeck, Haller, Spallanzani, Bichat, Berres, and Rudolphi, stands in favour of their possessing membranous enclosures. From the experiments of Rudolphi and Müller, the latter opinion is more generally received.

Circulation in the capillaries.

If the circulation in the capillaries of a transparent part (as the web of a frog's foot) be examined by the aid of the microscope, provided the animal be in health; there will be seen a remarkable difference from the circulation in other parts of the body. Instead of the periodic pulsatory motion of the blood, we observe merely one continuous current; but, if the animal be previously debilitated, so that the heart and arteries are incapable of their normal action, a kind of oscillation is observed; owing to the blood not reaching them in sufficient quantity at proper intervals. This oscillation has been stated by Kock, to be entirely independent of the heart; whilst Müller and Wedemeyer state, as the result of their experiments, that it entirely arises from the contractions of the heart being to feeble to overcome the resistance offered by the parietes of the capillaries, and by which a retrograde motion is produced, notwithstanding the presence of the valves. The cause of the equable motion of the blood is, in a great measure, owing to the propulsive force given by the heart being lost on arriving at the capillaries; or, according to Müller, that during each contraction of the heart, the blood is forced into them, but, during the intervals of the heart's action, the capillaries contract so as to force the blood onward, and convert its periodic action into a continuous one, although a periodically accelerated one. He agrees in the impulse given by the heart being lost when it reaches the capillaries, the reason for which, he states to be the continual and successive dilatation. the parietes of the arteries, Müller being one of the physiologists denying their contractility.

Cause of the equable motion of the blood in the capillaries.

The degree of resistance offered by the capillaries has been attempted to be proved by Keill and Hales; the former arriving at the conclusion that it would neutralize 4-15ths of the force with which the arterial blood moves.

Amount of resistance to the blood in the capillaries.

The diminished rate with which the blood moves in the capillaries, is owing to three causes; first, that the primum mobile of the circulation is in a great degree lost; secondly, that the size of the capillaries is much larger than the calibre of the Aorta, and as we have previously observed, the rate of a fluid decreases when it passes from a small into a larger canal; and thirdly, the resistance is much greater.

Causes of the diminished rate of the blood in the capillaries.

Though the circulation in these vessels occurs in a continuous stream, yet the same rate is not observed in all the capillary system, it being quicker in some parts than in others; which by

Do the red particles assist in nutrition?

Wedemeyer and Müller, is attributed to mechanical causes. The red particles, as we shall observe when treating of nutrition, do not combine with the tissues to assist in that process, but are carried on into the veins. This opinion is contrary to that of Doellinger and Dutrochet; but more accurate and recent investigation appears to have shewn the fallacy of their doctrine.

Source of motion of the blood in the capillaries.

Respecting the source of the motion of the blood in the capillaries, there have been different opinions, and it is not now by any means determined. It is more usually supposed to be owing to the contractility of the vessels, this property increasing with the diminishing diameter of the arterial tubes. Müller, from some experiments by Poiseuille and Magendie, states it to be his opinion that the motion is entirely owing to the action of the heart. Many physiologists, however, doubt or deny that the heart has the power to propel the blood into the capillaries, when there are, as we have seen, so many circumstances to retard the passage of the blood from that organ to these vessels; and Müller himself, in another place, expressly states, "that the impulse given to the blood, by each contraction of the ventricle, is lost in thus dilating the arteries."

Vital turgescence of the capillaries.

In reference to what is termed the vital turgescence of the vessels, there is supposed to be an attraction or affinity existing between the particles of the blood and the coats of the vessels, so as to give rise to the phenomenon, independent of the action of the heart; as in the genitals in a state of sexual desire, and in the uterus during pregnancy. The nerves are said, by Treviranus, to have a considerable influence on the circulation in the capillaries; Baumgaertner and Wilson Phillip also supported this assertion; and it is very probable, that to a certain extent, these opinions are correct, but their experiments were complicated with several sources of error, and admitted by themselves not to be perfectly conclusive. We must therefore, leave this subject for further investigation.

Influence of the nerves on the capillary circulation.

The next subject is to consider the chief points of difference between the circulation during fœtal existence, and that process after the uterine sojourn is completed. In an anatomical point of view, they are four in number. First, the umbilical vein, which having entered the umbilicus, separates from the uterine arteries, and passes to the umbilical fissure of the liver; it then divides into two branches, the one passing to the liver, and the other to the vena cava, receiving the name of ductus venosus. This vessel forms, in after life, the round ligament of the liver, having degenerated into a fibrous cord. Secondly, the umbilical arteries, which are derived from the primitive iliacs. These enter the umbilicus, and pass down parallel to each other, on each side of the linea alba, external to the cavity of the peritoneum; thence to the sides of the bladder, and finally terminate in the internal iliacs. After birth, they also degenerate into fibrous cords, and form two of the ligaments of the bladder. Thirdly, in the septum auricularum there exists an opening, the foramen ovale, which as we have before seen, becomes closed after birth, leaving the fossa ovalis. Fourthly, between the Aorta and the pulmonary artery a vessel passes, called the ductus arteriosus, the canal of which also becomes obliterated. Fœtal circulation. Anatomy.

The blood having been brought from the placenta by the umbilical vein, is carried to the umbilical fissure of the liver; one portion is then distributed to the substance of the liver, providing it with nourishment, and is afterwards emptied into the vena cava; the other, and the greater portion, proceeds through the ductus venosus directly into the vena cava, and in conjunction with that from the liver, passes into the right auricle. The greater portion, guided by the eustachian valve, is carried through the foramen ovale into the left auricle, then through the auriculo-ventricular opening into the left ventricle, and finally into the Aorta. The remainder passes into the right ventricle, and thence into the pulmonary artery. Here another division occurs; one portion passing through the ductus arteriosus into the Aorta, whilst the other continues its course along the pulmonary artery to the lungs, and is brought to the left auricle by the pulmonary veins; from thence it passes into Circulation.

the left ventricle, and finally into the Aorta to be distributed to the different parts of the system, after which it is returned by the umbilical arteries to the placenta. The foramen ovale remaining open in after life, gives rise to a disease termed cyanosis. The following is a table drawn up by M. Billard, shewing the relative periods at which this opening closes:

Period of the closure of the foramen ovale.

In 14 out of	19 at	1 day old.		17 out of	27 at	4 days old.
15	22	2 —		13	29	5
14	22	3 —		5	20	8

It may remain open a week or more without any evil resulting, although it more generally closes in two or three days after birth.

Circulation in the lower animals.

We shall now proceed to give a very brief description of the circulation, as it exists in some of the lower divisions of the animal kingdom, having taken the liberty of abridging the description given by Müller, in his excellent treatise on physiology.

Annelides.

In the annelides there is a progressive contraction of the vascular trunks, advancing regularly in one direction, and thus driving the blood in one continuous circle in the larger vessels; whilst, at the same time, the circulating fluid is thrown alternately from side to side, through the transverse anastomosing branches, one trunk being filled whilst another contracts. When the principal trunk lies at the side, as in the leech tribe, the circulation is horizontal; when situated above, and below, it is vertical. In the neiredes, Wagner has described two longitudinal trunks; one on the dorsal aspect, which pulsates and drives the blood onwards, the other on the abdominal aspect, which neither pulsates nor contracts; there being also superior and inferior transverse vessels.

Insecta.

In the insecta there is but one contractile vessel, but the circulation is perfect—not having the lateral fluctuating motion; but flows in a simple circle, impelled forwards by the dorsal vessel through the body; it returns in the opposite direction and re-enters the dorsal vessel, having, at the same time, distinct arterial and venous blood. The currents are simple and do not ramify. Whether the internal organs receive vascular currents is a still undetermined point.

In the arachnida and crustacea the circulation is nearly as simple as in the insecta, not having a distinct pulmonary circulation; but in the arachnida, with pulmonary sacs, a part of the blood is exposed to the influence of the air. In the arachnida with tracheal organs of respiration, as well as in insects, the blood is ærated by the trachea, which ramifies in all the parts of the body. In the higher crustacea there is either a long tubular heart, as in the squilla and allied genera, or a short wide one as in decapoda, when the blood is collected from the body by the veins, and carried to the branchiæ to be returned to the heart. Arachnida and Crustacea.

In the mollusca, the circulation is similar to the crustacea. In the acephela and truncata, the veins pass directly from the branchiæ to the ventricle. In the conchifera and most gasteropoda, the blood is first collected in an auricle, (or two as in conchifera) and thence passes into the ventricle. In the greater part of the mollusca, the blood passes to the respiratory organs; but in some genera, only a portion of that fluid is conveyed to those parts. Mollusca

In the sepia there are three seperate ventricles; the systemic ventricle or heart, which receives the blood sent by the veins from the branchiæ to the two lateral branchial hearts, and from thence is returned to the branchiæ. Cephalopoda

In fishes there is but one auricle and one ventricle. The venous blood from the body generally, being collected in the auricle, and thence transmitted to the ventricle, is impelled into the contractile bulbus arteriosus, which gives off the arteries for the branchiæ—generally four on each side. From the branchiæ the blood is returned by the same number of branchial veins, which unite tò form the Aorta, by the branches of which it is distributed to the body. Fishes.

Reptilia. In reptiles there are two auricles, and one ventricle imperfectly divided into two cavities. The venous blood brought from the body to the right auricle, is partially mixed in the verticle with arterialized blood brought from the lungs to the left auricle, and thence into the ventricles. From the right compartment of the ventricle the left pulmonary artery, and left Aortic trunk, commonly proceed; the latter usually supplying the blood which is distributed to the head and upper extremities. From the left compartment the right pulmonary artery, and the right Aortic trunk, proceed. The two Aortic trunks unite posteriorly to form the descending Aorta.

Amphibia. In the proteidæ the arterial trunks divide immediately into several Aortic arches, which unite again posteriorly to form the abdominal Aorta. In the frog, the circulation is more like fishes. The arterial trunk divides into four branchial arteries; and the branchial veins, collecting into larger trunks, run parallel to the arteries. After the metamorphosis, there remains but one arterial arch on each side, which unite to form the abdominal Aorta. The pulmonary artery and the vessels carrying the blood to the head are the remains of the branchial arteries.

In the earliest periods of fœtal life the embryo has clefts in the neck, and between these, arched plates. In these plates run the Aortic arches, which unite into one common trunk posteriorly. This is satisfactorily seen in the embryo of the bird on the third day of incubation, but is most distinct in reptiles. A similar structure exists in the mammalia and in man, but is much less distinct. In the higher vertebrata, no branchial lamella exist,—merely branchial arches, but which, in all other vertebrata, gradually disappear, being converted into the cornu of the os hyoides; hence, in all vertebrated animals, during the earliest stages of their existence, the main arterial stem is divided into Aortic arches.

Thus it appears that the parts pass through a state of higher and higher development, as we ascend to the higher classes of animals, until we reach the most perfect of them, man; in whom we find a heart divided into four distinct cavities, separating the arterialized from the venous blood, and perfect organs of respiration, by which the whole of the blood is exposed to the action of the air.

In the successive changes the human being undergoes during the fœtal state, the parts assume much of the character of the different classes we have now mentioned, in passing from its first appearance unto its perfect formation. In consequence of this, some physiologists maintain that man, at certain periods, belonged to the different classes of animals according to his state of development, and that at one time or other he belonged to each.

We shall, in the next place, proceed to treat of the blood. Blood.
The quantity of blood in the body has been variously stated by Quantity
different physiologists, but the average is about thirty pounds in the adult, one-third of which is, for the most part, in the arteries, and two-thirds in the veins. When drawn from the arm, it appears like a simple homogeneous fluid, of a colour General properties.
differing from a light red to a dark violet, and in many of the lower tribes of animals, is perfectly colourless. If now examined with the microscope, it presents the appearance of a number of red particles or globules, and a clear colourless fluid, the liquor sanguinis. The blood in the human subject (according to Bostock) has a specific gravity of 1.050., a weak alkaline re-action, a peculiar odour,—the halitus sanguinis, and a saltish taste. The temperature in the normal state is about 98° F, but by disease it has been observed as high as 107° F, and in cyanosis as low as $77\frac{1}{2}$° F. During sleep it is $1\frac{1}{2}$°lower. This degree of heat is nearly the same in all climates. If the blood be left at rest, it usually coagulates, in a period varying from Coagulation
3 to 7 minutes in the human subject. It gradually forms a gelatinous mass, which begins to contract, in consequence of which,

a yellowish coloured fluid is pressed out called the serum; thus dividing it into two portions, the red coagulam, or clot, and the serum.

Modifying circumstances.

If the blood be exposed to a freezing temperature, it may be preserved without change, but separates immediately on being thawed. Alkalies, even in very minute quantity, will prevent its coagulation, and the same occurs with some neutral salts. Fontana says, that if the poison of the viper, or ticuna, be added to about twenty parts of blood, it prevents its coagulation, whilst if that of the viper be introduced into the system during life, it immediately causes coagulation. In persons dying from the effects of electricity, blows on the stomach, poisoning from hydrocyanic acid, opium, and belladonna, and also from certain diseases, as the plague, cholera, and certain malignant fevers, the blood is said not to coagulate. Exclusion of it from air, retards the process of coajulation, according to Dr. Babbington.* Except under the above circumstances, the blood always coagulates when drawn from the body, independently of temperature, rest, or motion, or the presence or absence of air or other gases.

Cause of the coagulation of the blood.

As to the cause of this phenomenon, there have been numerous theories. Hunter believed that the blood was possessed of vitality, and almost of intelligence; conceiving that when the blood was in the vessels, in its proper place, and under ordinary circumstances, during life, it remained fluid, and apparently homogeneous; but when it was removed from the body, being no longer of use, and not capable of performing any function, it spontaneously separated. Others maintained, that during the passage of the blood from a fluid to a solid state, heat is evolved, which is the cause of this coagulation. This opinion was warmly maintained by Gordon, Thompson, and Mayer; but Dr. Davy and Schroeder-vander-kolk, have successfully opposed it; and it must be remembered that it is the effect of coagulation, and not the cause; and further, that heat would merely coagulate the albumen, not the fibrine. It has also been maintained, that its being simply left at rest would cause it;

* Med. Chirurg. Trans., vol. xvi.

but this is controverted by the fact, that if kept in constant motion, it still coagulates when removed from the body. Müller's conclusion is the following; that the proper combination of its elements is maintained so long only as the blood is under the influence of living surfaces, qualifying it however by the supposition that rest is necessary to coagulation; because if a quantity of blood be confined in a vessel, the two extremities of which are tied, it nevertheless coagulates, and blood extravasated in any part of the body usually coagulates. Schroeder-vander-kolk, has shewn that coagulation occurs very rapidly if the brain and spinal marrow be broken down, and Mayer states that a ligature on the par vagum caused the same phenomenon; but this statement is somewhat opposed to some experiments performed by Müller, Hewson, and others, who observed that coagulation occurred more rapidly in proportion as the strength of the animal declined. The cause of this phenomenon, it may be fairly stated, is far from being ascertained.

The serum is of a dirty straw colour, of specific gravity from 1·027 to 1·029; of a saltish taste, and a weak alkaline re-action in the higher animals. Its principal animal constituent is albumen; which is coagulated by acids, alcohol, and by 150° F of heat; but it does not spontaneously coagulate. The red coagulum may be readily separated into two parts, by merely shaking it with water, an opaque white substance, termed fibrine, and a number of red particles, remaining. In coagulated blood there is frequently a yellow coloured stratum upon its surface, called the buffy coat, which is pure fibrine. This exists particularly during utero gestation, in internal organic inflammations, (in which it is supposed to be the exciting cause) in acute rheumatism and in diabetes. Its presence is also modified by the manner of drawing the blood, and the vessel into which it is received. In these cases it is owing to the red particles having time to subside before coagulation has taken place.

Serum.

Division of the red coagulum.

Buffy coat.

The red particles in the blood were first discovered by Malpighi, and soon afterwards by Leenwenhoeck, who thought

Red particles.

them to be globular in the mammalia, flattened and oval in birds, reptiles and fishes. In 1774, Hewson gave a particular description of them, having ascertained them to be flattened in man and quadrupeds, and in all the vertebrata. He observed that their size does not depend upon the size of the animal, but is less in quadrupeds than birds; and that they are larger in the common fowl than in the adult human subject. He also pointed out the change in form they undergo from a flattened to a spheroidal one, when water was added; and he proved the central spot to be a solid nucleus. Dr. Young afterwards confirmed Hewson's opinion respecting the solid nucleus, but denied their presence in the human blood; in which he conceived the form of the particles to be similar to a double concave lens. Prevost and Dumas confirmed Hewson's opinion in the flatness of the particles, and of their consisting of a central nucleus and a coloured envelope. The following are some of the results of Müller's experiments, a part of which were known long before. First, their form is not the same in all animals; but whether elliptical or circular, they are always flattened. In the mammalia they are circular disks; in birds, reptiles, amphibia, and fishes, they are elliptical,—never perfectly circular, but in some fishes approaching to that form. In the human blood their thickness is one-fourth or one-fifth of their transverse diameter. In man, in the calf, cat, dog, and rabbit; and in birds, reptiles, and insects, they are flattened; but this flattening is more observable in the three latter, and of all animals the most is the salamander. Secondly, in the centre of each red particle there is a spot, the figure of which is the same as that of the red particles themselves. This, in the elliptical particles, has always the appearance of being produced by a central nucleus, but in the frog it appears to be an elevation, which is never the case in the mammalia. In some of the latter there appears to be an excavation from the circumference towards the centre; but he does not agree with Young, in supposing them to be concave. Thirdly, in size they are pretty uniform in the human subject, some being a little larger, but never twice the size of the majority. They are of the greatest size in the amphibia, less in birds, reptiles, and fishes, and smallest in the mammalia. In man, according to Müller, they measure from 0.00023 to 0.00035 of a French inch in diameter, (only one-fourth of the diameter of the elliptical particles of the frog) or 0.4029 to 0.2637 of an English inch. There are a number of other globules in the blood, called lymphatic globules, which were also demonstrated by Hewson, and are probably the nuclei of the red particles. If water be added in a considerable quantity to the red particles of the blood of the frog, the red colouring matter is readily dissolved, and after repeated ablution is entirely removed, leaving the nuclei which are not soluble in water, and not more than one-fourth of the original size of the particles. This demonstration cannot be given in the human blood, because of their minuteness, but from analogy it is probable that the same effect would be produced. The nuclei thus remaining are not of the original form of the particles; in the frog, they are round or oval, in the human subject Müller believes them to be globular. Water seems to remove the colouring matter in all proportions, notwithstanding the remarks of Prevost and Dumas, who believed that it did not. The reason of its not being soluble in the serum, was supposed by Hewson to be owing to the presence of salts, and by Berzelius, to the albumen; Müller, however, seems rather to agree with Hewson. Acetic and hydrochloric acids remove a portion of the colouring matter quickly, but leave a certain portion not removable by them. Chlorine removes the colour, but oxygen and carbonic acid do not effect it, and liquor potassæ dissolves the whole of the particles. Müller states that the size and form of the red particles are the same both in arterial and venous blood, though this statement is opposed to that of Kalterbrunner.

Lymphatic globules.

Solubility of the red particles and nuclei.

Form of the nuclei.

Operation of re-agents on the colouring matter.

The fibrine forms the principal portion of the cruor, having enclosed within it the red particles, the nuclei of which are formed by this substance. The presence of this principle in the fluid state is shewn by Müller, from simply placing a portion of frog's blood on filtering paper; the red globules do not pass through (as

Fibrine.

those of the human subject would, because of their smaller size) and the fibrine is easily separated. No globules are observed in this fluid under the microscope;* Bauer however states that it is composed of minute white globules. It soon coagulates, when it has precisely the appearance of human lymph. Another mode of shewing it, is to add, as Hewson did, a solution of salts to the blood, by which coagulation is retarded, and the red particles have time to subside.

Relative amount in arterial and venous blood

The proportion of fibrine in bullock's blood is, according to Müller, 0.496 in 100 parts; according to Fourcroy, from 1.5 to 4.3 in 1000 parts; whilst Berzelius states it at 0.75, Lassaigne 1.2, and Lecanu 1.360 to 7.235. The relative proportion of fibrine in arterial and venous blood is important and interesting, and, as would be expected, the amount is greater in arterial, because of its having to supply material for the nourishment, and to repair the waste, of the body, and from its having fibrine continually poured into it. The proportion in arterial and venous blood is as 0.483 to 0.395; or, according to Dennis as 25 to 24.

Serum.

The serum is the watery kind of fluid that separates from the blood during its coagulation, but is not the liquor sanguinis before spoken off, that being composed both of fibrine and serum. Besides containing albumen, it has a free alkali, soda, and according to Berzelius, potassa also, with neutral salts having these alkalies for their bases.

Amount of albumen.

Circumstances modifying the quantity of water.

The quantity of albumen modified.

According to Prevost and Dumas, in 100 parts of blood, there are 12.927 of coagulum, 8.69 of albumen, and 78.39 of water. They also shew the albumen in the serum to be about 1-10 of its weight. The quantity of water differs in the sexes; in 1000 parts, according to Lecanu, in the female, it varies from 790.394 to 853.135; in the male, from 778.625 to 805.26, shewing the quantity to be greater in the female. Dennis found the proportion to be greater in children than in old persons, but less in the sanguine than in other temperaments. The propor-

* Ph. Tr. 1820

tion of albumen differs little in the two sexes, varying from 57.890 to 78.270 in 1000 parts; neither does it differ much according to age.

There is no complete chemical analysis of the nuclei, owing to the difficulty of obtaining the separation in sufficient quantity. They are not soluble in water, acetic acid does not affect them for several days, and alkalies dissolve them; in which respects they somewhat resemble fibrine and albumen, but in others they are essentially different. Chemical analysis of the nuclei.

In the natural state oxygen increases the brightness of the red colour of hœmatin, carbonic acid being at the same time formed; but, if oxygen remain long in contact with it, it renders it black, probably from the carbonic acid combining with it. Carbonic acid, and the acids generally, changes it to a purple red, but its natural colour is restored by the admission of atmospheric air. Carburetted hydrogen, chloride of sodium, and nitrate of potassa, also brighten the colour of dark blood. It is soluble in water inevery proportion, the solution becoming less red on exposure to air. At 122° F. a blackish mass is formed, soluble in water, and at 150° F. it coagulates, becoming then insoluble. The mineral acids and alcohol coagulate it. The precipitates thrown down by salts and metallic oxides are of a brownish black or red colour. Lecanu supposed that it was composed of the true colouring matter, or globuline, and albumen; but the albumen may be derived from other sources, and not be necessary to its constitution. According to Michael, the destructive analysis of arterial and venous blood renders the following constituents;— Chemical analysis of thehæmatin. Destructive distillation of arterial and venous blood.

ARTERIAL BLOOD.			
Nitrogen 17.253	Carbon 51.382.	Hydrogen 8.354.	Oxygen 23.011.
VENOUS BLOOD.			
——— 17.392.	——— 53.231.	——— 7.711	——— 21.666,

shewing the two former to be greater in venous blood, whilst the latter are diminished. The following is the result of Berzelius' analysis of five grains of the ash remaining by calcining the Destructive analysis of hæmatin.

colouring matter; oxide of iron 50.0, subphosphate of iron 7.5, phosphate of lime and magnesia 6., pure lime 20., carbonic acid and loss 16.5; shewing that it contains one half per ct. of metallic iron; manganese has also been detected. Iron and lime in the blood appear not to be in the state of salts, for, according to Berzelius, the whole of the most delicate tests for iron are unable to shew it, until it be calcined. Roe however endeavours to prove it to be an oxide. From some experiments by Engelhart, he believes the colouring matter is in part owing to the presence of iron; but Gmelin, from other experiments, denies it. Treviranus, from an experiment of Wintels, believes the iron to unite with a peculiar substance to form this principle; but Müller, in repeating the experiment, did not arrive at the same conclusion. Hermbstaedt conceived that sulphur is also present in this fluid.

Destructive analysis of fibrine.

The ultimate analysis of fibrine, according to Gay Lussac and Thenard, is in 100 parts; nitrogen, 19.934; carbon, 53.360; hydrogen, 7.021; and oxygen, 19.685. When the serum is evaporated to dryness, treated with boiling water, and evaporated, the addition of alcohol will be found to have removed lactate of soda, chloride of potassum, soda, and osmazome. The substance left by the boiling water and alcohol is albumen. The three animal principles in the serum are lactate of soda, osmazome, and albumen. A sulphate of an alkali, carbonate and phosphate of lime have also been found in the blood.

Destructive analysis of serum.

Destructive analysis of albumen

Albumen exists in the serum as an albuminate of soda, but Berzelius states that the soda may be neutralized by acetic acid without any precipitation. The ultimate analysis of it, according to Gay Lussac and Thenard is, nitrogen, 15-705, carbon, 52.883, hydrogen 7.540, oxygen 23.872. According to Prout, nitrogen 15.550, carbon 49.750, hydrogen 8,775, oxygen 26.925.

In addition to the animal principles before-mentioned, fatty matter is sometimes found floating on the surface.

In the description which has now been given of the chemical constituents of the blood, and their proportions, I have not entered at length into any but that of the red particles: the chemical properties of fibrine and albumen more properly belonging to chemistry do not appear to be necessary to the composition of this essay.

Respecting the electrical properties of the blood, as attempted to be shewn by Dutrochet and Bellinger, I shall not treat here, as the inferences deduced from them appear to be decidedly erroneous; it having been proved that the electrical property of the blood is not greater than that of water. A similar remark is also necessary respecting a vital process, described by Schultz, to be constantly going on between the molecules of the blood, and the substance of the vessels. He conceived that there was a constant disappearance and new formation of globules occurring. This opinion has been combated with complete success, by Rudolphi, Purkinge, Koch, Meyer, and Müller, none of whom could perceive this new and fanciful phenomenon. This error, on the part of the learned professor, was probably occasioned by some optical illusion, owing to the rays of the sun falling upon the blood, and being refracted by its particles.

Electrical properties of the blood.

Vitality of the blood.

Mayer and Eber have attempted to prove that the red particles were animals belonging to the infusoria. This opinion, it need scarcely be said, has met with a similar fate.

The red particles said to resemble infusoria.

A confused motion of the globules of the blood, may be observed, for a few seconds, in a drop of blood placed on a glass under the microscope, which Mayer and Treviranus were disposed to consider as automatic movements. This, however, according to Müller, cannot be correct, because these motions may be observed in the the blood when long removed from the the body, and which could not be dependent upon vitality; they are probably owing to some physical cause, the nature of which is not well understood.

Automatic movements of the red particles.

Self-propelling power of the blood.

Another theory bearing upon the vitality of the blood, is that which ascribes to it a self-propelling power. On the affirmative side we have Keilmeyer, Carus, and Treviranus; whose opinions seem to be confirmed by the experiments of Pander and Wolff, respecting the passage of the blood from the area vasculosa of the chick to the heart; and also by the fact of the circulation being carried on, for some time, in parts separated from the body. Yet from an analysis of these and other grounds for the opinion, Müller entirely differs from them. To use his own words, "I deny, therefore, the existence of a self-propelling power in the blood." This singularly curious and interesting subject would well repay careful investigation, for with the few facts which we are in possession of, the subject must not be considered perfectly settled, although the arguments, on the whole, appear to favour Müller's conclusion.

Formation of the blood.

We shall now proceed to describe the sources whence the blood is derived. This fluid is formed from the contents of the absorbent system, which are, first, the transparent lymph, consisting of materials taken up from the intimate structures of the body, by the lymphatic vessels; and secondly, the chyle, which is produced in the following manner. The food having been conveyed to the stomach, it is there subjected to the action of the gastric juice, which converts it into chyme. This substance then passes through the pyloric extremity of the stomach into the intestinal canal, where it is subjected to the action of the bile and pancreatic juice changing it into the chyle, a fluid which has the appearance of milk. This is absorbed by the lacteals, which are particularly distributed to the upper part of the intestinal canal, and carried by them to the thoracic duct, where it is mixed with the fluid brought by the lymphatics from all the parts of the system. This fluid finally passes into the left subclavian vein, at the point of junction with the internal jugular vein. The former of these fluids, the lymph, bears great analogy to the liquor sanguinis, which contains lymph and albumen in solution, and may be termed the lymph of the blood without red particles; whilst the blood may be considered lymph

Digestion.

with red particles. The chyme contains no fibrine, that substance being formed during its passage in the absorbents previous to its entrance into the circulation. The lymph and chyle contain albumen and fibrine in solution, but in less quantity than in the blood; 100 parts of chyle containing from 0.17 to 1.75 of dry fibrine. Chyle possesses some points of resemblance to the blood; it is alkaline, though in a less degree than that fluid; it also contains a quantity of uncombined fat and iron, (less combined than in the blood;) and according to Emmert and Gales, it is composed of globules. Autenrieth supposes the chyle to be converted into blood in ten or twelve hours after its entrance into the circulation, the serum at that time being frequently observed to be milky. Müller thinks it probable that the change is effected somewhat more slowly.

Resemblance of the chyle and blood.

Where the red colouring matter is formed, is at the present time entirely a mystery. Hewson conceived it to be formed by the spleen, but this opinion was not drawn from accurate experiment, because that organ may be removed from animals without any obvious effect on the colour of the blood following. It is probably owing, in some measure, to respiration.

Where the redcolouring matter is formed

We now come to consider the important changes which take place in the blood, when carried to the lungs and there exposed, with the intervention of a delicate membrane, to the atmospheric air. It is well known that on the blood passing to the lungs, is of a dark red colour, and that it is returned from these organs of a florid red or scarlet colour. This process is termed arterialization. It is for us to ascertain the manner in which this change is produced, but to enter minutely into the subject would belong to an essay on respiration. The specific gravity of the blood, after passing through the lungs, according to Dr. Davy, is nearly the same as before, but the capacity for caloric is as 913 in arterial, to 903 in venous blood; thus proving that arterial blood has a greater capacity for caloric than venous. The change in the colour of the blood, after the exposure to air, is supposed to be owing to the absorption of oxygen, as a similar effect

Arterialization of the blood.

follows the admixture of oxygen with the blood. We know that during respiration oxygen disappears and carbonic acid is generated. It is also known that the quantity absorbed is greater than the amount of carbonic acid gas expelled will account for; and it is therefore probable that the greater part of the oxygen unites with the carbon of the blood, to form carbonic acid, whilst the remaining portion unites with the red particles of the blood, and is the cause of their change of colour. Whether this process takes place in the lungs, or whether the oxygen be carried into the circulation and there unites with the carbon, is an undetermined point. That it occurs in the circulation is the theory of Lagrange and Hasserfratz, and is supported by the experiments of Vogel, Home, Brand, Scudamore, Collard de Maligny, and more expecially by those of Sir Humphrey Davy and Magnus, who demonstrated the existence of carbonic acid in venous blood, and which is the most probable cause of its dark colour. The extrication of the carbonic acid, and the fresh absorption of oxygen, convert it into arterial blood. Stevens endeavoured, by a peculiar theory, to shew that the oxygen had no share in the change; but this is unsupported by experiment.

Change in the blood by circulation through the body.

The blood undergoes certain important changes during its passage through the system. Whilst in *transitu* the oxygen which it had absorbed unites with the carbon previously existing in the blood, and forms carbonic acid. This is said by some to take place only in the capillaries, an opinion we are not able, in the present state of our knowledge, to confirm or discard. This change, that the blood experiences, converts it into venous blood, and it would perhaps be better here to state the difference between arterial and venous blood. One or two facts respecting it have been previously mentioned, viz, the specific gravity, and the capacity for caloric. The temperature of arterial blood is higher by 1 or 1½° F., according to Dr. Davy; which statement is confirmed by Krimer and Scudamore. The arterial blood is also said to coagulate more quickly than venous, by Autenrieth, Mayer, Davy, and Blundell. Thakrah

Difference of arterial and venous blood.

however does not agree with them. Mayer, Blainville, and Dennis, state that arterial blood yields less serum and more coagulum than venous. Mayer and Emmert agree that arterial blood contains more fibrine than venous, and that it yields it in thicker, more solid, and shining bundles; and Müller ascertained it in the blood of the goat, to be in the proportion of 29 to 24. The greater softness of the fibrine in venous blood is probably owing to its greater division, because of its being in less quantity, a fact accounted for in two ways; first, by a portion being appropriated in the capillaries to the purposes of nutrition; and secondly, by the arterial blood receiving a constant supply of nutritious material from the lacteals and lymphatics, which is poured into the circulation from the thoracic duct. Müller states that it is also probable, that respiration contributes to the development of fibrine, because the blood in the fœtus contains but little, and in cyanosis, from malformation of the heart, there is a great tendency to hæmmorhages, frequently of a fatal character, which is probably owing to the defective coagulability of the blood. The following results obtained by Michaelis, from the destructive distillation of arterial and venous blood with peroxide of copper, also shew a difference between them ;—

VENOUS BLOOD.

Carbon 52.650,	Nitrogen 15.505,	Hydrogen 7.359,	Oxygen 24.484,	Albumen.
——— 532.31,	——— 17.392,	——— 7.711,	——— 21.666,	Cruor.
——— 50-440,	——— 17.207,	——— 8.228,	——— 24.065,	Fibrine.

ARTERIAL BLOOD.

Carbon 53.009,	Nitrogen 15.562,	Hydrogen 6.993,	Oxygen 24.436,	Albumen.
——— 51.382,	——— 17.253,	——— 8.354,	——— 23.011,	Cruor.
——— 51.374,	——— 17.587,	——— 7.254,	——— 23,785,	Fibrine.

thus shewing that arterial blood contains less carbon and more oxygen than venous blood. But it must be remembered that this analysis has not been repeated a sufficient number of times to command implicit confidence.

Uses of the blood.

We now enter upon the most interesting and important part of this division of the subject, viz. the use of the blood; for it would be altogether mis-spent time to accumulate facts, dry and comparatively uninteresting in themselves, were it not for the very valuable and essential office it performs in the animal economy. For probably upon no system in the body, is the continuance of life more dependent, than upon the integrity and constant performance of the functions of the circulating system.

Its importance. It is a fact, much more clearly ascertained at the present day, than it was a short period since, that a person in tolerable health may fall in a state resembling syncope, and die in an exceedingly short space of time, when no reason can be found sufficient to account for death except flaccidity of the parietes of the heart; so that death must have been owing (in all probability, if not certainly) to the non-performance of the functions of that organ. We are also well aware of the fatal result that too frequently, and at the same time very speedily occurs, when by mechanical or other means, any large arterial trunk is wounded or opened, and its contents poured out. The fact of aneurism of the larger vessels being liable to produce, as it were, instant death, and almost in a moment opening to the sufferer the awful realities of another world, is an appalling fact that too often attracts our attention, and tells us, in language louder than words, "*De animæ salute cogitare.*"

The necessity for the due circulation of the blood through the different parts of the body, is proved by simply applying a ligature around the vessel going to any part, when, as a consequence, that part soon becomes gangrenous and dies. It is from the influence of the arterial blood, that the brain and nervous system derive their energy, for nothing is more certain than that their powers are annihilated by withdrawing this stimulus from them. But the systems that are more particularly dependent upon the blood are the nutritive and the secretive; which are entirely and solely derived from it.

Nutrition. We shall first consider nutrition. It has been clearly ascertained that a certain change is constantly taking place in the solids and fluids of the body; that the former are being constantly removed from their situation, and that their places are filled by substances derived from the latter, which is the blood. It will be our object to endeavour to shew the method by which this is performed.

The theory which for some time was received by physiologists, was, that the red particles of the blood, or the nuclei, (which latter was the opinion of Prevost, Dumas, and Edwards) united directly with the tissues. This opinion, Müller with great apparent truth, decidedly opposes. He maintains that if this be the case, the parts composing the different tissues must bear some resemblance in size and figure to the red globules; and this he proves not to be the case. The muscular and nervous fibrils are said, by those who advocate that theory, to be composed of an assemblage of aggregated globules, whilst the red particles of the blood are never globular in any of the vertebrata, but are in the form of flattened disks. Müller does not conceive, with Sir. E. Home and others, that the primitive fibrils of muscles and nerves do contain globules; but that the muscular tissue is composed of simple fibres, having a number of enlargements closely succeeding each other. Schultze also believes them not to be globular, and to bear even less resemblance to globules than Müller does, there being merely irregularities on the surface of plain fibre. Further, the size of the red particles does not agree with the size of the supposed globules; and in the amphibia these particles are elliptical; how then, can the primitive fibres of nerves and muscles be formed from them? How effected.

The following theory is the one that appears more plausible: that the process of nutrition is carried on by the albumen and fibrine dissolved in the liquor sanguinis of the blood, passing through the parietes of the capillary vessels, and being imbibed by the tissues; and, whatever is superfluous for this purpose, and the process of secretion, is taken up by the absorbents. Any solid matter cannot pass through them, but is carried along to the

How is the colouring matter produced.

veins. Whether the parts that are coloured derive their colouring principle from that of the blood, or whether they possess the property of producing colouring particles, is not ascertained. It is however certain, that they do not assist in the process of nutrition by uniting with the tissues, though they fill some important office in the animal economy; being made of a bright red colour in the lungs, and when exposed to the action of the tissues losing it, and becoming of a darker hue, which change must occur about 480 times in every 24 hours. They supply a stimulating principle to the organs of the body, and particularly to the nervous system, by which it is enabled to perform its functions.

Effect of morbid substances introduced into the blood.

From the constant deposition of substances by the blood, it is easy to conceive of the effect which must follow, when any morbid substance is admitted into the circulating fluid. Thus, the excess of fibrine in the blood, though it is not a morbid production, yet the *excess* of it may be so considered, causes too great a stimulation of the parts to which it is distributed, and, as a consequence, inflammation is produced; the best mode of relieving which, is to remove a portion of this principle from the system, by repeated depletion; acting upon the long established maxim, that repeated abstraction of blood impoverishes it, causing a greater relative amount of serous fluid. The same occurs in acute rheumatism, and many other diseases, which it is not necessary here to enumerate. The disease termed hypertrophy essentially consists in a greater deposition of the nutritive parts of the blood, than is consistent with the healthy state of the organ. The opposite state, or wasting, is owing to the defective deposition of it. Again, purulent matter may be taken up by the veins, as from compound fractures, and be deposited in distant parts, which, whether from irritation or not, frequently causes abscesses to form, followed by fatal results. The malignant disease termed cancer, from the researches of Dr. Carswell, appears to originate in a peculiar morbid state of the blood. Many other instances might be adduced, but these will shew the influence over the different parts of the system, that the circulating fluid possesses.

It is owing to the property that vessels possess, of depositing substances, that parts are restored to their normal state, where solution of continuity has occurred, either in the soft parts or in the bones.

Secretion.

The second function of the blood to be considered, is the all-important one of secretion. This function is probably as important to animal life as the preceding, and, in some respects, may be considered much more so; for, before the substance necessary for nutrition can be produced, secretion must have been completed, and any impediment to the latter process must of necessity, sooner or later, stop the former. Again, so important is this function to all animated nature, that the reproduction of the species could not be effected without its agency, and, as a consequence, the world would soon be depopulated and sterile.

Its importance.

General divisions.

For the following classification of the secretions, I am also indebted to Professor Müller; and it appears to me to excel any previously produced, though not itself absolutely perfect. Secretions are divided into two classes; first, those which are formed ready in the blood, and in which, their presence would soon be injurious; and secondly, those which are not formed in the blood, but the elements for the formation of which (for the most part) are in that fluid, and are combined by a chemical process. Those of the first class are called excretions; those of the second, secretions—*properly so termed.* The excretions are the urine and the perspirable fluid, and are, in the human subject, acid. The true secretions are sub-divided into two classes; first, those which do not fulfil any further office in the economy, or are useful only for the self-defence of the animal; as the acrid secretions of many insects and reptiles, the secretion of the castor fiber and the moschus moschiferus. Besides fulfilling the last mentioned purpose, it is probable that these answer another

Sub-divisions of the true secretions.

very important end, viz., that of removing from the system the elements essential to their composition, which, remaining, would probably be injurious to the well-being of the individual. Secondly, those which serve important purposes in the economy, as the milk, bile, serum, mucus, gastric juice, saliva, and the pancreatic juice. The substances constituting the latter class are frequently alkaline, but not invariably so, the same fluid being changed from the one to the other state by very slight causes. The excretions are those matters ready formed in the blood, and which, after the removal of the secreting organs, may be eliminated from the system by some other part; as the urea, when suppression of urine occurs, being frequently exsuded from the pores of the skin, and deposited there in scales. But this cannot be the case with the proper secretions, because their elements not being combined together in the blood, require the intervention of a peculiar apparatus to produce that combination, consequently they cannot be produced when the organs are removed.

Explanation of the excretions.

Each peculiar secretion is produced by a distinct secretory apparatus, of which there are three kinds; first, simple cells; second, plane membranes; and thirdly, glands. The first kind are seen in the adipose tissue, in the vesiculæ graafianæ of the ovary, and in the seminal cells of some fishes; the testes not being furnished with excretory ducts. The deposition in the first situation is called fat, existing more particularly beneath the integuments in the young subject, but surrounding especially the internal organs, as the heart, in advanced age. In the second situation an albuminous fluid is deposited, having floating in it the rudiment of the future fœtus; and in the third situation, semen. The second kind is seen in the serous and mucous membranes, and skin. Those of the first are sub-divided into three sections; first, synovial bursæ, which are situated beneath tendons, or are subcutaneous,and are intended to allow parts to move on each other without friction; secondly, synovial sacs of joints, secreting an alkaline albuminous fluid, lubricating the surfaces of

Division of the secretory apparati.

Position of simple cells.

Examples of plane surfaces.

Serous membranes.

the cartilages, and preventing any loss of substance by friction; thirdly, the membranes lining the different cavities, and, for the most part, forming shut sacs; as the tunica arachnoides, pleuræ, the inner layer of the pericardium, the peritoneum, and tunica vaginalis testis. From the surface of these, a fine halitus is given off, which fills the cavity in the living subject, but, after death, is condensed into a fluid.

The mucous or second division of plane surfaces lines all the internal parts which communicate with the external; as the whole of the alimentary canal and the genito-urinary system, and all parts through which foreign substances are taken into the system, or by which matters are eliminated from it. They possess a considerable number of elevations, called follicles, from which the peculiar secretions were thought to be derived; but mucus is secreted in the tympanum, where there are none of these follicles. The only points in the human body where this class of membranes unite with the preceding, are at the fimbriated extremities of the fallopian tubes. The use of their secretions is to preserve them from the effects of acrid substances, which are constantly and of necessity applied to them. These secretions differ in character according to the situation of the membrane. Mucous Membranes

The skin, which is the last in this division, is furnished with several kinds of secretions. First, the peculiar secretion situated in the rete malpighi, determining the colour of the race; secondly, the secretion from the sebaceous follicles; thirdly, the hair secreted from the hair follicles; and fourthly, the perspirable fluid, which is found in peculiar small tubes spread over the whole surface of the body, pouring out their secretion through the minute pores in the epidermis, as described by Purkinge and Breschat. These tubes pass in a spiral direction through the rete malphigi, and, entering deeply into the cutis vera, terminate in a gland formed by a convoluted tube; so that these The Skin.

secretions are not, as was formerly supposed, furnished from the open ends of the blood vessels.

Division of glands.

The third class of secreting agents are glands, which may be divided into two kinds; first, those in which no efferent duct has been discovered, and consist entirely of a congeries of blood vessels; secondly, those which possess that appendage. The first kind of glands consists of two classes; those which are essentially formed of a mass of blood vessels, as the spleen, and those composed of masses of lymphatic vessels, as the lymphatic and mesenteric glands. The second kind of glands produces a change in the blood circulating through them, and by a peculiar action on certain elements contained in that fluid, form an entirely new product, which is removed by a duct or canal.

Process of secretion and the agents affecting it.

Having now taken a general view of the varieties of secretory organs, it would be foreign to our subject to enter more minutely into their structure, and describe the process peculiar for the production of each secretion; we shall therefore proceed to speak in a general manner only of the process and the agents affecting it. Secretion in every part of the system occurs through the medium of the capillaries. The liquor sanguinis, containing certain matters in solution, having passed through their parietes, one portion serves the purposes of nutrition, and the other is expended in the process in question. This process always takes place on free surfaces, and consists in the transmission of the blood from the arteries to the veins, through an infinite number of anastomosing branches. A certain change is produced, by which the fluid is converted into the peculiar secretion of the part; which is then removed by its proper canal.

In the liver.

In the liver, probably the most complex of all the secretory organs, the blood is brought by the vena porta, which, after having traversed through all the chylopoetic viscera, and received blood even from the liver itself, (the extreme branches of the hepatic artery terminating in the vena porta) ramifies through the structure of that organ, accompanied by the hepatic artery and duct, even to its minute lobules, by the intra-lobular veins. These are situated between the lobules, and give off branches ramifying from the circumference to the centre, and eventually terminate in the inter-lobular veins. A certain change is hence produced in the blood, by which the bile is formed, and afterwards removed by the hepatic duct; the residual blood passing into the inter-lobular vein, from thence to the infra lobular, and lastly into the common trunks of the hepatic veins.

We now come to a part of our subject which is difficult to understand, viz., how it is that the secreted fluid is always poured out on the free surface of the membrane, and never on that surface by which it is connected with the surrounding parts. To explain this interesting phenomenon, Professor Müller offers the two following hypotheses; but it must be remembered they are but such, totally unsupported by demonstration, and are therefore rather given for consideration than implicit adoption, although they are perhaps the best which have yet appeared. First, it may be imagined (he says) that the capillaries of the gland are provided with exhalant pores, so constructed as to allow fluids to pass through in one direction only, viz., towards the cavity of the glandular canals. Secondly, that by virtue of imbibition, or the general organic porosity, the fluid portion of the blood becomes diffused through the tissue of the secreting organ; that the external surface of the glandular canals exerts a chemical attraction on the elements of the fluid, infusing into them, at the same time, a tendency to unite into new combinations, and then repels them in a manner, which is certainly quite inexplicable, (although Müller considers this the preferable hypothesis,) towards the true surface of the secreting membranes or glandular canals. Dr. Wollaston attributed this agency to galvanism.

Why does secretion always take place on the free surface of membranes?

A much more interesting and important subject however, is the cause of the specific peculiarity of the secretions. For

Cause of the peculiarity of the secretions.

this, as for every other obscure phenomenon, multitudes of hypotheses, each alike unsupported by fact, have been given, almost every writer thinking it necessary to pull down the hypothesis of his predecessor, and to build up a new one; at the same time proving it to be much easier to find fault with the existing, than to frame one that should be less exceptionable. Haller supported, in some degree, the four following hypotheses. First, that the peculiarity of secretion depends upon the difference in the rapidity of the motion of the blood in the various organs; but this difference has never been demonstrated. Secondly, upon the difference in the supposed *free* ends of the arteries; but these have been shewn to have no existence. Thirdly, upon the various diameters of the canals through which the fluids pass in the different secretory organs; it has, however, been shewn that the greater number of the secretions take place on plain surfaces. Fourthly, upon the different angles at which the blood vessels divide in the secretory organs; but it has been demonstrated that the ramifications of the blood vessels in different organs are very similar.

Another theory, developed by Chevreul, and particularly supported by the experiments of Gmelin appears, at first view, much more correct. He conceives that all the elements forming the different secretions pre-exist in the blood, and that it is only the functions of the glands, to remove these from the blood, and to combine them in order to form the different secretions. This theory is supported by the fact, that a considerable number of the elements entering into their composition do exist in the blood; but, unless we could prove the existence of the whole of them in that fluid, which it is impossible to do, the theory cannot be admitted. We must, therefore, come to the conclusion that we remain as yet in perfect ignorance of the precise cause of this important phenomenon.

Influence of the nervous system over the secretions.

Another very interesting subject connected with the secretions is the influence that the nervous system exercises over them. It is ascertained, that on the division of the par vagum, the gastric juice is suspended, and the mucous secretion from the bronchial membrane is changed. The secretion of urine is not stopped, but is materially modified, as is shewn by the experiment of Krimer, in which rhubarb, and ferro-cyanide of potassium, which had been introduced into the system, and found in the urine, could not be detected on the division of the par vagum; but on uniting the divided ends by a galvanic current, these substances were speedily ascertained to have entered that fluid; thus demonstrating the influence of the nervous system on the secretions. In many morbid states of the system the secretions are materially modified, both in quantity and quality, as in the cold stage of an intermittent, which we must consider to be owing to a change in the nervous energy.

Another argument may be founded on the fact of the secretion from the salivary glands being instantly increased by the presence of their appropriate stimulus before its entrance into the system. Many other instances of a similar nature might be adduced, if necessary, but few will be disposed to deny the influence of the nervous system upon the secretions. Müller states it as his opinion, that the cerebro-spinal and sympathetic systems are the sources from whence the nervous influence is derived. Galvanism appears also to have considerable agency, and to be capable of supplying the place of nervous energy, at least to a certain extent, as in Krimer's experiment, and in that of Most, who found the deposition of the urinary salts to be much increased by galvanic action.

Influence of galvanism over the secretions.

We must, in the last place, give a general view of the uses of the different secretions. Some of them are solely for the purpose of converting the aliment taken into the system into blood; such are the saliva, gastric juice, bile, pancreatic juice, and enteritic fluid, whilst the remaining secretions subserve various other purposes in the economy. The office of the saliva appears to be merely that of preparing the food for mastication. What changes, or whether any, are produced on the food, to assist in

Uses of the secretions.

Saliva.

digestion, is not known; but it is supposed by some to possess no more solvent power than simple water. It has however, by Tiedeman and Gmelin, been said to possess a certain amount of additional solvent power, but allowed by them to be very slight. Leuches and Schwann state that it has the property of converting starch into sugar; this, however, has not been sufficiently tested. The use of the gastric juice appears to be that of a solvent of the food; the time required for this process differing according to the nature of the substance to be acted upon. Thus, bread was found to be dissolved in five hours; whilst meat required nine. This secretion is also different in different animals, as herbiferous animals are unable to digest the food of carniverous, and vice versa; but many animals are able to digest both kinds of food. On the addition of bile, in the duodenum to the aliment digested in the stomach called chyme, a white milky fluid is produced, termed chyle. The chief agents in the bile, are picromel, osmazome, a matter similar to gliadin, and cholic acid; with resin and colouring matter, which pass off as excretory substances. This action upon the chyme is not understood; it does not appear to be owing to the neutralization of the acid of the chyme by the bile. Another very important use of the bile is to stimulate the intestines to their peristaltic action. The pancreatic juice is usually said to be analogous to saliva, as in its action it much resembles it; but in many of its chemical properties, it decidedly differs from it. It is not considered to have any very important influence on digestion. The use of the seminal fluid does not require any explanation here. The humors of the eye, are for the purpose of refracting the rays of light; this property depending upon their relative densities. The pigmentum nigrum and the uvea are intended to absorb the rays of light, so as to prevent an indistinct figure being produced. The uses of the secretions from the serous and mucous membranes have already been mentioned.

Gastric juice. Bile. Pancreatic juice. Semen. Humours of the eye. Pigmentum Nigrum.

Animal heat. On the subject of animal heat, which is the last point to be considered in the first part of this essay, it will not be necessary to enter into all the details concerning it; we shall therefore only consider it as produced by the blood, which is the theory of Dr Crawford. He conceived, in the first place, that arterial blood possesses a greater capacity for caloric than venous blood, and that during the act of respiration, the oxygen of the air unites with the carbon of the blood, forming carbonic acid, by which a condensation in volume occurs, and, as a consequence, a quantity of latent heat is rendered sensible. This he conceived to be absorbed by the arterial blood, and to be given out by it, in its course through the system. Davy has shewn that the capacity of arterial blood for caloric is slightly more than venous. Secondly, it has been supposed that in the capillaries, where the secretions are given off, a quantity of heat is extricated, by reason of the capacity for caloric by the secreted substances being less than that of arterial blood. According to Dr. Paris, urine as compared to blood in this respect, is as 0.777 to 1.003. Dr. Davy has, however, ascertained that the difference is exceedingly slight; but it is obvious that a certain quantity of heat is given out whenever carbon and oxygen unite; because 100 vols. of the former always unite with 50 of the latter, and the result is but 100 vols., shewing a condensation of one-third, which will, of course, cause the latent heat possessed by the 50 volumes to be extricated. Again, the oxygen which unites with the red particles of the blood must undergo a condensation and a consequent development of heat be produced. But the amount of heat procured in this way does not account for the whole, and the phenomenon of animal temperature is, without doubt, principally dependent upon the nervous system.

Dr. Crawford's theory

PART II.

APPLICATION OF THE PRECEDING OBSERVATIONS TO THE MORE PARTICULAR OBJECT OF THIS ESSAY.

General view of the system as illustrating the wisdom, power, and goodness of God.

Having concluded the anatomical and physiological portion of this essay, we shall now proceed to point out, more minutely, the parts of this subject which tend especially to shew the wisdom and goodness of God. We cannot look at any part of the human frame, so "fearfully and wonderfully made," the parts of which are so aptly fitted for their respective positions and uses in the animal economy, without seeing, at every step, power, goodness, and design. There is no part redundant or superfluous, neither any part wanting to complete the original design; no part without a distinct and separate function to perform, and upon the due performance of which every other part or system is more or less dependent. There is no part having an independent existence, it being wisely arranged by the Great Creator, that the life or well-being of the individual should depend upon the due performance of the functions of an assemblage of organs, connected inseparably with each other. There are some organs in the body, the functions of which we do not understand, and which appear superfluous, the removal of them not producing serious results; yet it is probable that ere long, they will be found to fulfil some useful office; and I think we may say, without fear of contradiction, that the removal of any organ from the system, or the non-performance of its functions, must be attended by detrimental results, the amount of which will depend upon the rank it holds in the animal economy.

There are, however, certain parts more particularly shewing the goodness of an Almighty Creator, without which our system would be a perfect chaos, and not, as is the case, every part having a fixed and definite relation, from which it cannot pass without taking on the character of disease. We find no part interfering with the functions of another, but every part placed in the best possible position, and formed in the best way for the performance of its functions.

Again, we have not parts formed and placed in the system without reference to the symmetry and due proportion of them, neither have we the uses of parts curtailed to conform to appearance, as though beauty was the primary or sole object ; but we find that utility and elegance are inimitably combined in every part of our structure. The same with regard to convenience; we do not find that parts are placed without respect to convenience, nor for convenience only, but utility and convenience, like utility and elegance, are essentially and in every instance combined. For the performance of the different functions, the organs are not, as when made by man, a vast assemblage of different actions to perform a single office; not as though it was intended to make the system as complex as possible, but directly the reverse; every part is fashioned upon the simplest possible plan, the least number of agencies being used that could possibly effect the purpose. There are, it is true, certain parts of the body that appear to us very complicated in their mechanism, and which we find impossible to unravel, yet as generation succeeds generation, and wisdom and knowledge are increased and spread over the earth, discoveries are being constantly made, by which these complicated parts are rendered more simple, and, though the time may never arrive, when we shall know them in their perfect simplicity, still we must admit, that nothing, as far as we are informed could fulfil the different purposes with the same regularity, constancy, and ease, combined with such inimitable simplicity, as the different organs in the human frame.

We also find our parts passing through a constant series of development, from a simple homogeneous particle, gradually springing into life, we know not how; first appearing as a minute speck, gradually increasing, and becoming more and more developed, until the different parts put on the appearance of those they are intended to represent; when, after passing through an innumerable series of phenomena, superintended by the wisdom of an Almighty hand, we find it, by the time its uterine sojourn is completed, a beautiful mass of organised materials, each part capable of exercising the functions necessary to vitality, but no part as yet arrived at a state of maturity. During a series of years each part is undergoing certain changes, becoming more perfectly formed, and more capable of performing its functions, until the period has arrived when the being may be considered as perfect. After a certain number of years, during which he is enjoying the full plenitude of his existence, capable of drawing delight and pleasure from every object around him, and from those of his fellow creatures with whom his lot may be cast; he begins gradually to sink and decay, each part going through certain successive changes, by which it is rendered less and less capable of performing its functions, until at length the wheels of some vital part stand still, the functions of secretion, nutrition, circulation, and nervous energy are no longer performed, the body becomes a prey to natural affinities, and returns to the earth whence it was derived, and the spirit to the God who gave it. We may, with great truth, apply the words of the Psalmist;* "Thou hast possessed my reins, thou hast covered me in my mother's womb; my substance was not hid from thee when I was made in secret and curiously wrought in the lowest parts of the earth. Thine eyes did see my substance yet being imperfect, and in thy book all my members were written, which in continuance were fashioned, when as yet there was none of them."

Position of the heart.

In proceeding to our subject, we shall commence with the position of the heart, as demonstrating the wisdom and goodness of God. It is situated in a cavity, having in front a strong arched bone, the sternum; behind, the mass of bones constituting the vertebral column, forming an almost impenetrable

* Psalm 139.

barrier to any injury occurring in the median line; and on the sides, a series of arched bones, the ribs, bound firmly together by muscular and tendinous fibres, covered posteriorly by a large mass of muscles, serving, besides their own proper uses, to defend the parts within the cavity. Anteriorly, the ribs are connected to the sternum, by a cartilaginous substance, which, from its elasticity, would recede and rebound when any weight fell upon the chest, and by that means prevent fracture. Respecting the arched form of the ribs and sternum it will not be necessary to make any remarks, as that peculiar form is well known, and universally admitted, to possess far greater strength, than a plane flat surface. If the heart had not been protected by osseous coverings, or had those coverings presented flat surfaces, almost every action would have placed this vital and all-important organ in jeopardy, and the violence now received with impunity must have been certain death to the recipient.

Its resting upon the central tendon of the diaphragm is also a wise contrivance, inasmuch as that part does not materially follow, in the normal state, the motions of the muscular portion. Had it been placed in the latter position, every act of inspiration and expiration, sighing, laughing, weeping, and a variety of other motions dependent upon respiration, must have caused an ascent or descent of this organ, which, to say the least, would have been a material inconvenience. Its own proper capsule also tends materially to retain it in its proper position; being attached above, to the primary trunks; below, to the central tendon of the diaphragm; and on the sides, to the pleuræ. Its resisting fibrous nature must also assist in its protection. Fibrous pericardium

The smooth surface of the inner membrane of the pericardium and the outer surface of the heart, moistened as it is by a watery kind of vapour, also demonstrates the goodness of the Creator. By reason of this, the movements of the heart are not accompanied by the slightest injurious degree of friction, which would have Serous pericardium occurred had a fibrous membrane, dry and rough, been substituted for it; and by the irritation and inflammation which would have resulted, our existence would soon have been terminated, or constantly placed in precarious circumstances. It probably also performs another duty, viz., that of modifying or preventing the effects of concussion, a circumstance of the utmost importance to many, particularly to those who are constantly exposed to, and frequently receive, violent shocks by falls or other means. From the peculiar structure of this membrane, and its being larger than sufficient to contain the heart, that organ slides, as it were, from beneath the blow, and no doubt often avoids injurious results.

The relative strength of the walls of the cavities of the heart.

We, in the next place, proceed to consider the adaptation of the strength of the parietics of the heart, to the duty each portion has to perform; and here we have a demonstration which has been before mentioned, that every part is peculiarly fitted for its office, there being no needless expenditure of power, where that power is not necessary, neither any inconvenient diminution, when greater strength is essential. Thus, the auricles, having only to propel the blood into the ventricles, and that duty being materially lessened by the suction-power of those cavities, any considerable quantity of muscular fibre would be unnecessary. The right ventricle having to propel the blood received by it to the lungs, it becomes necessary that its muscular power should be greater, because the required force is much more considerable. Lastly, the left ventricle, having to propel the blood, either aided or not, through the whole of the arterial ramifications, and to overcome the obstacles opposed to its course, and, according to some, to project it through the capillaries themselves, it is essentially necessary that its muscular power should be much greater than that of either of the cavities just mentioned, because its duty is infinitely more burdensome. These different states we actually find to exist, each having an increase, or diminution corresponding to the amount of force required to fulfil its office. We also find the amount of force to be precisely adequate to the performance of the several duties, and, at the same time consistent with the well-being of the heart. If we had a diminution of its power, which state does exist under the influence of many diseases, the result that must inevitably follow, is, that the vitality of the parts most remote from the centre of the circulation becomes impaired, from its not receiving a sufficient supply of the fluid necessary for its support; and, after a certain time, vitality entirely disappears, leaving a lifeless mass under the influence of chemical changes. But these cases do not always terminate here. By the influence that each part possesses over the whole system, every part becomes more or less affected, and it not unfrequently results, that the loss of vitality in the affected one is only the precursor of what will occur to every portion of the same structure. Thus, we have a convincing proof of the goodness and infinite wisdom of the Almighty Being that made and fashioned us. May we not say, with the great Apostle of the Gentiles, " O, the depth of the riches, both of the wisdom and knowledge of God."[1]

We may find another argument in support of this position, in the peculiarity of the structure of the lining membrane of the left side of the heart. We have before seen that this membrane appears to be, in its structure, essentially the same with the one lining the arterial tubes; but, in the latter situation, it is remarkably brittle, and subject to laceration from very slight causes, it not being necessary that it should be capable of great extension, because of the function of those vessels not requiring it. But, had this brittle state existed in the heart, the consequence that must have resulted from the necessary dilatations of the cavities would have been the rupture of this important tunic, and the disease termed aneurism, which, fortunately for mankind is very rare in this situation, would have followed, and our frail existence been speedily terminated.

The existence of Septa in the heart dividing it into cavities, will scarcely require notice, because the necessity for their pre- Septa of the heart.

1 Romans xi., 23.

sence will be apparent to every person. Were it not for their agency, the pulmonary circulation could be of little service, if by any means without them, the blood could be exposed to the action of air; because, on the return of the blood from the lungs, it would be mixed with that brought by the venæ cavæ, and be deteriorated in its qualities before entering upon the systemic circulation. It is an exceedingly simple yet most important provision.

The valves of the Aorta.

We next proceed to speak of what has attracted the attention of all writers on this subject, viz., the valves. Probably nothing in the whole range of the mechanism of man is more demonstrative of the truth of our previous statement than these; for although it is certain that any change in the parts which we have described, would be followed by injurious consequences, yet it is equally certain that were it not for these appendages, life could not be maintained. The resiliency or contraction of the parietes of the vessels, while propelling one part of the blood onwards would give to another a retrograde motion, which meeting with no opposition would return into the cavity whence it had just passed, and impede the entrance of blood from the auricle; or, by the over distension which would follow the admittance of blood from both sources, the ventricle would be rendered incapable of contracting, and death of necessity result. We may also here observe the beautiful adaptation of the means to the end intended to be gained. The valves are formed of a reflection of the lining membrane, one border only of which is attached to the point of junction of the Aorta with the heart, whilst the other is free and divided into three portions; one surface, (that looking towards the ventricle) being convex, the other concave, no barrier is opposed to the exit of the blood from the ventricle, because, during the transmission of the blood from that cavity, the valves are closely applied to the sides of the vessel; but if any retrograde motion occurs the blood passing between the valves and the sides of the vessel, raises them from their previous position, and by virtue of their concavity in that direction, and their free borders being in apposition, (a fact of which any person may convince himself, by simply injecting water into the Aorta, in a direction towards the heart,) not even the slightest amount of blood can re-enter the cavity.

Action of the heart indicative of disease.

There is also an argument shewing the goodness of God, to be derived from the different actions the heart exerts, in different diseases; in some of them being increased in frequency, in others diminished; whilst in a third class the action is enfeebled, the heart being apparently rendered unable to perform its office; in a fourth it is too violent, and in a fifth irregular. By virtue of these different states, we are enabled to infer the presence of disease, the continuance of which must give an unhealthy character to the different organs, either in organization, or in the performance of their functions, and in many instances cause death itself. Thus, by increased action of the heart, irritation and febrile excitement are set up in the system; the various organs are prompted to more than wonted energy, and according to that well known law in the economy, that every excitement is followed by a corresponding collapse, this excitement induces a depressed state of the organs necessary to vitality. If the action of the heart be too powerful or violent, its parietes have taken on, or are about to take on the characters of disease; producing hypertrophy,a disease far from uncommon in persons under the necessity of using violent exertion. If the action of the heart on the other hand be below the natural standard, the various parts of the system are ill supplied with the food of life, and emaciation is the result. Lastly, if the action of the heart be violent and the pulsation slow and irregular, it shews us that there is a preternatural determination of blood to that organ, and that if not relieved, the cavity may become so distended, as not to be able to contract. We are perhaps going too far out of our path, to attempt to characterise disease; but it serves to prove, that if the Almighty had not been pleased, in infinite goodness, to shew us by means similar to these the abnormal actions occurring in the body, disease would have stalked undisturbed through our frame, and soon have rendered us a prey to the relentless grasp of death

Period of action and of rest.

We may also observe how admirably the heart is fitted to perform its functions, by being alternately in action and at rest. It is admitted that no assemblage of muscular fibres can remain in a state of contraction, consistently with its well-being, beyond a certain period. When that period has arrived, a sensation warns us that it is no longer to be borne with impunity, but that it will be followed by injurious consequences to the active organ. But, if the muscle be allowed to remain at rest for a certain time, its powers are recruited, and it is again enabled to perform its functions as readily as before. This is precisely the case with the heart; one portion of time being occupied by its active contractions, and the remaining portion by dilatations constituting its period of rest. By this means it is enabled to continue its contractions for an almost incredible period, its functions commencing long before utero-gestation is completed, and continuing to the last moment of our existence. In fact life may be considered to commence with its action, and to terminate with its cessation.

Having now referred to the more prominent parts connected with the heart in the adult, it becomes necessary to review it as we find it in the fœtal state.

Foramen ovale.

The first object that engages the attention of the observer, on opening a fœtal heart, is an opening in the septum auricularum, the foramen ovale. The use of this opening has been stated to be for the passage of the greater portion of the blood, which has been received by the right auricle, at once into the left, without traversing the right ventricle and the ramifications of the pulmonary artery and veins. In consequence of the function of respiration not being carried on during utero-gestation, there is no necessity for the whole amount of blood to pass to the lungs, as is the case in after-life. In order, therefore, that the blood may not traverse an unnecessary space, this opening is provided to admit it at once into the left auricle, shewing in an incontrovertible manner, wisdom and design.

But, although this opening is convenient during fœtal existance, its continuance after that period would be attended with great inconvenience, and herein the goodness of the Creator is perhaps more particularly evident. After utero-gestation, the child has to maintain a separate and independent existence, and in order that the necessary change may take place in the blood, the function of respiration must commence. But, if the foramen ovale remain open, little benefit will be derived from air, because only a comparatively small portion of the blood can be submitted to its influence; the greater portion passing again into the circulation, without the vivifying influence being exerted upon it. It becomes necessary, therefore, for the welfare of the individual, that a closure of this opening should take place. This process commences immediately after birth in almost all cases, the opening gradually becoming less, until after a period varying from two or three days, to as many weeks, we find it completely obliterated. The whole of the blood then passes to the lungs, and undergoes the necessary changes. In a few melancholy cases this change is not effected, and after several years we find the fœtal passage still open, and the patient labouring under a disease, which, from the blue colour of the skin arising out of the imperfect decarbonization of the blood, is termed Cyanosis. The unhappy sufferer is rendered almost utterly incapable of exercise, certainly incapable of any laborious undertaking; and after dragging a life, miserable so far as external objects are concerned, through a period seldom if ever exceeding twenty years, he becomes a prey to our last enemy.

Closure of the foramen ovale.

Cyanosis.

The valvulus eustachii previously mentioned is also of essential importance, during fœtal life, to direct the current of blood to the foramen ovale, without which that opening would be of little service, because the proper course of the blood, owing to the formation of the auricle, is to the auriculo-ventricular opening

Valvulus Eustachii.

When the period, however, has arrived for the obliteration of the foramen ovale,the continuance of this valve, retaining its original dimensions, would interfere with the passage of the blood into the ventricle. We therefore find it is so much lessened in size, that its presence does not produce inconvenience, although it is not entirely obliterated; a circumstance which also shews the care of the Creator towards the created.

We now proceed to consider the points having reference to our subject, as shewn in the arterial system, commencing with the position of the Aortic trunk.

Aorta. Position.

In the first part of its course, we find the Aorta behind the arched flattened bone before mentioned, which forms a very powerful defence against any injury occurring from before; and for a farther protection, it gradually passes backwards, and becomes more deeply seated. It is then closely applied to the bodies of the vertebræ, by which, and the muscles of the back, it is protected from injury behind. Whilst passing through the thorax, it is covered by the different organs contained therein, constituting another source of defence. The same in the abdomen, it being still applied closely to the vertebral column, and behind the different organs contained in that cavity, shewing to us the important rank it holds in the animal economy, and the care exerted to guard it as much as possible from injury.

Its outer surface covered by a seroos membrane.

The fact of its outer surface being covered by serous membrane, is also another evidence of Divine care. The unprotected state of the cavity of the abdomen renders it peculiarly liable to external injury, and the numerous concussions to which the internal parts are subject from blows and falls, render it desirable that their effects should not reach this important vessel. We therefore find, that by virtue of the polished surface of this membrane, (moistened with a watery vapour, as in the pericardium before mentioned.) covering the external surface of this vessel, and the parts contained within the abdominal cavity, they recede, as it were, when any force is applied to the parietes of that cavity, from which circumstance the effects of concussion are not conveyed to the deep seated organs. The same remark which was made when treating of the pericardium relative to the motions of the heart not being accompanied by an injurious degree of friction is applicable here, inasmuch as the organs of the abdomen are in continual motion, which would produce precisely the same effect, if the character of the membrane was changed, as was then described.

The Aortic opening in the diaphragm is also demonstrative of the wisdom and goodness of God. We find it formed by the aggregation of a number of tendinous fibres, making a canal which is considerably larger than the Aortic trunk. Had this vessel passed through the muscular fibres of the diaphragm, it must have been constricted by every contraction of those fibres, and as this, in the normal state, is the chief respiratory muscle, the circulation through the vessel would have been constantly subjected to interruptions. But in the position in which we find it, no pressure whatever is exerted upon it, the tendinous fibres forming the boundaries of the canal not being subject to motion. This is also the case with other vessels, as the femoral and tibial arteries. In fact, in every instance where it is necessary for a large arterial trunk to perforate a muscle, we find it surrounded, and protected from pressure, by tendinous fibres. This is more particularly the case with the Aortic and femoral arteries; the latter of which is covered, for some distance before it reaches the triangular opening in the adductor magnus, by a dense fascia, which protects it from the action of the powerful muscles of the thigh. This opening is very distinct, and does not admit of any injurious pressure being exerted upon the vessel. This appears to me, to be a fact of vital importance, upon which life itself is dependent, and for which every reflective individual cannot feel sufficiently grateful to the Divine Artificer of his frame.

Aortic opening in the Diaphragm

In the structure of the vascular system we see perfect subservience to the design intended, in the uses to be derived from it.

Structure of the blood vessels

Thus, we find that the vessels have to exert a share in the propulsion of the blood, consequently they are provided with a fibrous coat of sufficient strength to resist any pressure made by the blood on the parietes of the vessels; and, that the contraction of the vessels should be in the necessary direction, the fibrous coat is deposited in complete circles around them. Had the contraction been in the longitudinal direction, it is unnecessary to say that it would have been ineffective. This coat forming *complete* circles around the vessel, is also necessary for the more effectual protection from disease. Without this, lateral dilatations would occur much more frequently than under existing circumstances they do, causing large sacs or aneurisms to form, and placing the life of the individual in constant jeopardy. We also find this coat in greater abundance about the arch of the Aorta, where the disease just mentioned is so liable to occur; in consequence (amongst other reasons) of the force of the contraction of the ventricle impelling the blood against the point where the artery bends.

Fibrous coat

Forming complete circles

Smoothness of the lining membrane

The lining membrane of this vessel is also peculiarly fitted to its office, its smooth surface diminishing the friction resulting from the rapid transmission of the particles of the blood over it. This friction would be much increased, if the membrane possessed a rougher texture; the obstacles retarding the circulation would be more powerful, and the required force of the heart and arteries greater.

Arteries capable of dilation

The arteries being capable of dilation appears a wise provision; had they been rigid, in-elastic tubes, unyielding when they were full, as is constantly the case, the blood impelled into them by the ventricle would have been partially or wholly returned into that cavity, putting a stop to the circulation; but as they now exist, when the ventricle contracts, the force impressed on the blood within the vessels causes a dilatation of them, or a temporary enlargement of their capacity. When the contraction of the ventricle is past, the Aortic valves become properly closed, and that vessel immediately contracting propels the blood through the whole system, whilst its return into the ventricle is effectually prevented. The increased capability of contraction in the arteries, as they proceed towards their terminal ramifications, (for it will be remembered we did not agree with the doctrine of the heart being the sole motory cause of the circulation,) still illustrates our previous position. By the time that the blood reaches the termination of the arteries, the propulsive effort of the heart is lost, and if the smaller arteries did not exert an increased power over the blood, a stagnation of that fluid must occur on reaching those parts. The inferior contractile power of the larger arteries shews that strength is not given, when not required; for in these, a very slight amount of contraction is all that is necessary to aid the action of the heart in the circulation of the blood through them.

Increased capability of contraction in the smaller arteries

Diminished capability of contraction in the larger trunks

The fact of the vessels, in moveable parts, being always placed in the direction of flexion, is a mark of design; for, had such not been the case, every attempt at flexion of the limb must have ruptured the vessels.

Vessels placed in direction of flexion

The larger trunks giving off a number of branches, and widely ramifying, is necessary, in order that the blood may be distributed to every part. Though there be but one primary systemic trunk, yet by the branches it gives off, and those in some instances dividing into eighteen or twenty others, each of which in turn subdivides in a similar manner, we have an almost infinite number of arterial ramifications, and by them the blood is carried to every part of the system. Were this not the case, the greater part of the body would be deprived of the benefit of the circulating fluid. A number of these branches pursues a very tortuous course, particularly those of the mammæ, uterus, and testes. The design of this is supposed to be to retard the circulation of the blood through them. If the vessels of the uterus at the full term of utero-gestation were perfectly straight, and possessed no tortuous character, the blood would flow more rapidly after the detachment of the whole or a part of the placenta, and give rise to more alarming consequences. For

Ramification of the vessels

Tortuosity of the vessels

with the extremities of the vessels open—so much enlarged—little time would suffice to reduce the system so much below par, as to preclude the possibility of its recovering the shock. Under certain circumstances, even with tortuous vessels, but very little time is required to produce exhaustion from hæmmorrhage, but if they were straight, that time would, in all probability, be less. The phenomenon of the various and very frequent anastomoses which are found between distant arterial trunks, by means of their ramifications, is of the most vital importance. Without these, when by any means obliteration of an arterial trunk occurred, the part to which it was distributed, in consequence of the supply of blood being cut off, must inevitably perish. The surgeon would also be deprived of the only remedy which he possesses in aneurismal enlargements of important vessels. As they exist, he knows that by applying a ligature around the diseased artery, he not only prevents the circulation being carried on through it, thus effectually preventing the risk of its bursting, and probably of fatal hœmmorhage, but, that the branches of the vessels by anastomising with those of neighbouring arteries, will be enabled to carry on the circulation. Could this not be effected, the person must live as if he was dying, from the constant apprehension of sudden death as a consequence of his disease.

Arterial anastomoses

Arteries capable of increased dilatation

Connected intimately with this subject, is the power that arteries possess of dilating according to the quantity of blood which it becomes necessary they should convey. Anastomoses would be of little service, were the arteries incapable of increased dilatation; because, as a general rule, when anastomoses occur, it is through the medium of the minute ramifications of the arteries, which of necessity could not transmit a sufficient supply of blood to the part previously deprived of its support unless those ramifications were capable of enlargement. This is happily the case to a very great extent. The cause of this dilatation does not appear to be certainly known; the fact itself however we do know, and we also know, that it is of great importance to the well-being of the individual, and evinces the goodness and wisdom of an Almighty agency. Probably there are few subjects that a reflecting mind might be led to dwell on with more pleasure than this, or more calculated to excite gratitude to supreme wisdom.

Formation of coagula within the vessels

The formation of coagula within the vessels, when a ligature has been applied around them, is also of great moment. On the application of a ligature to a vessel, the inner coat of the artery is divided, and after a certain period, ulcerative inflammation commences, continuing until the coats of the artery are divided. On this taking place, unless some means had been used to fill up the extremity of the divided portion, hæmmorrhage must have occurred. On opening a vessel under these circumstances, we find a coagulum (consisting of the fibrine of the blood) formed within it, passing upwards to a considerable distance, and constituting a barrier to the egress of any fluid. The sides of the extremity of the divided vessel being brought together by the ligature, adhesive inflammation occurs, which perfectly seals the vessel. In some cases this takes place without the intervention of surgical aid; in others, as a cure of disease; as in aneurism, when successive layers of fibrine are deposited, till the calibre of the artery be filled up, and the disease cured.

Internal actions being involuntary

Another source of gratitude may be found in the different internal movements being involuntary. A little reflection will shew the value of this provision. Supposing that every internal organ had been voluntary,—had for its stimulus the influence of the mind, who, I would ask, could direct operations, which *must* be carried on incessantly, or life be extinguished? Who could direct the functions of the heart and arteries, digestion, nutrition, and secretion? It would be impossible for any individual so to divide his attention, as that a sufficient amount might be given to each to keep it in perpetual action; and it being impossible for him to direct the operations proceeding within his own system how could he attend to external circumstances? Again, if such were the case, there would be no time allowed for sleep, because the moment his attention was drawn away from the internal organs, they would cease to act. We therefore see what an invaluable benefit it is to us, that our attention is not necessary for these different agencies. How grateful ought we to be, that they perform their wonted offices with the same regularity, constancy, and ease, when our attention is directed to other objects, as when it is given to them. Surely we shall say with the Psalmist, "I will praise thee, O God, with my whole heart."* There is also another reason why they should be involuntary. As life itself is dependent upon their due performance, an individual under the influence of strong excitement, when passion has overcome his reason, would have it in his power, by a simple act of volition, to terminate his existence, rashly precipitating himself into the presence of his Creator. Or persons, when reason did not retain her wonted seat, in an unlucky moment might cut the slender thread. But it is needless to multiply illustrations, as any one would be sufficient to shew the impossibility of the existence of man under other circumstances.

Arteries terminating in veins

The fact of the arteries terminating in the veins is a matter of some moment; for, had this not been the case, the blood would have been extravasated into the different tissues, and an end soon be put to the circulation, not only from the blood being out of its proper track, but from the separation of its coagulable part.

Blood

We now pass to a consideration of the blood itself. This fluid, as we have before seen, contained within certain vessels passes through the whole of the body, and by the minute ramifications of the arterial tubes, is enabled to penetrate every part. After distributing the food of life, it is collected by the capillary terminations of the veins, and by virtue of certain forces is brought again to the heart. If we examine this fluid when it commences its course, and again when it has completed the circuit, we shall find a material difference in colour, and some alteration in chemical composition. From the various changes

* Ps. 86 & 12.

it produces in the different parts of the body, we find it to have lost a considerable quantity of oxygen, and to possess an excess of carbon. In this state, its power of stimulating the organs to continued exertion is entirely or nearly lost, and it is therefore incapable of performing its office. It consequently becomes necessary for the continuance of the life of the individual, that the blood should be restored to its pristine state. For this purpose the all-wise Creator established the function of respiration, and so contrived the different parts of the circulating apparatus, that all the blood might be exposed to the action of the air, and afterwards returned to the heart to be again carried into the systemic circulation. Thus, we find, that when the blood is brought to the right side of the heart by the Venæ Cavæ, it is transmitted to the lungs by the pulmonary artery, and by the minute ramifications of that artery, called the Rete Mirabile, ramifying on the inner surface of the air-cells, is exposed (with the intervention of a membrane, so tenuous and delicate, as to admit of its influence, whilst its structure is such as to prevent the escape of the blood) to the action of the air. By this admirable provision, oxygen (as we have before seen) is absorbed by the blood, one part uniting with its carbon, the other with the red particles, and enabling the blood again and again to perform its functions. What simplicity do we find for the fulfilment of so important a purpose, and what an instance of exquisite design and care on the part of the Creator does it not furnish us with! It would have been of little use to have formed the circulating fluid to stimulate the organs to the fulfilment of their various duties, had there been no care about maintaining the necessary stimulating character of that fluid. For we find that when from Asphyxia by various means, the blood is not renovated by contact with the air, the short space of three minutes, or even less, is sufficient to prevent the great centre of nervous energy from exercising its benign influence over the system ; consequently our existence would have been as short in duration, as useless in its character.

Nutrition

But there is another evidence of Divine goodness connected with this subject, which is highly important. We have before seen that one of the great functions of the blood, is to repair the waste that the various parts are constantly undergoing; and also, to lay up a store of material, which, when necessity requires, may be taken into the general system, and applied to the purposes of nutrition. We have also seen that the principal component parts of the blood become deposited in the tissues of the body for that purpose. Now, it must be evident, that the stock of nutritive material contained in the blood, would by this means soon become exhausted; and consequently that this all important function must be annihilated, unless means be provided to throw a fresh supply of this substance into the circulation. To fulfil this purpose, food is taken into the system, and after passing through a variety of states before described, is converted into a milk-like substance, which is poured from the thoracic duct, into the circulation, and after a time becomes perfectly identical with the blood. Who is there that would choose to say, that this is not demonstrative of wisdom and design? "The fool hath said in his heart there is no God."*

Secretion

The last subject, connected with the blood, that demands our attention, is secretion, which is involved in much obscurity. Tis true, that certain persons have developed peculiar theories to account for this process, and the changes that the blood undergoes, but they have failed to satisfy the minds of the majority of physiologists, and in many instances, have not satisfied themselves. But what is of the greatest importance to us, the fact, is well understood; and it is of little consequence to our purpose, whether these theories be correct or not. The importance of secretion we have, in another place, considered;—that nutrition could not be effected without secretion;—that our race would soon be extinct; and that by the continuance of certain noxious fluids in the blood, life itself must be annihilated. The goodness of God, therefore, in the establishment of this function, must be evident to even the most

* Ps. 14 & 1.

superficial observer. By the intervention of certain organs of peculiar structure, or by simply removing substances, already formed, from the blood, this function is carried on. The means the most simple, the end all-important. An instance of the simplicity and wise adaptation of the secretions to their offices may be observed in the gastric juice. A fluid, apparently not of active properties, is enabled to effect the solution of what, if man was the operator, would require the most powerful corrosive substances with which we are acquainted. The gastric juice is also possessed of the most powerful antiseptic properties, being able to restore to its natural state any substance in which putrefaction has commenced. This fluid possessing different properties in different classes of animals is also an exceedingly wise provision ; for had herbiferous animals been furnished with the same kind that carniverous possess, is would have been incompetent to have dissolved their proper aliment, and *vice versa*. Again, how wisely is it adapted to man—both an herbiferous, and carniverous animal ; the secretion in this instance being capable of dissolving either kind of food and thus giving him the power to select it either from the animal or vegetable kingdom. If we look at the Semen, how simple and apt is the means for so important a design ! A little fluid in which thousands of Animalcula are seen to sport, by a process which is to mankind a sealed mystery, is converted into an animal resembling the one whence it was derived. Lastly, respecting the dark colouring matter of the eye, nothing could be more simple, nothing more efficacious ; yet by a mere secretion, the object is at once attained.

Gastric juice

Semen

Uvea and Pigmentum Nigrum

From what has been stated in the previous part of this essay, every person must have been struck with the marks of design and contrivance, evinced in even the most unimportant part of our frame. We cannot look at any part, however insignificant, which does not shew wisdom and power, that mock the puny contrivance of a mortal hand. Where is the man however learned he may be, however deeply versed in the arts and sciences, however applauded and admired by his fellow-men, who can form the smallest portion of the tissue that pervades every part of our fabric ? Have any of the men who have passed to the earth's remotest bounds ; who have shivered beneath the cold of a northern pole, or burned beneath an equinoxial sun ; who have traversed countries most remarkable for the benefits of civilization, or regions where barbarity universally prevails ; who have visited a race of beings boasting of their long line of ancestry, tracing back their empire for thousands of years, or those who know no relic of ancient days, except their immediate progenitors ; who have endeavoured to scale the heavens and trace the starry multitude, or dive into the secret recesses of the great deep ; have any of these discovered a method of forming a human being ? Have any of the men who spend their lives in collecting heaps of ancient lore, or trying to penetrate the hidden mysteries of futurity, made even a human hair ? Have the men who spend their lives in the pleasing subjects of imagination ; who " soar aloft on fancy's airy wing" and ne'er descend to objects of reality, in their imaginary dreams e'er seen such process ? Certainly not. We are constrained to say in the language of the psalmist, " Know ye that the Lord he is God, it is he that hath made us and not we ourselves." *

From the proofs already given, we should be disinclined to believe, that any man could have the hardihood to deny the existence of a great first cause ; could persuade himself even for a moment to believe, that man was made without the agency of an Almighty hand, but that his parts came together by "chance." Whence are the valves so nicely fitted, or the different parts of our structure so admirably adapted to perform their functions, without a designer and contriver. How came the different parts of the eye, to be so beautifully fitted for their respective offices ; a piece of mechanism that the inventive mind of man could never have produced. How came that darkened curtain, the Iris, to exist, and to oppose by its contractions the entrance of too many rays of light under the influence of a mid-day sun ; or to allow a greater number by its dilitation

*Ps. 100 & 3.

when the last glimmerings reach it from a Western sky? How came the different fluids in this organ to be of various densities, and each precisely proportionate to its office? How did it occur that the posterior surface of the crystalline lens is more convex than the anterior, when the greater convexity was necessary in that position? Lastly, how came the optic nerve to be broken up and so accurately applied to the posterior part of the eye? It is impossible to see these things, and say they were placed by "chance."

There is now the all-important question to ask if we believe that God was the architect and builder of our frame giving us power above the remaining portion of the animal creation; for it is said "Thou hast made him a little lower than the angels;"* will he not require some return on our part? Is it not reasonable to suppose, and do we not find it expressly stated in Holy Writ, that God made the body for his glory, and expects us to use it to his service. And if we do not shall we not fall under his displeasure? We know that ere long this beautiful fabic will moulder into dust, and the immortal spirit, which has dwelt within it, return to the God who gave it. In the words of Job, "I know that thou wilt bring me to death, and to the house appointed for all living." † The term of our lives is also exceedingly short and uncertain: knowing therefore the uncertainty of life, the certainty of death, and of a judgment to come, may we live the "life of the righteous, and let our last end be like his."‡

*Ps. 8 & 5. †Job 30 & 23. ‡Numbers 23 & 10.

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