

Bennett
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On the Circulation

London and Lendrum

A few words, on the gradually increasing complexity of development of the vascular system in the animal series, may advantageously preface a consideration of the mode in which the circulation of the blood is maintained in its normal condition in the highest form of development—as it exists in man. This will be the more interesting because we find that some animals exist without any distinct vascular apparatus at all and hence the question naturally suggests itself, under what conditions does a vascular system become necessary to the due maintenance of nutrition?

To answer this question it will be necessary to consider the general structure of these animals.

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To answer this question it will be necessary to consider the general structure of these animals.

The lowest class of animals have no intestines Tube, properly so called, but merely a cavity in the body communicating with the exterior and in no way differentiated from the general substance of the animal, some creatures indeed only form this cavity at will, when it is required for the reception of some article of food, by extension of the body over and around the material until it is completely enveloped; such a process occurs for example in the Amoeba, but, in short, be the cavity permanent or otherwise, as it has no peculiarity of structure it is not adapted for effecting any preparatory action on the food, which latter is therefore absorbed directly by the tissues themselves, and applied to their nourishment and growth.

All animals with this characteristic are included under the Protozoa.

Proceeding a step higher we shall find that the medusae, actiniae & other animals classed under the Coelenterata, as distinguished from the remainder of the Radiata, are remarkable still from the absence of any proper vascular system and also from the peculiarity of their

alimentary canal. The mouth, it is true, in these animals opens into a distinct cavity having a wall which separates it from the surrounding parts of the animal's body which may be considered analogous to a stomach, but this organ instead of continuing with its proper walls to an ending externally, opens, after a short course, into the cavity of the body so that the alimentary matters, having undergone doubtless some change whilst in the stomach, finally reach the tissues which they are destined to nourish by entering the general cavity of the animal, just as we have seen the unprepared food to do in the ~~previous~~ previous class of animals.

The large size and greater development of many of these animals renders a simple central cavity inadequate for approximating the nourishment sufficiently to the tissues and hence we find the cavity as a consequence prolonged by a series of radiating canals passing throughout the body of the animal & which communicate with a circular canal at its margin; in this way the fluid matters are brought into a proximity with every part of the tissues suffi-

(contd.)

recently close to enable them easily to obtain their nutriment, The passage of the fluid along these canals is effected by the contractile action of the whole body, and in these arrangement we seem to have the first indications of the composite and secondary origin of the separate vascular system, which we find from embryological investigation to be developed in the higher animals from a combination of the primary layers, the animal and the vegetative layers, of the embryo.

It is only in the next class, the Echinodermata, that we find that the high development of the organism is such as to require the separation from the food of a new nutritive matter (the chyme) & consequently the existence of a complete intestinal, digestion, tube, and immediately in conjunction with this appears the vascular system, for the alimentary matter when received into the mouth & elaborated in the intestinal canal is now no longer able to come in contact with the tissues it is to nourish and is in fact physiologically as far separated from them by the

walls of the digestion tube as it is in many cases whilst still without the organism, and the primary function of the Circulatory System, that of conveying the nutritive fluid from the elaborating organ to the tissues for which it is destined, is immediately called into play.

In each succeeding class of Invertebrates, the lower, less developed, forms exhibit numerous instances of the absence of any vascular system but as my object now is merely to mark a few points in the progressive development of that system, I shall only refer to each of these classes in so far as they are illustrative of that point.

I have spoken above of the primary function of the vascular system as that of conveying the prepared nutritive material to the tissues to be nourished but there are two other points which require to be mentioned here.

First. The Tissues which receive nourishment are constantly throwing off effete matter in return, & a function, scarcely if at all secondary to the above mentioned is that of affording a channel by which these effete substances may be conveyed to some organ or organs, provided

for their elimination.

Secondo. In many animals the food is not sufficiently elaborated for the use of the tissues, previous to absorption from the intestinal canal, & consequently requires some further preparation before it can be applied to nutrition, this then is effected by its being passed during its course in the circulation, through certain other organs commonly called blood-glands.

Hence, the Vascular system may contain

- 1.^o imperfectly developed nutritive material, as derived from the intestinal canal (chyle)
- 2.^o material ready for use in the growth of tissues or chyle which has been passed through the final elaborating organs.
- 3.^o Effete matters passing onwards to the excretory organs.

It is the mixture of these materials to which the common term "Blood" is applied.

We must not however forget that the effete matters themselves are to be looked upon as nutrient in relation to the excretory organs by which they are eliminated, as also expressed in the laws of Trevisanuzzi that each part of the body

in respect of its nutrition, stands to the whole body in the relation of an excreted substance.

Only there is this important difference between excretory and other organs, that the former only continue to exist as a consequence of the presence of that which forms their ^mnutrients whilst tissues generally, exist for other purposes than that of using up particular materials and consequently the absence of the nutritive matter proper for the latter is directly injurious to the normal activity of the animal body.

It is necessary then (in order that the chyle may be duly elaborated, the effete matters brought to the excretory organs, and the tissues generally obtain their due nourishment) not only that a channel should exist but that means should also be provided by which the blood may be kept in continual motion from one part to another. The nature of the channels and means of locomotion vary, not in their essential nature, but in their degree of development as we ascend the animal series.

It will I think be at once conceded that it is quite unnecessary from a physiological

point of view, to consider that the circulatory system must invariably present a continuous closed canal, for as we find the tissues in the lower ~~animals~~ Radiata exhibiting their nutriment by direct contact with the chyle so we may suppose that they can do so in other creatures which are nevertheless provided with disconnected tubes to bring the fluid to the part & remove it again; How far this is really the case is still a matter of dispute amongst Histologists, the appearance of the vascular system in many worms, arthropoda and particularly insects, is that of one or two principal vessels opening into cavities in the substance of the bodies of these animals, from which other vessels again pass off to other cavities or to meet the principal vessel. Many histologists however affirm that these lacunae (sinuses) are all of them lined with a continuation of the inner layer of the larger vessels so as to keep up the continuity of the whole system. It is a question only to be decided by observation because, as mentioned above, the former hypothesis is quite admissible, as physiological

considerations do not interfere with the mechanical.

The principal vessels, possess the power of emptying with the second indication by means of the contractile, muscular structure developed in their walls externally to the lining membrane, but here again the series affords examples of great variety of modifications.

It would lead me too far were I to attempt to trace minutely the gradual development of the several portions of the circulatory system upwards to man, but a consideration of a few of the lower forms exhibits how the agent of motion at first very indistinctly separated from a separate portion of the ~~vascular~~ vascular tube, is gradually more and more developed in one or several parts which then take on special functions. To take first the Schizodermata (in which however we must beware of confounding with the proper vascular system another set of tubes communicating with the external medium and very latterly distinctly differentiated as the Water vascular system - this series of vessels appears to afford a free communication ~~with~~ between the tissues and the

aerating medium & perhaps corresponds in some ~~de~~ degree to the ramifying air tubes of the insects.)

We find then in the astereis a contractile organ situated in the central portion of the animal and connecting two rings which surround the digestive canal. The structure of this part and especially of the vascular ramifications has not been fully investigated; on the other hand in the Holothurida, whilst the vessels which ramify on the digestive canal, are very distinctly traced as also those which ramify generally through the bodies of these animals, a distinct central organ is not very well made out.

From the higher worms we gain an illustration of further advancement; for in many of these we find a dorsal & ventral central vessel connected by transverse anastomoses; it is generally the dorsal vessel and sometimes one or more of the connecting lateral tubes which are enlarged and apparently so developed as to act more particularly as the propelling agent or agents, it is only in a few specimens however that the presence of valvular arrangements indicates more distinctly the functional

peculiarities of these parts and even here it would appear that when the organs of respiration are well developed the action of the contractile organ is ~~started~~ primarily exerted sometimes upon the branchial, sometimes upon the general Circulation.

The existence, in numerous specimens amongst the Arthropoda, of a more defined form or even of muscular structure in particular portions of the vascular Canals indicates more distinctly in such specimens the special functional character of those parts; even in this class the arrangement of the central organ is very variable, in some it is a short and dilated cavity, in others a more elongated structure apparently representing a great part of the central vessel, which is situated beneath the dorsal integuments. The other portions of the vascular system are more or less perfectly developed, but in some groups the greater portion of the circulation appears to be performed through non-differentiated cavities throughout the body of the animal.

Although the Class of Mollusca would furnish specimens of all grades of vascular development, as ^{gradual} ~~complete~~ almost, as may be selected from the series generally, yet we advance in the higher forms to a

grade of development completeness beyond that last indicated so that the higher molluscs exhibit a very distinctly separated central organ which in some cases consists of two portions and ~~consists~~ has often a well marked muscular structure & an investing membrane. Finally in the class of the Vertebrata with a small exception the existence of a central distinct organ is complete and universal. Hence it is ~~sovereign~~ seen that whilst the vascular system, as a whole, has two great functions to perform; viz; to secure intercommunication & to provide the agents for transmission; it is only by a gradual development, that, portions of the system, more and more distinguished from each other, are set apart for the special performance of one or other duty.

It is necessary, then, in sketching the mechanism of the circulation to consider 1° the Heart or the central motor organ 2° the influence of the transmitting structures arteries capillaries & veins; and 3° certain external forces which, though not essential to, exert more or less influence upon the circulation.

I discuss at once anatomical description &

proceed to consider the functional action of the Heart.

As the heart has a double circulation to maintain the organ is provided with two muscular cavities for that purpose, the right and left ventricles each of which is supplemented by a secondary cavity the auricle. The valves of these cavities prevent more or less completely the passage of Blood in the wrong direction. The propelling force originates in the muscular fibres, which from their peculiar arrangement admit of concentric contractions by which the diminution or obliteration of the Cavities is effected, whilst the relaxation of the muscles passively allows of re-dilatation by the rushing Blood.

The Ventricle is the real pump and is therefore provided with thick muscular walls the degree of development being proportional to the obstruction which has to be overcome. This cavity on receiving a supply of Blood through the auriculoventricular opening contracts upon it and the Blood, being immixed behind the valves which in the mean time have lain against the walls of the cavity, presses them forwards so that they meet across the orifice

which communication with the auricle and thus re-
 sorption is prevented; but as there is no equal
 interpressure exerted from the side of the latter
 cavity these valves would be everted were it not
 for the tendinous attachments which connect
 their margins and part of their ventricular surface
 to the walls of the ventricles. During the contractions
 of the ventricles it is necessary that these at-
 tachments should be shortened as the surfaces
 approximate, which is effected by muscular
 development (musculi papillares) which, being
 associated in action with & extending into the
 general muscular arrangements of the walls,
 keep up a due proportion of tension; By this
 means the only exit left for the compressed
 fluid is by the arterial orifice and thus the
 whole of the blood is expelled from the ventricular
 cavity. As the walls now relax the obstruction
 to the opening of the auriculo-ventricular valves
 is removed, and the return of the blood from
 the arteries would also be allowed but for the
 existence of the semilunar valves, which
 which whilst forced inward and across the orifice
 by the same process as occurs with the other

valves, are restrained in their action not by tendons or muscular attachments as above described, but by their baglike form which causes their margins to meet centrally and afford mutual support.

one microscopist believes that he has detected muscular fibres in all these valves, which serve, in the former class, to prepare them for shutting and in the latter to initiate opening. I can well conceive the action of the former class, which, by separating the valves from contact with the walls of the ventricular cavity, ^{would} admit of the passage of blood behind them, but it is the same action which one would think most required in the semilunar valves also, and not any additional power to aid in their ~~opening~~ reopening.

Any material check to the venous return during the contraction of the ventricle is obviated by the action of the auricles which during that period gradually become distended with blood, when the ventricle relaxes - the auricles remain for a time in a state of distention whilst the superfluous blood passes onwards into the ventricle; the auricle then contracts and, by the addition of its contents to that which has already flowed on, the ventricle is refilled &

the series of Phenomena recommence. The function of the auricle is certainly a purely secondary one and I think that portion of the heart might with great propriety be considered morphologically a development of the venous system.

Its presence admits of the onward flow of the venous blood with much less interruption than could otherwise take place as it prevents any check during ventricular contraction, and only acts partially in opposition to the flow when itself contracting to fill the ventricle and the occurrence of an interval during which the ventricle and auricle are both passive diminishes still more the circulation.

Further with respect to the twofold structure of the organ - the two sides act synchronously, the ventricles contracting together and the auricles the same - It is I think generally held that whilst the auricles are not completely emptied by each contraction the ventricular cavities are so; It follows therefore of necessity that the two ventricles must be capable of holding an equal amount of blood otherwise we should gradually get an accumulation in one or other of the Circulatory Systems.

A single series of Phenomena is called a Rhythm
 the time of a Rhythm may be conveniently divided
 into sixths - it has then been found that the
 ventricular Systole and diastole are of equal
 duration, each occupying $\frac{3}{6}$ the that the auri-
 cular Contractions occupy only $\frac{2}{6}$ the and that
 they do not follow immediately on the ~~diastole~~
 Systole but commence after a pause = $\frac{1}{6}$ the &
 continue until the commencement of the next
 Systole.

Were the vessels a set of rigid tubes we should
 of course perceive as a result of the heart's action
 an intermittent propulsion of the blood "en masse"
 by a distance proportionate, in any vessel, to
 the capacity of the vessel under observation & to
 the amount thrown out of the ventricle
 into the aorta. Such however is not the case for
 microscopic observation shows that the capil-
 lary circulation is carried on in a continuous stream
 whilst it does not require such refined aid
 to observe that that of the venous system is
 of the same character. It is upon the structure
 of the ~~venous~~ arterial walls that the change
 in the character of the motion depends

On the contraction of the ventricle a certain amount of blood is forced into the aorta, this increases the pressure in that part and as the force is exerted through the fluid in all directions the arterial walls bear a large proportion of this pressure, under a due amount of which their elastic walls yield and are distended, but their elastic recoil continues to react upon the column of blood which then stands under greater pressure in the arterial tubes than in the veins. The tendency of nature is to equalize this pressure by forcing the blood onwards through the capillaries until the veins become so distended as to balance by their elasticity the tension of the arterial coats; and were this effected the circulation would cease were it not for a new accession of force from another ventricular contraction. If the arteries and veins were directly connected or by large tubes which would offer little resistance to the onward passage of the blood the pressure would be very rapidly equalized but the small arterial subdivisions & the capillaries so retard the motion of the fluid through them that the passage of the blood onwards can only be very gradually effected.

It is evident that the arterial tubes must be in a state of permanent tension apart from the additional strain which they suffer at each systole for, were it not so the capillary circulation would undergo a retardation so different from that which would result from the independent action of the heart inasmuch as the current would be most rapid immediately after the arteries were fully distended and the auricle full and would almost cease when the arteries, having fully equalized the pressure, were waiting pass for, ~~over~~ or undergoing, redistribution by the systole, moreover such a state of things would not admit of any variations in the rapidity of the cardiac rhythm without serious changes in the state of the general circulation; on the other hand the overdistention which permanently exists supplies a compensatory force for any slight variations which occur. That such a state of matters does exist is shown very plainly by the Hæmodynamometer of Poiseuille by which it has been satisfactorily ascertained that the pressure to which a column of Hæm is exposed is equal to about 4 to 6 oz. to each square inch of surface and that this varies to a very slight extent

as the distance from the heart diminishes, only in so far as is due to friction and like disturbing causes; from this standard he has calculated the amount of absolute pressure on the column of blood in different arteries of the body such as the radial in which he found it equal to 4 lbs. from these calculations it has been erroneously argued that, by the time the vis a tergo which originates in the cardiac contraction, has reached the capillary circulation it will be almost entirely expended; but this is quite fallacious for the pressure remains there as in other parts equal to the same amount per square inch as in the larger arteries. On the other hand it has been thought necessary, with equally little accuracy to calculate that the heart itself contracts with a force of enormous magnitude whereas its real force is only such as to equal a pressure above mentioned of about 4 lbs. 4 oz. per square inch.

It is observed that the pulse, which is the indication of the distension of the arteries longitudinally & transversely by the increased amount of blood forced into them, does not become apparent in all parts of the body at the same time; it has

hence been deduced that the phenomena are
 of the following nature - Each impulse of the
 heart is first given to the column of blood
 in the aorta by which it is transmitted to the
 arterial walls of that part and distends them;
 these react upon the distending force & compress
 the adjoining part of the column, from which
 the impulse passes to the next and next, be-
 coming less perceptible as the force of the heart
 is equalized by the elastic resilience of the
 vessels. There are however not exactly the
 facts for ~~it~~ it implies that the blood passes
 onwards in stages and that the whole force of
 the heart is expended where the pulsations cease
 which would under the phenomena of the cir-
 culation very different from what we find them.

It is true that the pulse is not absolutely
 synchronous in all parts of the body but it
 must not be explained by supposing the
 recoil and recontraction of the arteries in the
 first portion to be the originators of the like
 phenomena in the succeeding ones, but by
 the onward passage of the wave produced by the
 injection of the column of blood into the vessels &

which passes onwards in each part of the arterial system as that part becomes distended.

Numerous objections are urged against the opinion that the heart is the sole motor force in the circulation of the blood, either on the ground that such force, (admittedly only $4\frac{1}{2}$ to 43 lbs. square inch) is not sufficient to overcome the force of inertia and of friction through such an extent of circulation; ~~and~~ or on the ground that other forces are shown to act materially and must therefore be recognised. The former objection was founded on such a consideration as the following, that whilst an artery cut across in the living body allowed of a jet of blood being projected several ^{feet}, an artificial injection made to supply the force of the heart would not do more than send the water trickling slowly from the orifice - the explanation of this is however simply that so long as the arterial tubes are not distended as in the healthy state, the force of the injection is partly expended on the walls themselves.

It was probably on account of this supposed insufficiency of the cardiac action that the first experiments were made to find some supplementary agent - amongst such was one (the belief in which I believe now to be entirely exploded), which supposed

that the force of attraction and cohesion which exists between substances in contact, was suspended during life, between the vessels and their contents; such an assumption was altogether devoid of direct proof and could only be brought forward as a possible explanation of what was a supposed fact.

A still more common assumption has been the existence of regular contractions in the arteries themselves similar to the contractions which take place in the heart - there have been supposed to aid the circulation by supplementing the heart's action with an additional power, and two facts appeared to confirm this view - one is the existence in some animals particularly Batrachians of a form of heart the rhythmic contractions of which begin quite distinctly in the veins and passing onwards through the auricles and ventricles, extend into and along the aorta; the other fact is the existence of muscular fibres in the arteries; but it may be objected that these rhythmic contractions are not seen; and, did they exist, their effect would be to increase rather than diminish the intermittent character of the circulation, and moreover were the muscular structure developed for this purpose and not as I ~~believe~~ believe it

must be, for regulating the supply of Blood in any particular part by affecting the diameter of the vessels, we should find the development of the fibres proportional to the size of the artery and amount of Blood to be propelled and not as is the case, much more developed in the smaller than in the larger vessels. the explanation offered of this increase of muscular structure in the smaller vessels, was that in them the blood was less under the influence of the cardiac impulse who had become in great part expended before reaching that part of the system but we have already seen that this force is not to any great extent used up until it becomes influenced by the force of friction and attraction in the minute vessels, whilst the actual pressure of the blood is not increased as indicated by the Hæmodynamometer; hence it is evident that this explanation is incorrect.

Capillary attraction even has been asserted as a source of the Circulation of the Blood - on the other hand this has also been brought forward as one of the great hindrances to the Circulation and of the two views the latter is the nearer to accuracy although in fact where the capillary attraction has only to be overcome so

far as to effect a displacement of one portion of fluid by anything of the same character the force to be overcome is ~~not~~ simply that of friction, quite different from, and greatly less than would be exerted were it attempted to eject the fluid from a capillary vessel by means of any medium having less affinity for the walls of the tubes.

The great secondary agent however in the circulation which has been just pointed out repeatedly is the attraction of the tissues w^h are nourished, either by simple attraction, change in the ^{electric tension} ~~electro-tonic~~, chemical constitution, or Endosmosis. and in support of this doctrine numerous vital phenomena are referred to of which the principal are - The contraction of arteries after death; The circulation in acardiac fetuses; The circulation in the vegetable; and vital Turgescence - and first as to the nature of this attraction, secondly the phenomena on which the opinion is founded.

Firstly. Some writers considering that the Capillaries play an important part in the nutrition of the tissues, ascribe to them the same action upon the circulation as is ascribed by others to the tissues themselves; Considering that the Capillaries can be looked upon as passive agents in nutrition, allowing of the approximation to the tissues of their contents, but not in any way aiding the tissues in the selection

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of nutrient materials, it will be sufficient of to treat now the above views as relating to the tissues themselves.

Simple attraction exercised by the ~~blood~~ tissues on the circulating fluid might at first sight appear an important element in the onward progress of that fluid; but when we consider that this attracting force acts laterally to the course of the circulation upon a mass of fluid extending in each direction past this ~~attracting~~ force, it will be seen that, granting a portion to be drawn towards the tissues it will produce a more or less perfect vacuum acting equally upon the column of blood beyond and behind the attracting agent. i.e. tending to draw indeed some fluid onwards from the arteries, but tending also equally to draw some fluid backwards from the venous radicles. Such an influence could hardly aid in any way the circulation or at any rate, if it did to some extent assist the arterial flow, its action would be worse than nil upon the venous return.

On the detection of the fallacy of this view a modification was advanced to the effect that some changes were effected by the tissues on the specific tension of the blood during its conversion from arterial to venous character - this can only be looked upon as a suggestion founded I believe only upon

the general fact that salivariation has some influence upon the motion of fluids - of a similar nature is a still more recent view that the affinity of the tissue for the blood (en masse) is greatest when it is highly oxygenated and first entering the arterial capillaries, that having entered, changes occur by which this affinity is lessened, the blood becomes venous, and this portion of the fluid is pushed onward by a fresh supply of oxygenated blood which has come within the sphere of attraction.

Such hypothetical explanations can hardly be considered of great weight so long as it is found possible to explain the phenomena of the circulation by more simple means.

As to osmosis I need only say that the conditions for the phenomena do not exist unless we consider that the minute bore of capillary vessels is equivalent to the inappreciable pores of the animal membranes in which the phenomena of osmosis are usually observed.

It is not necessary, in denying an hypothesis, to offer an explanation of the phenomena which are supposed to maintain the views combated; but the phenomena above referred to may perhaps be explained without expressly acknowledging any active force in the circulation apart from the cardiac

action. With regard to the great muscular apparatus of arteries, this is merely an effect of their natural elasticity, by which they contract upon the contained fluid in the absence of that force which constantly in the living body sustains them; for I have mentioned in an early part of this paper that the arterial coats are in a state of permanent distention, & acting constantly by their resilience a pressure in the blood which is so great as to undergo but little appreciable change in the ordinary phenomena of the circulation.

No deduction can be made from the existence of a cardiac pulsus until it has been ascertained satisfactorily that they may exist without vascular connection with a normally developed fetus - in the mean time I am not aware of any recorded case in which ~~a~~ such an independent state of existence has been demonstrated.

The phenomena of the flow of sap in vegetables & of vital fermentation are of more weight than the preceding. Of the former of these it is said that the arteries are proved to play an important active part in the circulation, because in the vegetable the sap flows onwards without the assistance of a heart to propel it. I venture to believe that the phenomenon in the vegetable

osmosis is altogether different from that which I am
 now considering - for if we keep in mind the mode
 in which the passage of the sap is really effected we shall
 find that probably here the force of osmosis plays an im-
 portant part although erroneously ascribed to the
 process in the animal. The effects of evaporation on
 the upper parts of the plant tend to favour the change of
 Endosmosis from these portions which being unexposed
 are less exposed to evaporation and at the same time con-
 stantly absorbing from the ground large quantities of
 moisture, this action taking place from cell to
 cell and from tube to tube, and increased when
 the leaves are developed the exhalation from their sur-
 face tends to induce a greatly increased movement of
 sap upwards - but even here a great amount of
 force is evidently propulsive depending probably upon
 the rapid absorption of water by the roots of the plant
 which then strive to displace the more dense fluids
 above - as is proved by experiments which were
~~also~~ instituted to determine the force of osmosis
 of sap; in which a flexible bag connected with a
 tube of mercury was attached over the cut surfaces
~~of various kinds of stems~~ of stems when the sap ^{was} pressed out
 upon the cut surfaces with such power as to raise the
 column of mercury in the tube to a surprising extent

on some instances to a height of forty inches -

Total transference is after all the stumbling block which appears to many & necessitates the acknowledgment of some special attraction exercised upon the blood by the Capillaries, by means of which the amount furnished to any particular part may be ^{pro}portioned to the requirements of the part for the time being -

It cannot but be an erroneous assumption that this vital action resides in the Capillaries, for the reason they are merely passive as regards nutrition, I can understand that such an action might be ascribed to the Arteries which when stimulated to increased growth and nutrition would attract to themselves an increased amount of nutrient fluid, but the effect of such attraction as before mentioned, would not aid materially in the Circulation; on the other hand I think that the phenomenon under consideration can only be ascribed to changes in the diameter of the vessels which aid, by their dilatation both the amount, and by lessening the friction, the capacity also, of the blood in those parts, and these changes depend as is not denied, by on the influence of the sympathetic fibres upon the walls of the vessels excited either by the peripheral stimuli or

or ~~central~~ centric influences - It may be objected that dilatation of vessels would hardly, from analogy, be expected from increased stimulus & consequent activity - that such occurs as the result of mental emotions ^{when} influencing the circulation, is I believe generally admitted; if it is thought, on the other hand, that contraction would follow stimuli from local irritation or sympathy it is still doubtful whether that would not also, by increasing the tonicity, render the flow of blood more easy and rapid; as it has been found that fluids pass much more readily through a rigid tube of small size than through a larger one ~~more~~ more flaccid - but in fact we know so little of the effects of vasomotorious influence upon the vessels that either view may be maintained with equal plausibility.

There is another mode in which the circulation is supposed by some to be in part carried on viz: by the act of dilatation of the ventricle - it was at one time even supposed that the ventricle possessed an active power of dilatation by which a vacuum force was exerted on the venous return; this theory is I think now totally abandoned but a modified view is held by some to the effect

~~the effect~~ that as muscular fibres when inactive do not remain in a state of contraction but become again elongated, so in the heart when the contraction of the ventricle is completed the fibres relax and in becoming elongated exert some force by which the ventricular cavity is opened out - I cannot

conceive however that the force, if existing, is anything more than sufficient to reduce to a minimum the resistance offered to the ~~ventricular~~ reentrance of Blood into the cavity, so that none of the force of the circulation is exerted needlessly in making a way for the fluid.

Two agents, external to the Circulatory ^{System}, are brought forwards as important & constant aids to the Circulation - Muscular action & Respiratory movements. - Of the former it appears to me that very erroneous views have been prevalent; it is usually stated that when a muscle contracts it presses on the veins and that these having valves which prevent the retrograde movement of the blood it is necessarily forced onwards - this is granted but what follows is that whilst this portion is forced onwards a hindrance is offered to any fresh supply of Blood entering, proportioned exactly to the force employed in expelling the first portion - this latter part is usually

overlooked whereas if the duration of contraction rigidity be greater than the process of contraction, by so much is the amount of blood pressed onward by those particular veins diminished - on the other hand it is argued that the flow of blood must be accelerated because we find it flow faster through the other capillaries & through those veins of the part which are not under the influence of muscular contractions. But this is only due to the obstruction to a part of the channel for venous return and in fact proves that muscular contraction is obstructive rather than otherwise - for since the amount of blood brought by the arteries (to an arm for example) remains the same; whilst $\frac{1}{3}$, $\frac{1}{2}$ or even $\frac{2}{3}$ of the venous return is obstructed it follows of necessity that the return through the remaining pass must take place much more rapidly.

Finally the respiratory movements are thought to aid the circulation by some, and truly, inspiration, by tending to create a vacuum in the chest must enable atmospheric air to play an important assisting part in forcing the venous return onward to the heart whilst the greater rigidity and thickness of the arterial coats prevents the counterbalance which would otherwise be exerted on that portion

of the circulation. But when an expiration is effected this is all ^{reversed} ~~reversed~~ we have a re-expansion as far as possible, and at any rate a check, in the veins and consequently a hindrance equal to the previous assistance; so that, with the whole, there forms a series of intervals balance each other. The central pulsation is a sufficient indication of the mode in which Respiration as a whole influences the circulation.

So that it would appear, that, whilst the heart is the primary originator of the force which maintains the circulation of the blood, this force acts almost entirely through the resilient coats of the arteries, & thus the circulation is liable to some modification, hindering as well as, accelerating, by several occasional causes such as, change in the nutrition, muscular action & Respiration.
