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On the General Anatomy Physiology and Developement of the Arterial System.

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The Arteries. The term "Artery" is applied by Anatomists to the trunks and branches of the great Veſsels, iſsuing from the Ventricles of the Heart. Like many other terms used in Scientific Nomenclature, this appellation was applied from the prevalence of an erroneous idea, as to the functions of these Veſsels. Derived from the Greek, the word artery signifies air veſsel, and until the time of Galen the function of carrying air was ascribed to them. He however demonstrated, that in the living body these parts of the vascular system contained blood, although after death they are usually found empty. In Man and the higher forms of Animals, there are two distinct systems of efferent bloodveſsels proceeding from the Heart: the function of one, being to circulate the impure blood through the lungs, where it may receive fresh Oxygen, and the accumulation of Carbon and Hydrogen may be removed; that of the other, to carry the blood, thus purified and oxygenated, through the body. The names "pulmonic" and "Systemic" are given respectively to these different systems of arteries.

I shall first proceed to notice some facts connected with the general distribution of Arteries.

The General Distribution of Arteries. The Arteries are distributed throughout the animal system by branching. This may take place in different ways. Thus, an artery may end by dividing into two or more equal or unequal branches, or during its course, it may give off lateral branches. The angles at which these leave the parent trunk, are different in different situations; thus, we find every degree of acute, and sometimes obtuse and right angles presented in their distribution. It was supposed, that the force and velocity of the circulation through a branch, was influenced to a great extent, by the angle at which it quitted the main trunk. This opinion however Prof. Weber has shewn to be untenable. Such a circumstance could have little or no influence, on the paſsage of fluid through a system of elastic tubes, which are constantly kept full, and the progress of whose contents meets with much resistance at their extremities. The trunk of an artery diminishes, in proportion to the number and size of the branches given off. An artery which runs a long course without giving offsets, does not lessen in calibre or weight. An inch taken from the terminal end of the common carotid artery, will weigh as much as a similar piece taken near its aortic extremity. Mr Hunter found that the calibre of the long carotid of the Camel, underwent no decrease throughout its whole extent. Santorini, states however, that he observed the carotid artery of an Ostrich, to have become narrower in a portion of its course of six inches in length, for which space no branch had been given off. The sum of the areas of the branches, into which an artery divides, is as a general rule, greater than the area of the parent tube; the area of each separate branch, being however less than that of the vessel from which it takes its rise. The increase of the available capacity of the arteries has been much overrated, especially by the mathematical Schools of Physicians. Exceptions have been observed to the above rule; one of the most notable, being in the case of the Common Iliacs and the middle Sacral;

the sum of their bores, not being greater than the bore of the termination of the aorta. (It has sometimes occurred to me, whether this circumstance may not in some way be connected, with the obliteration of the hypogastric arteries, at the ceſsation of foetal life. I do not wish to expreſs this as an opinion, but merely as a surmise.) The ratio of the increase of the area has not been correctly estimated, as far as I am aware. It has been said, that at each division the area increases as two to three. This, I believe, is generally held to be a great deal too great an estimate.

Arteries frequently anastomose or inosculate. Such junctions are very frequent amongst the smaller arteries, also they are not wanting amongst the larger. The effect of such unions must be to equalise circulation, and obviate the effects of local interruption or injury. The general anastomoses of arteries may be described under the following heads. 1. Anastomosis by inosculation, or by loops, in which two veſsels running in opposite directions open into each other by their extremities, and form a loop. 2. Anastomosis by transverse

communication, as when two parallel trunks are united by means of a branch, at right angles to their own direction; for example, the anterior communicating artery of the Brain. 3. Anastomosis by Convergence, in which two arterial branches unite to form a large artery, as in the union of the Vertebral Arteries to form the basilar trunk. The tortuosity of some arteries, as the labial, is easily accounted for by a consideration of the mobility of the part; but we meet with great tortuosity in other situations, where the purpose of the arrangement is not equally clear. I may adduce as instances, the long coiled Spermatic arteries of the Ram and Bull. The physical effect of such tortuosity must be to diminish the velocity of the circulating fluid, by increasing the surface offering friction. Sir C. Bell, believing that the arteries were instrumental in propelling the blood, supposed that the tortuosity would increase the rapidity of the circulation through the testicle. It is however generally admitted that the arteries have not this power, hence such an opinion cannot be entertained.
In some situations, an artery is seen to

divide into a number of branches, which again unite into a trunk. A familiar instance of this arrangement is seen in the mesentery of the Pig. This arrangement, must evidently have the same physical effect as that produced by the great tortuosity of a trunk. But in some animals, and in some situations, it appears to serve other purposes. The uses however of the "Rete Mirabile", as it is termed, will be again referred to in another part of this paper. It will be sufficient in this place, to mention some of the principal situations in which it occurs. The internal Carotids of Ruminantia, on arriving at the sides of the Sella Turcica, subdivide into innumerable twigs, which again reunite to recompose the arterial trunks. It was to these instances of its occurrence, that the term "Rete Mirabile" was applied by Galen. This arrangement however is not found in the Solipeda as the Horse. It takes place in some Carnivora, as the Cat and Lion, but it is not observed in Man, or in the higher Quadrumana, or in animals (as the Small Rodentia) where the vertebral arteries are larger than the internal Carotids, and are the chief arteries for the supply of blood to the brain. Moreover, we do not find it in the plantigrade Carnivora. In the tardigrade Sloths and loris, the brachial and femoral arteries, by dividing into many branches, which again reunite, have a similar plexiform arrangement. The same is observed in the extremities and tail of the anteaters. They are also observed, in the orbits of many Mammalia, and birds (Rapp & Barkow), giving origin to the arteries of the eyeball. In Cetaceous Animals, we find many and remarkable instances of a similar division. M. V. Baer was I believe the first to give an accurate account of the subdivision of the brachial and caudal arteries in the Porpoise. But previously, John Hunter had described the great tendency to division and tortuosity existing in the whole arterial system of the Whales and Dugongs. He found that in animals of this tribe, "the inter-costal arteries divide into a vast number of branches, which run in a serpentine course, between the pleura ribs and their muscles, making a thick substance, somewhat similar to that formed by the Spermatic artery of the Bull. These veſsels, everywhere lining the sides of the Thorax, paſs in between the ribs, near their articulation, and also behind the ligamentous attachment of the ribs, and anastomose with each other. The Medulla Spinalis is surrounded with a network of arteries, in the same manner, more especially where it comes out from the brain, where a thick substance is formed by their ramifications and convolutions, and these veſsels most probably anastomose with those of the Thorax". (J. Hunter) The anterior tibial artery, in many aquatic birds, is often accompanied by an enveloping plexus of its smaller anastomosing branches, which reuniting join it again at the heel joint. Many instances of Retia Mirabilia have also been observed in fish. Muller and Eschricht, have given a description of these, in their paper on the Arterial and venous retia mirabilia in the liver of the Thunny. Such are a few of the best known examples of these arterial networks. I have mentioned them here, merely to shew the various circumstances under which they occur; their probable uses, in their several situations, will be noticed hereafter. It is, I believe, at present a matter of doubt, as to whether the arrangement of the efferent and afferent vessels in the Malpighian Corpuscles of the Kidney, are instances of Retia mirabilia, or whether, as Mr Bowman supposes, ~~[illegible]~~ the efferent vessel is to be considered a vein, establishing an analogy between the renal and ~~[illegible] as analogous to the~~ portal circulations. This latter opinion is generally held, I believe to be the more probable, being borne out, as it is, by the existence of a renal portal circulation in Fishes Reptiles & Birds.

Arteries in their course usually choose the most protected situations. Thus in the trunk, the principal artery has the great mass of viscera in front of it, and behind it is well protected by the osseous framework. So in the limbs, the chief arteries will be found on the aspect of flexion, rather than on that of extension. In illustration of the tendency of arteries to seek protected situations, we may state, that arteries which would be very liable to pressure, in some instances seek an osseous protection from the neighbouring bone. Thus, in most Carnivora, many Rodentia, Edentata, Monotrema, Marsupialia, Insectivora, and quadrumana, animals with free prehensile use of their arms, the brachial artery paſses through an oſseous canal, above the inner condyle of the humerus. An approach to this has been occasionally observed in the same situation in man; the artery, (which in these cases deviates from its usual course), turning round a prominence of bone, to which it is bound by a fibrous band.

In most parts of the body, the artery runs in a sheath of dense cellular tiſsue. Such a sheath does not neceſsarily enclose the artery alone, veins and nerves may be likewise included. In some parts the arteries want this investment. The arteries within the cavity of the Cranium may be taken as examples of this latter fact. The artery is connected to the sheath by means of fibres of cellular tiſsue, stretching between the one and the other, but the connection between the artery and this investment is not very close. The union is so lax, that it allows the elastic artery when cut, to shrink back within this adventitious covering. Frequently on entering an organ, the artery receives a sheath from the fibrous covering of the organ; we have examples of this in the liver spleen and kidney. Before entering the substance of an organ, an artery sometimes ramifies into a minute network, and thus subdivided, penetrates the proper tiſsue of the part. The Cerebral ramification on the pia mater, and the spermatic on the tunica vasculosa of Sir A. Cooper, may be cited.

The Arteries terminate in the Capillaries. The only exception, (if it be an exception,) is in erectile tiſsue, as in that of the Corpus Cavernosum penis.

Different observers have given different accounts of their termination in this situation. It is generally aſsumed that they end here, as in other parts, in a capillary network. Valentin, however, considers that the minutest arterial twigs terminate directly in the venous cavities, by widened orifices. This however has not been confirmed.

Müller describes the arteries of the Corpus Cavernosum as terminating in two ways. Some, which he calls the "nutritive" arteries, end in the ordinary manner, in a capillary network, leading in the usual way, to the veins. Others, which he terms, the "Helicine" Arteries, and which he describes as short tendril like trunks, coming off from the "trabecular" arteries, project into the vein, so as to be covered by its lining membrane, and end abruptly by dilated extremities. These little arteries may be single or in tufts. This account has been confirmed by Krause Hyrtl and Erdl. Muller and Krause suppose that the dilated extremity of the artery opens into the venous cavity, this however has not been confirmed by observation, and Müller himself allows that they may be merely arterial diverticula. Various opinions have been held by the older anatomists, as to the probable terminations of arteries. It will be sufficient here to enumerate some of them, stating at the same time, that there is no foundation for credence being given to any of them. One opinion was, that the arteries terminated by open mouths in exhalent veſsels; another, that they were continuous with the ducts of glands; a third, that they were continuous with lymphatic veſsels; a fourth, (and this obtained universal belief during the last century,) was that they ended in finer veſsels than the Capillaries, veſsels which admitted only the Colourleſs part of

* Wagner (Wagners Physiology translated by Dr R Willis 1844) says; "the finest veſsels that are known in the human body are of leſs diameter than blood corpuscles, and measure no more than from the $\frac{1}{600}$ to the $\frac{1}{800}$ of a line in diameter; there are consequently veſsels, and these are conspicuous enough in the frog, that transmit no blood corpuscles, nothing but liquor Sanguinis." To this statement, I would oppose the following quotation taken from my notes of Dr Sharpey's lectures (delivered at Univ. Col. London). "Direct evidence of the existence of vasa serosa cannot be got, We have injections, much finer than the red blood particles, which would penetrate into finer veſsels. Dr Sharpey took the web of a living frog, and put it under the microscope, he then adapted the micrometer to the instrument. He then took another frog's foot, which was very minutely injected, and subjected it to an equal magnifying power. had there been serous veſsels, on comparing the injected specimen with the web of the living animal, he ought to have seen many more veſsels than in the living web, and the meshes between them should have been much smaller. This however was not the case. The meshes and size of the network, were exactly the same in both specimens. If vasa serosa had been present, they would in all probability have been filled."

the blood. The names vasa serosa, or vasa non rubra, were applied to these. One reason for the aſsumption of such tubes, was that on their existence, many influential doctrines in pathology and medicine were founded, especially Boerhaaves theory of inflammation. He supposed that inflammation was an "error loci"; the red particles getting into the vasa serosa, and from their small calibre blocking them up. It is sufficient here to say, that we have every positive and negative proof against their existence, and there is not the slightest neceſsity for its aſsumption. (Vide note on opposite page*).

Structure of Arteries. An Artery may be said to consist of superimposed layers or coats, which differ from each other in the structure of their tiſsue, and in the properties which they poſseſs. It has been the custom to speak of an artery as consisting of three coats, to which the terms, External, Middle, and Internal, or Cellular, Muscular, and Serous, have been applied: later researches however, have shewn that these coats, are respectively made up of other layers, differing equally in their texture and Endowments.

and that hence, the three coats of which an artery is commonly said to consist, may be farther subdivided into other, or secondary tunics. As however, the division of an artery into three tunics has been so long and extensively adopted in Medical treatises, and as moreover it is the natural division which presents on examination with the naked eye, I think it will not be improper to arrange, what information I have been able to collect as to the arterial structure, under a similar division.

The Internal Coat. (The following description of these Coats is the substance of that given by Henle.) The internal coat, to the naked eye, appears as a colourless delicate transparent membrane, Elastic but easily broken, especially in the transverse direction, so that it cannot be stripped off in large pieces. Longitudinal wrinkles are observed in it as a postmortem appearance, most probably depending on a contracted state of the artery after death. On examining it microscopically, it is found to consist of two structures 1st An innermost or epithelial layer of the scaly variety. This, as described by Henle, is a thin simple layer of elliptical or rhombic particles, which are sometimes elongated so as to resemble spindle shaped fibres. These epithelial elements have round or oval nuclei; which however may disappear; indeed the whole structure sometimes becomes indistinct. These epithelial scales may be obtained for examination, by scraping the inside of an artery with a knife, but the epithelium can rarely be separated as an entire layer. The different intervening forms between the elliptical or polygonal scale, and the much more elongated form described above, may be met with in the same artery. 2nd. The outer structure entering into the formation of the inner coat, is that which has received the different names of "Fenestrate", "Perforated", "Reticular", or "Striated" Membrane. It consists of one, or several, thin brittle transparent filmy layers, which may be scraped off the internal surface of an artery, in the form of fine shreds, having a great tendency to curl up at their upper and lower borders, - rolling themselves up. The layers are marked separately by fine pale streaks, principally following a longitudinal direction, joining each other obliquely in a sort of oblong network. Henle considers these lines to be reticulating fibres formed upon the membranous layer. The membrane, is also perforated by numerous round oval or irregularly shaped apertures of different sizes. When there are several layers of perforated membrane, it often happens that the outermost layers lose their membranous structure; the transparent structure existing in the areolae of the fibres, disappearing, and leaving only the longitudinal network. Such a degenerate fenestrate membrane, reduced to a mere reticulation of fibres, is sometimes spoken of as constituting a distinct coat. The fibres are quite similar to fine fibres of elastic tissue, resisting the action of acetic acid. In fact it seems probable, that the fenestrated membrane is merely a modification of elastic tissue. It is on this structure, that the thickness of the inner coat mainly depends, but the number of layers of which it consists varies much in different situations. In cases where the Epithelial layer has disappeared, the fenestrate membrane forms the innermost lining of the vessel.

The Middle Coat. This is the thickest of all the arterial tunics, and is relatively thicker in some arteries than in others. In the larger arteries it is made up of many layers, thus upwards of 40 have been counted in the aorta, 28 in the Carotid, and 15 in the subclavian artery. Frequently between these layers fragments of fenestrate membrane may be found. Hence the fenestrate membrane is not confined to the internal coat. In colour it is of a tawny or reddish yellow, the internal layers are frequently found to be redder than the external, but this is probably a postmortem appearance, depending on transudation of blood. This Coat consists of distinct circular fibres, disposed round the vessel, although each fibre does not form a distinct ring. Under the microscope, the fibres may be found to consist of two kinds, one being quite analogous to the unstriped muscular fibre, the other closely resembling the fibres of yellow elastic tissue; the former are pale translucent soft flattened fibres, measuring from $\frac{1}{5000}$ to $\frac{1}{3000}$ of an inch in breadth; they present, here and there; the appearance of elongated nucleiform corpuscles, and <u>longitudinal</u> striæ on their surface. The yellow nuclear fibres lie amongst them, frequently alternating with them in layers. They, (the elastic fibres), join together as usual in an irregularly reticular manner. On the addition of acetic acid, the soft fibres become indistinct, and the elastic fibres and nuclei better observable. This coat is thicker in some parts of an artery, than in others: thus at the convexity of the aorta, it will be found of greater thickneſs, than in that part of the artery near the vertebræ. The contractility of the artery is dependant on this coat. As a general rule, the elastic fibres are relatively in greater proportion in the middle coat of the larger arteries, whilst the smaller obtain the larger share of unstriped fibres. Yet, it is not true that the large arteries are totally destitute of the latter tiſsue, for they have been proved, (as will be afterwards shown,) to poſseſs vital contractility, although in leſs proportion than the smaller branches; and we know that the power of contracting on the application of a stimulus, is not an endowment of the elastic fibre.

The External Coat. A difference exists in the construction of this coat, in the larger and smaller arteries.

In the smaller it consists of interwoven fibres of elastic and cellular tiſsues, whilst in the larger and middle sized arteries, two distinct coats may be enumerated. viz. An internal layer of genuine elastic tiſsue, which is perfectly distinct in larger arteries, but becomes gradually leſs appreciable in those of smaller calibre; and 2dly an external cellular coat, consisting of an interlacement of ordinary filamentous tiſsue. The filaments are closely interwoven, and in the larger and middle sized arteries they chiefly run diagonally or obliquely round the veſsel. Towards the exterior of the artery, the tiſsue becomes more open, and the reticular arrangement more lax, where the veſsel is connected with its sheath or other surrounding parts. In the smaller arteries, this cellular coat is usually of great comparative thickneſs.

Some arteries, as those within the skull, and in the vertebral canal, are very thin in proportion to their calibre. This does not depend upon the entire absence of any of the proper tunics; all the three coats are present, although the external and middle are comparatively very thin.

The following is an account of the structure of arteries but one or two degrees removed from the capillaries in size. According to Henle, capillaries of more than $\frac{1}{2400}$ of an inch in diameter consist of the primitive simple membrane forming the wall of the smaller capillaries, but the longitudinal nucleiform corpuscles, which lie upon or are imbedded in it, are more numerous and elongated; a scaly epithelium exists on the inside of the primitive membrane; and on the outside is superadded a layer of nucleiform corpuscles elongated in a direction acroſs the diameter of the Veſsel. This layer corresponds with the middle or muscular coat of the arteries, and accordingly in veſsels of greater size the characteristic circular fibres of that tunic appear in the layer in question, as well as the nuclei. Outside of all, a layer containing longitudinal nuclei marks the position of the cellular coat. It is probable that in a higher stage of developement, the nuclei form the elastic fibres, whilst from the intervening tiſsue the circular fibres take their rise. In Veſsels of $\frac{1}{60}$ of an inch in diameter, the striated membrane may be discovered, although in some cases it is altogether wanting. In still larger veſsels the primitive membrane with its longitudinal corpuscles may have disappeared, and this is generally the case in the Arteries, whilst, according to Henle, in the veins it frequently remains, although converted into one or more layers of longitudinal fibres, which are partly of the elastic kind, and partly pale flattened and parallel. Such a coat is to be found between the fenestrate and circular fibrous coats of many veins, or, when the fenestrate membrane is wanting, immediately under the Epithelium. Between small arteries and veins but two or three degrees removed from the capillaries in size, no difference of structure can be perceived. The Coats of the Arteries receive distinct Vasa Vasorum for their nourishment. These are both Arterial and Venous. The Arteriolae Arteriarum are not direct openings from the cavity of the vessel into the coats, but they are little twigs given off from small branches, which arise either from the vessel which they are destined to nourish, or from a neighbouring artery; these divide into smaller branches in the sheath, and on the surface of the vessel before they enter its coats. They form a network in the tissue of the external coat, which may be regarded as a sort of matrix or bed for their division; from this a few penetrate the middle coat, and follow the circular course of its fibres; none have been discovered in the internal coat. Minute venules return the blood from these nutrient arteries, which however they do not closely accompany, and discharge it into the satellite vein or veins accompanying the artery.

Arteries are generally accompanied by larger or smaller nerves, but the vessel itself when in an healthy condition is insensible. Nerves however are distributed to the Coats of the arteries, probably for governing their contractile movements.

The sympathetic system is the chief source of these nerves, although some are furnished by the Cerebro-Spinal. They form plexuses round the larger arteries, and run along the smaller branches in the form of fine bundles of fibres, which here and there twist round the veſsel, and single nerve fibres have been seen closely accompanying minute arteries. There is leſs certainty as to the extent and mode of distribution of the nerves in the arterial coats; some observers state that filaments may be traced on as far as the middle coat, and Valentin describes them as ending there in a network. The principal feature of interest connected with the *Chemical Composition* of the arterial tunics is, that Chemical analysis of the middle coat leads to results coinciding with what the microscope and experiment have taught us, as to its structure and properties. Dr Retzius has found in this coat a proteine compound, which neither cellular or elastic tiſsue contain; and Dr Donders has proved the same more perfectly. When he says nitric acid is applied to any compound of proteine, it forms with it what is termed Xantho proteinic acid, which with ammonia produces a yellow Xantho proteinate of ammonia. On applying this test, with the requisite cautions, to the coats of the blood veſsels, he found that the middle coat alone aſsumed the characteristic yellow colour. The other coats as well as all the coats of Veins remained unchanged in colour. He found also that potash acts on the middle coat of arteries, as on organic muscle; separating its fibres, making them granular, and finally diſsolving them. Chemical Examination therefore confirms the claim of this coat to the appellation Muscular.

Developement of Arteries. Under this division of my subject I shall first endeavour to give a slight sketch of the general developement of blood veſsels, and then subjoin what I have been able to collect, respecting the mode of formation of the larger and smaller arterial trunks.

Developement of blood veſsels generally. Two views have been prevalent amongst the later Physiologists, as to the mode of formation of blood veſsels. One party following the view of Schwann, who described the proceſs as consisting solely in the direct transformation of nucleated cells; another claſs agreeing with Plattner Prevost & Lebert, who consider that new bloodveſsels are never formed except as offshoots from previously existing veſsels. To the late valuable researches of Kölliker however, we are indebted for the reconciliation of these apparent descrepances. His observations were made on Batrachian larvæ, but Mr Paget has found that the mode of formation described by Kölliker, holds good in Mammiferous animals. The researches of Schwann on this subject, led him to expreſs himself in the following manner; "Among the cells," he says, "of which the germinal membrane consists, several at certain distances from one another, by lengthening out on different sides into star like figures, form the primary capillary vascular cells. These elongations of different cells encounter, grow together, the septa between them are removed, and so a network of fine canals of various diameter is engendered; for the produced portions of the primary cells are much smaller than the bodies of the cells. These prolongations, or anastomosing Canals of the bodies of the cells, however enlarge until they are of equal size one to another, and also to the bodies whence they spring, consequently until they have formed a network of Canaliculi of equal dimensions."

Plattner, on the other hand, from his observations on the tail of the Tadpole, was led to believe that the bloodvessels were only formed by the growth and coalescence of processes from previously existing capillaries. He says that in this growing texture, capillaries may frequently be observed which end abruptly in closed extremities, and that from these, long narrow offshoots may be seen issuing, which either unite to form a loop with similar processes from neighbouring vessels, or gradually disappear. The arch formed by the union of two such offshoots gradually enlarges, and becomes permeable to blood corpuscles. Prevost and Lebert, who observed this process in the tails of tritons and tadpoles, and also in the chick, give a very similar account of the vascular formation. They believe that vessels are always formed centrifugally, under the influence of the circulation, by arches passing from a minute artery to a corresponding vein. They further state, that such arches are formed in the intercellular spaces, from the separation of cells, and not from the coalescence of branches proceeding from cells, as Schwann described. Kölliker, whose observations were likewise made on the tail of the tadpole, states that the vascular formation is a double proceſs, consisting both in the metamorphosis of cells, and the production of offshoots from tubes already in connection with the circulation. He says that the extremities of the main venous and arterial trunks which communicate by a single arch, elongate by pushing forth narrow pointed proceſses, which meeting with elongated or star shaped cells in the substance of the tail, coalesce with them, and thus a simple arch is formed. Such an arch becomes permeable to blood, sends forth new proceſses, which meeting with other radiated cells join with them for the formation of secondary arches, and in this manner the capillary network is formed. The prolongation which takes place from the veſsel, is at first perfectly solid, and may not exceed the thickneſs of a fibril of fibrous tiſsue, but by degrees, especially after its junction with a cell, or another prolongation, its size increases and it becomes hollow. This enlargement not only takes place at its point of departure from its parent veſsel, but also at its point of junction with the cell; so that a capillary at its first formation will present great irregularity in its form and size. Of the star shaped cells observed by Schwann, only a few are destined for the formation of blood veſsels;

lymphatic veſsels are formed from some, nerves from others, and many appear not to undergo a metamorphosis of any kind. Mr Paget has observed a proceſs corresponding closely with the one described by Kölliker, in the foetal membranes of the Sheep. His researches are highly interesting, proving as they do that the plan of developement is exactly similar in Mammalia and Reptiles. He notices also that the filamentous prolongation from a veſsel may not only enlarge and become tubular at its points of developement from the parent trunk and of union with the cell, but also at isolated parts; and in such distended parts, groups of blood corpuscles may be seen, although they are shut off from the general circulation by the entire impermeability, (or at least extreme narrowneſs of cavity, if such be in the progreſs of developement,) of the fine thread like structure of the rest of the offshoot. These observations therefore tend to prove, that blood corpuscles may be developed in parts not as yet in communication with the general vascular system, and from other materials than those derived directly from the contents of the blood veſsels. The walls of the fine tubes, as observed both by Kölliker and Paget, appear to be formed of the membrane of the cell, which is drawn out into the Elongating filaments proceeding from these bodies; in structure it appears quite homogeneous. The larger veſsels poſseſs delicate walls, with a fine longitudinal fibrous structure, and scattered nuclei imbedded in their substance. Opposed to these observations, we have the opinion of Vogt, who believes that the blood veſsels invariably originate in the cellular interspaces, from a simple separation of cells from each other, and that this takes place quite independently of the heart and the general circulation. In this latter opinion his views are quite opposed to those of Lebert and Prevost, for he believes that the channels, at their first formation, have no Communication with the previously existing veſsels. These channels at first he thinks have no distinct walls, but they afterwards get a delicate membranous lining, formed apparently by a layer of cells, in the midst of which the developement takes place. This mode of production Vogt observed in the formation of the first Embryonic trunks, in Connection with the heart, and also of the finer veſsels in other parts. Kölliker allows that it prevails in the first case, but it is totally at variance with his observation on the developement of the finer vessels. (This mode of formation, as described by Vogt, is strikingly analogous to the manner in which Schleiden and Meyen maintain the Cinenchyma, or laticiferous tissue of plants, is formed.) That Köllikers description is the correct one, there appears little reason to doubt, confirmed as it is by the researches of Mr Paget, and with it the views of Schwann and Platner are quite reconcileable. The description furnished by Vogt is so much at variance with that given by Kolliker, that the difference must either be ascribed to the misconception of appearances, or what is less probable, to the existence of another process by which the developement of blood vessels may be effected.

Developement of larger Vessels. The smaller arteries and veins are, in all probability, developed primarily in the same manner as the Capillaries; the additional coats, which we have seen them posess, being an after acquisition. It seems not at all unreasonable to assume, that the several gradations, seen as permanent conditions in vessels of successively larger calibre, may represent the successive steps, by which a vessel having originally the simple structure of a Capillary, arrives at length at the magnitude, and acquires the complex tunics of an artery or vein. Kölliker states that many veſsels, which eventually attain a median size, are originally derived from round cells, which unite in single or double rows, and form the primitive simple membranous tube of such veſsels, by the Coalescence of their cavities and walls. He thinks that in other moderate sized veſsels, the proceſs of formation is the same as in the heart, and large venous and arterial trunks, which are formed not after the manner of the Capillaries, but by an agglomeration of cells, in the situation of the future heart, and along the line of the great veſsels, forming at first a solid maſs, but subsequently becoming hollow within, by a liquefaction in the centre; whilst the circumferential cells are metamorphosed into the fibres of the heart, and the several tiſsues Constituting the Coats of the Veſsels

The Arteries may be said to increase in size and Capacity, in proportion to the demands made on their service. The Uterine Arteries during pregnancy present a good instance of this, as do the Spermatic arteries of many animals at a particular season of the year. It is by this provision, a limb is supplied with blood, when the circulation through the main artery is stopped by the application of a ligature or otherwise. Collateral branches, previously of insignificant size, augment in calibre, and afford a paſsage to the increased quantity of blood which they are required to transmit. In such veſsels, the augmentation takes place in length as well as in breadth, hence a tortuous condition of the tubes so increased is commonly observed.

Properties of Arteries The properties of arteries may be referred to two heads; viz, 1st. Their mechanical properties, properties which they poſseſs in common with lifeleſs matter; and 2ndly; their Vital Properties, or those with which they are endowed by virtue of their organised structure, and the important place they hold, and functions they perform in the animal body; and which moreover are not poſseſsed by inorganic material.

Mechanical Properties. The arteries poſseſs a large amount of strength and toughneſs; by which they are enabled to resist preſsure from without. A great part of the strength of these tubes depends on the dense external tunic. The internal and middle coats are brittle, this is well exemplified by the well known fact, that on tightening a ligature round an artery, the internal and middle coats are cut through, the external remaining uninjured. A most important mechanical endowment of arteries is their elasticity. This is a property not only of the external and middle coats, in whose structure the presence of much elastic tissue is observed, but also of the fenestrated membrane, which many regard as a modification of the same tissue. The elasticity of an artery causes it, on being cut across, to shrink back within its sheath; and it is also extensible and retractile in the transverse direction. An artery when cut across remains patent, in this they differ from venous tubes, whose cut orifices collapse unless prevented by their surrounding connections. The important uses of the elasticity of the arteries will be referred to again, in speaking of the phenomena presented by the arterial circulation.

Vital Properties. The arteries are not endowed with much sensibility. When pain is complained of on the application of a ligature, it depends on an accompanying branch of nerve being also included: but, in the normal condition, these tubes are insensible.

Vital Contractility. The property of arteries to contract under certain circumstances to a leſs diameter, than their unaided elasticity would enable them to aſsume, was unexplained, until the sagacity of Hunter, unaſsisted by microscopical observation, led him to consider it a *muscular act.* This opinion however, fell into disregard for some time; many writers, including Prof. Muller, although they allowed that the arteries under certain circumstances presented a state of diminished calibre, referred the production of such phenomena to no particular structure. To Henle's researches we are indebted for the anatomical verification of Hunter's opinion, and late experiments have afforded us abundant proofs of its correctneſs. The nature and degree of the contractility poſsessed by arteries, is quite analogous to the same property observed in unstriped involuntary muscular fibre. It is slower, and more enduring than the contraction of voluntary muscle; and unlike the latter, it does not alternate with relaxation. This property of the arteries is always in action, counteracting the distending effect of the heart, and adapting the calibre of the tube to the amount of blood it may receive. In this no doubt, it is aſsisted by the Elasticity of the Coats, but we can prove that the vital Contractility can diminish the size of the veſsel, beyond the limit at which the Elasticity ceases to operate. From its Constant operation, it must offer an unceasing resistance to the distending force of the blood, and as the veſsel will contract to a greater degree, the leſs the amount of blood propelled into it, it must keep the arteries in a state of Constant tension. From these circumstances, the term "tonicity" has been applied to this Contractility; but the fact must not be lost sight of, that like the Contractility of other muscular organs, it can be excited to much more violent action, than is seen in the balanced Condition it usually presents by the application of stimuli; and on the other hand, it may be diminished, so as to offer leſs obstacle to the distending vis a tergo, and admit a larger quantity of blood into the veſsel than it usually conveys.

That this diminution of the contractile action takes place suddenly in the phenomenon of blushing, and is also concerned in the production of Erection seems highly probable.

We have before seen, that the amount of unstriped fibre poſsessed by the smaller arteries, is proportionally greater to the quantity of the same tiſsue with which the larger tubes are endowed. The amount of Contractility consequently is greater in ~~the~~ the smaller veſsels; and in enumerating the proofs of the poſsession of this property, the smaller arteries, in which the phenomena are more easily observed, will be noticed, before we speak of the same endowment as being poſsessed, although in a leſs degree, by veſsels of a larger calibre.

Proofs of the Contractility of smaller arteries.

(a) Mechanical Stimuli. On drawing the point of a needle two or three times quickly acroſs a little artery, in the web of a frog, it will be seen gradually to diminish in size. The Contraction may occupy several minutes, the current of blood in it will become leſs, and on repeating the stimulus, the calibre will be so much diminished, that it (the current) may Entirely disappear. The Contracted State, after occupying several minutes, will gradually become relaxed, and the vessel will resume its original size.

(b.) Chemical Stimuli. The same phenomena will take place on the application of Alcohol or Turpentine: but from the action of Chemical Stimuli on the tissue, they are not so well adapted for Experiments of this nature.

(c) Cold. The mere Exposure of a small artery to the air, in a living subject, will produce a gradual but manifest contraction. The same effect will be produced in a greater degree, by the application of a few drops of ice cold water, as was shewn by Schwann in his Experiment on the mesentery of a living toad. Connected with this property is the useful application of cold in arresting haemorrhagy.

(d) Electro Magnetism. Wedemeyer, E. & E. H. Weber have observed that an increased contraction of arteries is capable of being Elicited, by this stimulus. The Experiments of the Webers were most conclusive on this point; they were performed on the small mesenteric arteries of the Frog.

When an artery of from 1/7 to 1/7 of a Paris line in diameter, was exposed to the electric stream, its transverse measurement in from 5 to 10 seconds became one third less, and the area of its section about one half. On continuing the stimulus, the narrowing gradually increased, until the calibre of the tube became from three to six times smaller than it was at first, so that only a single row of blood corpuscles could pass along it at once; and eventually the vessel became completely closed, and the current of blood through it arrested. During the contraction the walls of the artery became thicker, and the velocity of the stream of blood through it was accelerated. When the irritation was long continued, or the stimulus very powerful, the portion of the artery narrowed by it, lost the power of again contracting, and even dilated until it became double its former size: (the contractility having been exhausted by the unwonted stimulus). The mode in which the Webers operated was by sending a rapid succession of shocks through the vessel by means of a coil.

(c) Increased contractility may be called into play by taking off the distending power of the Heart.

On placing a small weight on the artery of the mesentery of a Frog, the part below the preſsure will shrink momentarily from its Elasticity, gradual contraction ensues, which will continue for some time; and on removing the weight, the artery is seen narrower at that point than the part above. The same effect will be produced on cutting through the larger trunks, or on removing the heart, and in this manner taking away the distending force. Poisseuille performed the same experiments on the artery of the mesentery of the mouse, and obtained a corresponding result.

Proofs of the Vital Contractility of the Larger Arteries.

In consequence of this property being poſsessed in a leſs degree by these tubes, the proofs are not so obvious, although if the experiments be performed with the requisite care, it may be clearly demonstrated.

(a). A sufficiently decided, though by no means striking degree of contraction slowly follows the repeated application of mechanical or the galvanic stimulus to the larger arteries. (Many authors have denied the contractility of these veſsels, because they have not been able to elicit this result: the probable reason of this, was twofold; 1st because they trusted too much to sight alone in estimating the effect on the calibre of the tube; and, 2ndly, because they did not keep up the application of the stimulus for a sufficiently long time) In proof of this the following Experiment of Dr C. J. B. Williams may be cited. He tied a bent glaſs tube into the cut end of an artery, and filled the veſsel as well as the tube with Coloured water; the application of galvanism caused a narrowing of the artery, the reality of which was made manifest by a rise of the fluid in the tube.

(b.) It is a well known fact that the larger arteries shrink on exposure to cold. This fact is familiar to every one who has noticed the difference of the pulse when a limb is cold, and when it is warm. The Author above quoted says "On plunging into cold water the aorta of an Aſs just dead, it contracted so closely as to obliterate its cavity; and it required some force to paſs the little finger into it" (Williams's Principles of Medicine Note P. 54)

(c) On taking off the preſsure of the heart, by putting a ligature on one of the larger arteries, more blood is forced out of it, than its elasticity would account for; there is a slow and gradual contraction. The emptineſs of the arteries after death, is doubtleſs owing in a great measure to this cause. When an animal is bled to death, there is a greater amount of shrinking observed in the larger arteries, than is attributable to their elasticity. Dr Parry of Bath made most conclusive experiments on this point. He bled a sheep to death; previously to the extinction of life the circumference of the Carotid was $\frac{320}{400}$; after its death the measurement had diminished to $\frac{160}{400}$; this contracted state remained until vitality became extinct, after which it dilated to $\frac{234}{400}$, at which point it was finally maintained by its Elasticity. John Hunter's Experiments on the arteries of the Horse led to a similar conclusion.

The Contractility of Arteries continues in action for some time after death. Hunter found that in the case of a woman delivered on a Thursday afternoon, the contractility of the arteries of the umbilical cord was not extinguished on the following Sunday morning.

Purposes of the Vital Contractility. We have no proof that it aids in any degree in forcing on the blood; in fact it could not have this effect unleſs it alternated with relaxation, and the contraction and relaxation were coincident with the Diastole and Systole of the Ventricles; or unleſs it produced a sort of peristaltic or vermicular action, commencing at the heart and proceeding rapidly along the arteries; but there is not the slightest evidence of such phenomena occurring. One of its chief uses seems to be the adaptation of the size of the vessel to the quantity of its contents; this could not be effected in every case by the limited elasticity. Another important purpose it serves, is the regulation of the quantity of blood which a part is to receive. We know that in the different states of functional activity and rest, an organ must require a varying amount of blood; it is impossible for the heart to regulate the quantity that is to be received by any particular part; it must be the contracted or dilated state of the arteries, that shall at one time, to a certain extent oppose, at another, freely allow the passage of the circulating fluid. We have also in the action of the vital contractility of the arteries, a beautiful provision to prevent the permanent distension of the arterial system. If it were not for this power, which is always new, and always in action, the elasticity might be overcome by the constant distending force of the heart. (It has occurred to me, whether perhaps the greater frequency of aneurismal dilatations in the largest arteries, may not partly be accounted for, by the small amount of vital contractility with which they are endowed, for resisting the distending power of the Ventricle, and which is not altogether made up for by their augmented Elasticity).

When speaking of the nerves which supply the arterial Coats, it was observed that one of their chief purposes probably was to preside over the contractility of the muscular coat. The phenomena of blushing shew how completely the local circulation is under the influence of the mind, which can only act through the medium of the nervous System. According to Valentin, the aorta of the horse diminishes in size, when a Stimulus is applied to the thoracic ganglia from the third onwards.

Phenomena presented by the arterial Circulation.

The blood is propelled into the arteries in successive portions, by the Ventricular contractions; whilst in the capillaries, as seen in the web of the Frog's foot, its movement is equable and regular, unless the Heart be acting weakly. On opening an artery, in the living subject, we observe that although the blood retains the successive impulses which the ventricular contractions have impreſsed upon it, that now its flow is no longer in divided portions. but in a continuous stream, accelerated however at every beat of the heart. The nearer the blood approaches the capillaries, the leſs is the impulse perceived, until it can no longer be observed. Hence in the arterial system the succeſsive quantities of blood are blended into an uninterrupted stream, in which at last, not even an acceleration can be noticed. The mode in which this change is effected is explained on reference to the mechanical properties of the tubes. That it is not eſsentially dependant on any vital endowment, is proved by the simple experiment of injecting water in succeſsive portions into arteries in which all vitality has become extinct; it will be found to flow out at the distal extremities in a continued stream, which is accelerated at each stroke of the piston. To the elasticity of these veſsels, we are indebted for this effect. At each ventricular systole a portion of blood is propelled against the arterial walls, these yield to a certain extent, becoming proportionally more tense, the greater the amount of dilatation they undergo. During the diastole of the ventricle, the elasticity of the distended artery reacts, and reflects as it were, the force which it has received on the blood. In this manner the resilient action continues onwards the propelling power, in the interval during which the propelling organ no longer acts. We have seen that there is a certain amount of yielding on the part of the arteries, this no doubt breaks, to some extent, the shock with which the blood is impelled, and furnishes a guard against the danger of rupture. The preſsure exercised by the recoiling arteries is of course propagated in every direction, and would tend equally to propel in a backward, as in an onward course, were not such an effect prevented by the closure of the arterial valves. As it is a law that elastic bodies return to the state of rest, with the same force as that by which they were disturbed therefrom; so, by this arrangement there is no loſs of ventricular power experienced. All the power of the heart, in the arteries, is expended on the propulsion of the blood; none is absorbed by the arterial walls, (except that which is neceſsary to overcome the mere friction, which however is very slight); whatever they receive, they return. The resiliency however generates no new force; it merely borrows and pays back, so to speak the power with which it is entrusted. It is by the process we have been endeavouring to describe, that the flow of blood is rendered equable and continuous. The whole phenomena may be compared to those which are noticed in the action of a fire engine; during the intervals of the strokes, the water is forced on by the elastic power of the air, its pulsatory accelerations are destroyed, and it issues from the tube in an uninterrupted stream. On the other hand, when the heart is acting feebly, and from the imperfect distension of the vessels their elasticity is allowed to remain dormant, an acceleration, corresponding with the hearts beat, is perceived in the capillaries. Imperfect working of the fire engine furnishes an apt illustration of this also. Just as in the flight of an arrow from a bow, the reaction which follows is proportional to the force exerted.

In the arteries, when the heart is acting properly, the column of blood must be continuous: there is no empty space; the arterial system however becomes more distended after each beat of the heart in consequence of the blood being delivered suddenly into these tubes, whilst it is transmitted more slowly through the Capillaries.

The Velocity of the Blood in the Arteries. In estimating the rapidity of the bloods motion, we must not form our judgement from the rapidity with which it flows from a veſsel when divided. In the latter case, the rate of motion is the result of the entire preſsure to which the whole maſs of blood is subjected in the vascular system, and which at the point of incision in the veſsel meets with no resistance. In the closed veſsels, on the contrary no portion of blood can be moved forwards but by impelling on the whole maſs, and by overcoming the resistance arising from friction in the smaller veſsels. We may state generally, that the Velocity of the blood is greater in the arteries, than in the veins, or Capillaries. It is also greater in proportion to the size of the arteries; its flow being more rapid through the large, than through the small tubes. This difference is no doubt owing to the increased capacity of the arterial system as the blood advances; just as the water of a stream widening into a lake, progresses more slowly. Another cause is the increase of friction to which the blood is subject, for "coeteris paribus", the friction is proportional to the amount of surface over which the circulating fluid moves. The effect of the friction in the smaller tubes is however not confined to the circulation through them, it must also tell back, so to speak, on the blood in the larger ones. The relative size of the smallest vessels and capillaries moreover, has an influence on the local circulation - Many experiments have been made to determine the absolute velocity of the blood, but as these have generally had reference to the time consumed in traversing the whole round of the circulation, they do not come directly within the range of the subject of this paper. I shall therefore content myself by stating, that from the experiments of Hering, Blake, Magendie, Poisseuille, and Valentin, it appears that the blood completes the entire circuit in man in less than a minute.

The force of the blood in the arteries. This was a favourite subject of investigation amongst the Mathematical Physicians; Amongst the older experiments made to determine this point, we find one which was performed by Dr Hales, who introduced a long glaſs tube bent at the lower part, into the artery of a horse, and observed the height to which the column of blood rose in the tube. In later times, M. Poiseuille's hæmadynamometer has enabled us more conveniently to estimate the force of the blood in the arteries. This instrument has been so generally used for this purpose, that I shall not occupy space by its description. M. Poiseuille found ~~found~~ that in the horse and dog the blood supports a column of 6 inches 1½ lines of mercury, or a column of water 7 feet 1 line in height. He found the preſsure the same in all the arteries which he examined, difference of size and distance from the heart being unattended by any corresponding difference in the force of the Circulation. Other observers have confirmed these observations, and they have found moreover, that the preſsure of the blood in the arterial system of all the larger quadrupeds is about the same. Poiseuille estimated the amount of the pressure of the blood in any vessel, by multiplying the area of its transverse section by the height of the column of mercury supported by the force of the blood in any part of the arterial system. In this way he found that as the power capable of supporting an inch of mercury is equal to the pressure of half a pound on the square inch, and assuming that the force of the circulation in man is the mean of that observed in animals, then if the diameter of the human aorta be said to be 1.36 inches, the force with which the blood is propelled in the commencement of the aorta will be indicated by 4 lbs 4oz avoirdupois: by the same mode of calculation, he estimated the force in the aorta of the mare as 11 lbs 9℥; and in the radial artery at the human wrist as 4 drs.

The column of blood in the tube is not stationary: it is subject to two oscillations: The blood rises at each ventricular systole, and falls during the dilatation: Hales observed this in the experiment noted above, and Ludwig has recorded it more minutely. It also rises with each expiration, and falls during inspiration. These oscillations are greater than the former; according to Poisseuille, the rise and fall of the mercury was the same in arteries, the distance of which from the heart was different, and in ordinary tranquil respiration amounted to from 4 to 10 lines. The rise during expiration is caused probably by the pressure of the parietes of the chest and abdomen on the arteries, for, pressing the hand on the abdomen produced a similar effect. The decrease of the blood's impulse in inspiration is in some persons so great, that the pulse at the radial artery becomes imperceptible when inspiration is long continued, and the breath held. It has been already stated, that the force, with which the blood moves in the arteries, is found to be much the same in the whole of the arterial system of the animal; at least in all the arteries whose calibre allows the introduction of the tube. Very little of the force of the ventricles is consumed in overcoming friction in the arteries, we have before seen that none is expended on the dilatation of the arterial walls. Dr T. Young calculated, that the loss of force in the arteries is so slight, that if one tube were introduced into the aorta, and another into any other artery, even into one as fine as a hair, the blood would rise in the tube from the small vessel to within two inches of the height to which it would rise from the large vessel. We can only speak with certainty however, in reference to vessels whose size permits the introduction of a tube. The force of the blood is increased or diminished in proportion to the weak or strong action of the heart; Magendie and Valentin, moreover, find that on drawing blood from an animal, the mercury falls, whilst on returning it, the column again rises.

The Pulse. The Phenomenon of the Pulse is occasioned by the increased quantity of blood that is impelled into the arteries by the ventricular contraction. The pulse is not felt in all parts of the arterial system at exactly the same moment; there is a fractional difference of time between the pulse of the foot, and that, for instance, of the Carotid. We shall first state the exact condition of the artery when the pulse occurs, and then give a short account of the most probable theories of its propagation.

During the phenomenon in question, the artery is distended; there is not the slightest doubt of this. But the distension may take place in two ways, longitudinally and laterally. The former is the most considerable. The longitudinal distension of the arteries produces a change in their form, the straight ones become curved, and those already curved become more so; but they recover their previous form when the ventricular contraction ceases, and their elastic walls recoil. The increase of the curves and the succeeding recoil are well seen in the prominent temporal artery of the aged. With regard to a lateral distension, some doubt has been raised as to its existence; Dr Parry of Bath denied it, because it cannot be perceived by the eye, and others have followed his opinion. Attempts however have been made to demonstrate it, on the supposition that it might take place, although unobserved. Poiseuille having laid bare the carotid artery of a horse, fitted to it a tin tube closed at both ends; he then connected with the metallic tube a glaſs one, by which he filled the apparatus with water; he found that on each pulsation the water rose in the glaſs tube. This Experiment is not satisfactory, for although it is probable that the rise partly depended on the lateral dilatation of the artery, yet it might have depended altogether on its longitudinal distension, the veſsel becoming curved in the tube to permit of its Elongation. Flourens fitted a steel ring cleft at one point on the artery of a dog, and he found that the interval in the ring was widened at each pulsation; here however it is difficult to be certain that the ring did not previously compreſs the veſsel to some extent. In fact it must be a matter of great difficulty to fit a ring exactly on the artery of an animal. It may be asked however, what doubt can there be of the lateral enlargement, for it is felt whenever we place our fingers on the pulse: but it must be recollected that under such circumstances the artery is compreſsed and not in its natural condition. The most powerful argument for the lateral dilatation of the artery, is the physical neceſsity for its existence; and this is the ground on which Physiologists aſsent to it, for it seems difficult to prove the doctrine by Experiment.

We may thus conclude that the artery, during the phenomenon of the pulse, is elongated and somewhat distended laterally; we now come to consider the manner in which this condition of the arteries is propagated from one part of the arterial system to another. The theory advanced by E. H. Weber, and which has been widely adopted is the following. He considers that the impulse given to the blood by the heart distends first merely the arteries nearest the heart. These by their elasticity again contract, and thus cause the distension of the next portion of the arterial system, which also in its turn by contracting, forces the blood into the next portions, and so on. In this view the arterial pulse is regarded as the effect of an oscillation or undulation, produced first by the pressure of the blood on the aorta by the ventricular systole, and thence propagated along the walls of the arteries, and along the blood itself. To this theory however the following powerful objection, first pointed out by Mr. Colt, presents itself. One of the first effects of the elastic recoil of the arteries nearest the heart is the closure of the semilunar valves, and the production of the second sound of the Heart. The pulse therefore except in those portions of the arteries close to the heart, ought to follow or at least be synchronous with the second sound. This however is not the case, the pulse throughout the whole arterial system is perceived before the second sound is heard. The theory proposed by Mr Colt to reconcile all the facts of the case, especially those two which appear most opposed, viz, that the pulse always precedes the second sound, and yet is perceived later in the extreme arteries than in those nearest the heart, is the following. "It supposes that the blood which is impelled onwards by the left ventricle, does not so impart its pressure to what the arteries already contain as to dilate the whole arterial system at once; but that as it enters the arteries, it displaces and propels what they before contained, and flows on with what may be called a <u>head wave</u>, like that which is formed when a rapid stream of water overtakes another moving more slowly. The slower stream offers resistance to the more rapid one, tile their velocities are equalized: And because of such resistance, some of the force of the more rapid stream of blood just expelled from the ventricle, is diverted laterally, and with the rising of the wave the arteries nearest the heart are dilated and elongated. They do not at once recoil, but continue to be distended so long as blood is entering them from the ventricle. The wave at the head of the more rapid stream of blood runs on, propelled and maintained in its velocity by the continuous contraction of the ventricle; and it thus dilates in succession every portion of the arterial system, and produces the pulse in all. The rate of its movement which represents also the velocity of the blood in the arteries during the ventricular contraction, may be estimated by the interval between the pulses near and far from the heart. At length the whole arterial system (wherein a pulse can be felt) is dilated; then it begins to contract, and the contractions of its several parts ensue in the same succession as the dilatations, commencing at the heart. The contraction of the first portion produces the closure of the valves and the second sound of the heart, and both it and the progressive contractions of all the more distant parts maintain, as already said, that pressure on the blood during the inaction of the ventricle by which the stream of the arterial blood is sustained between the jets, and is finally equalized by the time it reaches the capillaries."

The Vital properties of the arteries do not necessarily interfere in the production of the pulse; they however are instrumental in modifying its character under certain circumstances, (rendering it harder softer &c) The *frequency* of the pulse is one of the most important features connected with this phenomenon. Its ordinary range may be stated at from 70 to 75 per minute; but of this there are many modifications from various causes. Age, sex, idiosyncrasy produce differences in its rapidity. It is said to be increased on rising considerably above the level of the sea, this probably is not owing to the rarefaction of the air affecting *directly* the circulation, it seems more likely that it increases the rapidity of the hearts action indirectly, by augmenting the frequency of respiration. Poiseuille, in experimenting on cold blooded animals, found that different degrees of rarefaction of the air did not affect the movement of the heart at all, provided their respiration was prevented. Different periods of the day produce an effect on this quality of the pulse; it is more frequent by a few beats in the morning. Posture of the body modifies the rate of pulsation; we owe our knowledge on this subject to Dr Bryan Robinson and Dr Guy of King's College.

The following is the average alteration:— In standing, the number of beats is 81 per minute, in sitting 71, in the horizontal position 66. The cause of the increased frequency of the heart's action is the greater amount of muscular effort necessary to maintain the body in the erect position: that it is not, as some have believed, from the change of the hearts position, is proved by the simple experiment of placing a person erect, and then allowing him to lean against a support, when the pulse will fall in quickness. The acceleration is increased relatively in pulses of different frequency, or in other words, the effect of posture increases in proportion to the rapidity with which the pulse is beating at the time. A person whose pulse whilst in the horizontal position is beating at 80 will have an acceleration of 19 per cent, whereas one whose pulse is at 60 will only have an acceleration of 15 per cent on assuming the erect posture (Dr Guy). The effect of posture is not so well marked in females or in children, perhaps from less muscular effort being made. In some diseases, as Phthisis, the change is not so appreciable.

<u>The Forces moving the blood in the Arteries.</u> The

Ventricular Contraction is the great efficient power propelling the blood in the arteries; if other forces have an effect, they are merely auxiliary. In support of this proposition are two great arguments; 1st By measurement the force of the heart may be proved to be more than sufficient. 2nd The beat of the Ventricle may be perceived in the Capillaries, when the heart is acting feebly, how much more then does it produce its effect, when its action is strong. The supposed participation of the arterial walls in propelling the blood has been previously examined. It has been seen that the elasticity generates no new power; and that from the mode of action and nature of the Vital Contractility it cannot be proved to serve this purpose. It remains to examine some of the arguments which have been brought forward in defence of the supposition that the arterial contractility is instrumental in forcing on the blood.

(a) It has been argued from the analogy of the dorsal vessel in Insects, which contracts and impels the blood; but this is really an elongated heart. It is nothing more than a series of Ventricles with valves between them. It is not analogous to an artery.

(b) From the Contraction of the arterial bulb in Fishes. Here however we have a distinctly muscular structure whose contractions are rythmic, — a thing not seen in the human body. There is no proof that the other arteries of the fish contract rythmically, as does this.

(C). The Heart is wanting in acardiac Foetuses. It has been asked what moves the blood on in these cases, if it be not the instrumentality of the arteries. It may be answered that in a large number of these cases, there is a perfect twin foetus at the same time, and that through the placental medium the heart in the perfect foetus moves the blood in the acardiac. But even supposing only a single foetus to exist, is it not probable, that from arrest of developement, its heart has remained in the primary Condition of a simple tube, which has been mistaken for a bloodveſsel; but which is analogous to the permanent Condition of the Cardiac organ in beings lower in the scale of Creation.

The Effect of the Respiratory movement is doubtleſs an auxiliary in the propulsion of the Circulating fluid. But it is by no means a neceſsary force; on keeping the chest perfectly still the blood moves on, although ordinarily, at each Expiration the blood is propelled with greater force, owing to the preſsure on the arteries of the Chest and Abdomen.

Peculiarities of the Circulation in different parts.

In the arrangement of the arteries, which are employed in transmitting the blood to the brain, we observe provisions against disturbance to the equability of its flow, also against an undue amount of distension taking place, and to some extent the blood must be retarded by the amount of friction which it undergoes in paſsing through the flexuous course of the Carotid and Vertebral Arteries. The first object is effected also by the wide anastomoses which occur between the larger veſsels; and in like manner, by the network into which the arteries are divided before they enter the organ. Distension moreover must be guarded against by the oſseous canals through which the Carotid Arteries especially paſs. The inosculations of the Arteries provide also, to some extent, against the effect which would ensue on the stoppage of any one arterial branch. It is by these arrangements that the Cerebral Circulation is rendered equable and uniform; remaining unaffected in a great degree by those influences by which the flow of blood through other parts is liable to be disturbed.

The Uses of the Retia Mirabilia. There can be no doubt of the general physiological interest which attaches itself to these vascular plexuses. Their occurrence however in such various situations, and in creatures whose modes of living, and positions in the scale of being are so different, has contributed not a little to involve their uses in obscurity, and to make their probable purpose a ground of dispute. In every instance the blood in traversing them must undergo a retardation, first, from the wider area of the space through which it passes, and secondly from the greater amount of friction which it undergoes. But we cannot suppose this to be their only purpose in all situations, and accordingly we have had various theories enunciated to account for their existence. Some of these I shall now subjoin.

Where the rete mirabile occurs on the Carotid by the side of the Sella Turcica, there can be little doubt but that it serves a similar purpose, and probably more effectively, with the anastomoses which we find ordinarily taking place between the Cerebral Veſsels. In the Ruminantia, their occurrence has been connected with the position in which the animal holds its head whilst feeding; it being supposed that these plexuses guard against the effect of gravitation on the blood. Although this theory wears at first sight an air of probability, yet an objection presents itself in the non existence of a similar arrangement in the Horse, whose circulation is exposed to the same influence. Again it has been given as a reason for its occurrence on the Carotids of Felidæ, that its use is to prevent the effects on the cerebral circulation of the enormous springs which these animals take in seizing their prey. At least, in these it cannot be specially provided to prevent the effects of gravitation. In the limbs of tardigrade Mammalia, it has been said, that the existence of the rete mirabile is connected with the slow enduring contraction of their muscles. This I think can be hardly admitted when its existence in the flipper of the porpoise is called to mind, the movements of which organ are remarkable for their rapidity. It seems more probable, that when they are found on the brachial and crural arteries of animals well fitted for climbing and prehension, their use may be to obviate the effect of the long continued pressure which the main trunk would otherwise undergo, in the ascent of trees &c. These movements being continued for a great length of time by the slow moving sloths &c.

It has occurred to me, that perhaps a similar reason may be given for the presence of the rete mirabile on the anterior tibial artery of the swan goose &c. In the movement of swimming, especially when the animal is impelling itself against an adverse stream, these arteries I should suppose are, to some extent, under the influence of the pressure of the current, and it has suggested itself to me, that the occurrence of the plexiform arrangement might perhaps be intended to obviate its effect on the circulation through the extremity.

A purpose of much higher physiological

importance was aſsigned to the ramified and Convoluted arterial plexuses of Cetaceans by John Hunter. He believed, that they were intended as reservoirs or stores of arterial blood, to be Expended by the animal whilst it remained under water. The prolonged duration of time during which these animals will remain under water, without rising to the surface for the purpose of breathing, is well known. The Spermaceti Whale has been observed to remain submerged for an hour at a time. Whether the Extraordinary arrangement met with in so many parts of the arterial system of these Creatures be intended for the above mentioned End, has yet to be determined. But at least, the opinion of John Hunter is not to be paſsed by without due consideration. It has been suggested, that during its transit through these plexuses, the blood undergoes some peculiar Chemical Change, of this however we have no proof, and I believe the theory is not generally received. The doctrine of the bloods retardation, in its paſsage through the Retia Mirabilia, is doubtleſs true, in all cases of their occurrence; although in some situations they appear to serve other purposes.

Some structures are liable to great temporary differences in the quantity of the blood which they contain. Such structures have received the name of Erectile. The Corpora Cavernosa and Corpus Spongiosum penis in the male, and the clitoris in the female; also in a leſs degree the nipple of the mammary gland, are structures of this nature. In the Corpus Cavernosum, which is the best example of an erectile texture, this peculiar property mainly depends on venous plexuses, and on the muscular preſsure to which all the veins of the penis are exposed. Muller however believes that his discovery of the helicine arteries throws a new light on the phenomena of erection. He says "although no openings can be discovered in the coats of these fine arterial excrescences, yet there is no doubt but that it is through them, that the blood which is ordinarily carried into the texture of the Corpora Cavernosa by the minute nutrient branches of the arteries, is in the act of erection poured directly into the venous cells and sinuses. When the arteria Corporis Cavernosi is injected with size and Vermilion, the injected matter always fills the venous cells; and if it is afterwards washed from them the arteriæ helicinæ will be seen injected. The means by which during life, they are enabled to force blood into the cells, must be an increased attraction excited between their coats and the blood, by the nervous influence transmitted to them by the spinal cord, in consequence of which an increased quantity of blood flows to them." The direct opening of the helicine artery into the venous cavity however cannot be considered as proved. The existence of these arteries is denied by Valentin and Berres, who think that what Muller called helicine arteries were small arteries running in the septa and bands of fibrous tissue which intersect the corpus cavernosum, and which when torn across, assume a contorted somewhat spiral figure. On the other hand the observations of Krause Hyrtl & Erdl appear to confirm Mullers original observation as to the existence of the arteries, whatever may be the purpose which they serve.

I have thus endeavoured to draw from the sources which lay within my reach, an account of the structure and physiological uses of the arterial system; which, imperfect as I fear it must necessarily be, will I hope not be found to be altogether erroneous. If however any of the principal observations and theories which I have inserted be considered as unimportant or mistaken, their introduction in this paper will I hope be attributed rather to the effect of misdirected study, than to wilful carelessness or thoughtless indifference on the part of the writer.

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