A brief view of the immediate causes of the Circulation of the Blood.

James George Sutherland Grant

June 1855, 1859
A brief view of the immediate cause of the Circulation of the Blood.

The object of this paper is an endeavour to, so far as the present state of our knowledge will admit, to account, though briefly, for the circulation of the blood.

A condition so essential to the more complex organisms in particular, that coincident with its destruction, the manifestations of life, cease to exist. With this view, there is also an effort to advance such facts, as bear more directly upon an explanation of the movements observable in human blood; though, from the nature of such investigations, the analogies are derived chiefly from experiments made on the lower animals.

In treating a subject like the present, the most comprehensive and orderly plan to adopt, one that suggests itself naturally, we think, is to follow the course of the blood, beginning them with its presence in the
heart, we shall dwell on its passage through and from that organ, into the arteries, through the capillaries, and its returning flow by the veins.

The heart, consisting of its four muscular cavities, and a beautiful adaptation of valves, has been likened to a forcing pump, which during activity is alternately filling at one part and emptying at another. It may be deemed out of place here, to enter on more anatomical detail, though, if only to preserve continuity in our progression, it is necessary that something however brief, should be said on its mode of operation, and the action of its valves: which latter, in common with all the valves of the vascular system, may be regarded as passive agents in the propulsion of the blood, determining by their mode of arrangement, the direction this great cycle of liquid habulm, is observed to have, in the larger vessels more especially. The systemic venous blood, that enters the right auricle during its
diastole, is forced by its systole into the right ventricle, the regurgitation into the veins, during this auricular contraction, being in great part prevented by the valves with which they are supplied: the right ventricle thus distended, contracts and so immediately after the auricle, that the one contraction seems a continuation of the other; simultaneously with this systole of the ventricle, is the contraction of its fleshy columns, which thus draw the auriculo-ventricular valves, away from the internal surface of the ventricle; the blood now passing behind these valves, and pressed by the contracting chamber, pushes the flaps together, so as to close the auriculo-ventricular orifice — the blood, still pressed by the contracting ventricle is thrust into the pulmonary artery, pressing freely, past the semilunar valves, which are, however, suddenly, and effectually closed, the instant that the visceral or ventricular systole, has ceased to operate;
Since in the backward tendency of the fluid, these cup-shaped valves are filled, their free edges brought into close opposition, and all reflex into the non-dilating ventricle, completely arrested. It is almost unnecessary to add, that the blood having traversed the lungs, and there been subjected to certain changes, is again in the left cavities of the heart, subjected to a mode of propulsion identical in principle, with the one we have so hurriedly noticed; thence, as it whirled on its systemic course, in a marvelously short interval, calculated from the results of numerous experiments, to be something short of a minute. Tracing then the course of the blood we observe that it is expelled from the left ventricle into the aorta and its branches, with a force, estimated by Valentin, equal to one fiftieth of the weight of the whole body; according to this, the left ventricle of a man weighing eleven stone, would exert a propulsive force of three pounds, and
The Physiology of Man: by R. B. Todd, M.D., and W. Bowman, F.R.S., to London.
the right ventricle a half of this, since it is believed to possess about one half the power. From the experiments of Dr. Sharpey, on a dog recently killed, it would appear that a pressure of two pounds sufficed to accomplish both the abdominal circulations and of one pound, that of the pulmonary. Now unless we believe that there are greater obstructions to the passage of the blood through the vascular system during life than exist after death, we are forced to conclude, that the propulsion power of the heart, which in man, probably does not exceed five pounds, is sufficiently competent to drive the blood through the three sets of blood tubes, and to maintain the current of the circulation, and that this force alone is capable of producing all the grand phenomena of circulation*. Hence then, the heart in man, and in all animals that possess one, may, we have reason to believe
be regarded as the chief, though not the sole source of the power by which both the systemic and pulmonary circulations are sustained. This statement receives further support from the well known facts, that the circulation in most animals ceases after removal of the heart, and that on applying a ligature or other pressure to the main artery of a part, the circulation beyond the point of obstruction is instantly arrested. Other evidence, leading to the same conclusion will appear, in considering the remaining divisions of this subject. Nevertheless, there is reason to believe that the heart force is not the only power, by which the circulation is maintained, and we are induced to seek for the presence of other agents, in order to explain the "residual phenomena", which seem to indicate the existence of forces peculiar to the vessels, and tissues that surround them, exerting a general, and local influence on the circulation.
*Principles of Human Physiology* by Dr. W. B. Carpenter, London
That there are indications of an influence which the tissues seem to exert over the circulating current there can be little doubt, appearing to arise from those changes that constitute the processes of nutrition, secretion, growth, and the like. Such for instance would appear to be the interpretation of the fact, that whilst any variations in the heart's action affect the whole system alike, there are many variations in the circulation, which being very localized, cannot be attributed to such central disturbances,* and must therefore be dependent on causes more limited in their influence; to determine their nature, so far as our powers carry, the phenomena of the circulation in each system of blood tubes, must be analyzed, but before entering fully on a consideration of the blood's passage through the arterial system, we cannot refrain from expressing our regret, that an expression founded on inaccurate observation and false theory should still be found current, in
the physiology of advancing Medicine to the heart, in common with the larger arteries, was ascribed (as we understand the expression) the faculty of pumping more blood to one part than another; not that they did so always, but when certain conditions favoured the operation—thinks about, what were (not the power to observe still continue to be) termed “determination of blood”. With a clear view of the heart as a central organ of propulsion, connected with a series of continuous tubes, freely communicating, it is difficult to conceive, how any mind ever entertained the idea, that this beautiful, but simple pump, should be invested with a faculty (litle short of intelligence) to direct, which in this sense means to determine, more blood to one point of the system, than to another—we have no more reason for ascribing to the heart any such power, than we should have in attributing an artificial power so remarkable a property.

But to resume—during the contraction
of the left ventricle, the force of which we have else where noticed, a certain quantity of blood is pumped into the aorta and its branches, which are already full—how it follows, that if these vessels were a series of non elastic tubes, the force of the heart would, according to the laws of the propagation of pressure through fluids, be transmitted without loss, through the whole column of blood in the arteries, at one and the same moment, and as a result of this condition, the blood would be subject to great varieties in velocity, rushing with ferocious impetuosity during the ventricular systole, but relaxing during each diastolic interval, into a state of repose—in short, an intermitted current would ensue—but we know that such is not really the case, since, in consequence of the eminently elastic, and extensive character of the arterial walls (due in chief to their middle coats) space is
obtained for each fresh injection of blood, which exceeds the quantity, that is simultaneously expelled, from the opposite extremity of the vascular system. In thus yielding to the force of the heart, at each successive impulse, the arteriole so dilated, are now, by virtue of their elasticity, in a position that enables them to call into play, a power, which, in great measure, reverses as it were, the force spent on them by the heart. The instant that the ventricular systole has ceased, and the diastole begins, the arterial walls recoil or contract upon their contained blood, propelling it on, from the heart, at back, or to the heart, but the blood's course in this latter direction is promptly checked, by the instant and "forcible closure of the aortic valves, under the steady pressure of the regurgitating current"—Necessarily, the mass of the blood is forced onwards to the capillary system; actuated firstly
by the heart's impulse, and secondly by the elastic reaction of the arterial parietes. It is evident, that the recoil of the arteries, is synchronous with the ventricular dilatation, and thus by preserving an equal pressure on the column of blood, exercises an equalizing influence over the circulation; causing the blood to flow in an even stream, as well during the diastole as the systole of the heart; converting in great part, its jerking impulses, by this contracting into a steady expansive force, of a more continuous and uniform character—The ordinary fire-engine supplies a familiar illustration of this principle; i.e. the reacting property of an elastic body used as an agent to convert a jerking impulse, into one of a more steady operation. It can no longer be doubted, that the smaller arteries possess through the agency of the unstriped muscular fibre, in their middle tunics, an inherent power of contractility—the question arises does this power assist in the propulsion of the
blood? It could not do so, unless it possessed a kind of peristaltic action, commencing at their cardiac extremities, and thence passing rapidly along their distal terminations; or unless they had the property of alternately contracting and dilating coincidently with the diastole and systole of the Ventricles: but we have no ground for believing that the arteries ever act in either of these modes — nor can we, in supposing a simultaneous contraction of these muscular walls, attribute to such a mode of action any propulsive power, but rather on the contrary an obstructive one, for since the contractile fibres are chiefly found in the smaller arteries, the effect of such a contraction would be to diminish the calibre of their distal extremities, and thus, especially in the absence of all valvular apparatus, a direct obstruction to the centrifugal progress of the current, would be the result. Having thus briefly considered
the principle causes which affect, and modify, the flow of blood in the arteries we may next in order regard, the Circulation in the Capillaries — this is principally maintained by the Visceral force of the heart; since this force has been proved capable of propelling the blood through the whole system — however, the following facts further tend to set the matter at rest: 1st: The pressure of the blood may be measured in the veins, in the same way as in the arteries, and this varies with the force of the heart. 2nd: If then, the heart's force extends to the veins it must do so through the capillaries. 3rd: The Capillary and Venous circulation in any segment of the body, is greatly influenced by the circulation in the main artery of that segment — thus, Meyendorf found, the circulation much retarded in the femoral vein by stoppage of that in the corresponding artery: and
Food and Brown's Physiology of Man
by the hemodynamometer, it may be shown, that the force of the blood in the veins diminishes, or increases, with that in the corresponding artery; under certain circumstances.

In debilitated animals, it is evident, from the jerking movement of the blood, in the Capillaries, consequent with that action of the heart, that the impulse of the organ, is extended to these vessels, unbroken by the elastic reaction, or the muscular contractions of the arteries. This is well seen in the frogs' web; hence we infer, that the heart's force is not only quite equal to, but it is the chief agent in, supporting the Capillary circulation; but then, nevertheless, do remain, certain phenomena in the circulation through these delicate blood-vessels, referred to in an earlier part of this paper, which do not admit of a satisfactory explanation, on the supposition, that...
this vis a'lergo is the only force exerted in sustaining the circulation in the capillaries. Since there are indications of some hidden force, superadded to this of the heart, giving rise to phenomena, which are peculiar to, or dependent on, the circulation through these vessels. For example, in cold-blooded animals, the movements of the blood in the capillaries, has been frequently seen even after excision of the heart. In the early embryonic state of the highest animals, the motion of the blood, is independent of any central organ, and seems to be due to some diffused power. In the acardiac stales, this "capillary force" as Dr. Carpenter terms it (by which we understand him to imply, merely, that this force-attraction, or whatever else it may be, is exerted at the capillaries) supplies the place of heart up to the time of birth. In accumulations of blood arising
Dr. Todd and Bowman's "Physiology of Man"
from local irritation - inflammation - active growth, and the like.

These and similar phenomena, in the present state of our information, are best accounted for by those, who hold, that in the ordinary molecular changes which take place, in the nutrition of the tissues, a force is generated, which, in its normal state, must promote by an attractive influence, the flow of blood through the capillaries. The cessation of such a force would operate unfavorably to the flow of the blood through the capillary systems; whilst its existence in greater power, at one point, than another, would cause a greater efflux of blood in the former, than in the latter direction.*

Certainly, to our way of thinking, a far more reasonable mode of accounting for a certain class of congestions, mid-term "determinations of blood"; and supported by very fair analogies: thus, the
Arterial blood, is supposed to be attracted by the tissues, to which it is brought by the Capillary System: this force of attraction draws on the blood from the Arterial side of that System, with a power, which, at the same time, helps to propel the de-oxygenised blood into the Venous Nervules. It remains to be proved however, how far this explanation is correct, and applies; it is only by admitting the influence of such attractive force, that the complex Circulations of the Polypifer and Articulata are most reasonably explained. It appears then, that at the Capillaries, we are warranted in assuming, there is exerted an attractive, and distributive power, over the blood "regulating the local circulation, independently of the central organ, in obedience to the necessities of each part." We are now better able to enter on an examination of the Causes, that carry forward the Circulation in the Veins.
The fact, that the blood moves through these vessels in a continuous stream, is evident to all who have examined the venous radicles under a microscope; or have had the opportunity of watching its flow after resection. That the force of the heart is quite competent to sustain the venous circulation, has been, we think, sufficiently established by those facts already cited, in ascribing to it a power over the capillary circulation. Though since the capacity of the venous system is less than that of the entire capillary system, the velocity of the blood, in the former, will be greater (and is found to be so) than that in the latter. There are besides the forces above alluded to, as maintaining in common, the arterial, capillary and venous circulations, some concurrent causes, which, by many
are believed to exert much influence over the venous circulation in particular. These are—(1.) The suction power of the auricles, acting it is supposed during their dilatation, by drawing the blood towards them; now though auricles and ventricles do dilate spontaneously, there is little ground, if any, for the belief that they thus exercise a sucking pump action. What appears more consistent with truth, is, that they in so dilating at most, offer no resistance to the influx of the fluid; in this way, saving the force, which would else be necessary to distend them. (2.) There can be no doubt that respiration exercises some influence over the circulation; the "respiratory pulse," described by Haller, is evidently due to this cause. The effects are most obvious,
during forced respiratory efforts. For example, a deep inspiration increases the cavity of the chest—a vacuum would result were it not obliterated by the simultaneous rush of air and blood, into the lungs or thoracic cavity, effected by the atmospheric pressure from without. The blood thus injected is chiefly venous, since the capacity of the veins, and the surfaces of the venous tree, is greater than that of the aorta and its branches. Besides, it is reasonable to infer, that the outward flow, or in other words the centrifugal current of the arterial stream, would require to have its momentum neutralized, so any part of the fluid could be sucked into the cavity of the chest, whence it has already taken its departure. It is probable, that on the other hand, forced expiratory efforts, tend to promote the arterial flow, and con-
Versely retard the venous return; but this retarding influence of inspiration, is apparently of little moment to the venous afflux; since the values with which the veins are supplied, prevent any extensive regurgitation: thus, leaving as it would appear, a slight balance in favour of the systemic circulation; the pulmonary circulation, having been ascertained, by observation, to be little affected, either one way, or the other, by the movements of the thoracic walls: nor indeed, to the ordinary movements of natural respiration, render more than a very slight aid to the circulating mass.

We pass on to the consideration of such effects as are brought about, by the pressure of muscular action, in the circulation, more especially of the veins — It is we believe, generally held, that muscular pressure aids the circulation of the blood in veins supplied with valves, by squeezing
The blood on to the heart, with greater rapidity, than it would otherwise reach that organ, in the absence of such pressure; since, the fluid so urged, is unable by the valvular arrangement, to move in the opposite direction. Now, without denying the fact, that during the short interval, included between the first moment at which the vein is subjected to pressure, and that instant, when the full effect of the pressure is consummated, there undoubtedly would result, an acceleration in the stream, from a divided vessel. Nevertheless, we would urge, with all respect, that this phenomenon does not warrant us in concluding, that the ultimate velocity of the blood is accelerated, under similar conditions of pressure, when the blood tubes are entire, and their continuity unbroken. It was shown by Müller, that the velocity of the blood, in the uninjured blood-tubes, cannot be
estimated by the rapidity of its flow from a divided vessel - the conditions are different - in the unopened vessel no part of the blood can advance with greater rapidity, without affecting the velocity of the entire mass whereas, in the divided vessel, the velocity of the stream results from the pressure sustained by the entire vascular system, which meets with resistance everywhere, save at the point of incision from which it has free exit. We are therefore at a loss to understand, how the effects observed, during the operation of venesection, should be taken as illustrations, in support of the belief, that muscular pressure aids, or accelerates the circulation of the blood, in closed tubes; the two conditions being incomparable. But to place it differently, let us consider the question of muscular pressure as exerted on undivided blood tubes: it is
evident, that if the pressure were continuing, it resolves itself into nothing more, nor less, than an absolute obstruction. Therefore this exclusion, we are justified in understanding, muscular pressure, alternating with relaxation; bearing on its mode of operation, an analogy to a little instrument called we believe "Higginson's Syringe" consisting of an elastic tube, fitted with a ball valve, and worked by the alternate pressure, relaxation, of the hand — the analogy appears to us, just sufficiently close to mislead by its specious plausibility. The fluid acted on by "Higginson's Syringe" is in a state of rest, and is simply impelled into a certain velocity, bearing a direct ratio, to the will and power of the operator. Nor does it act in the course of a series of shut-tubes (as muscular pressure does) propelling fluid, into no such cunning mechanism as the heart, with its complex valvular apparatus, so di-
posed us to admit just so much fluid, in a given time, and no more—It is far otherwise with muscular pressure exerted in the course of a vein, whose contained fluid is already in motion, and it remains to be proved, whether the muscles acting, however rapidly, could impart a velocity greater than that, which the blood may have already attained: Again, even admitting that this be effected, the blood so accelerated in its motion by the muscles of a part, is but a segment, if we may so express it, of an inseparable cycle; therefore, the whole circulation, is hastened: but the whole circulation must pass through the heart; Ergo, the heart's action is accelerated also. This mode of reasoning, has, it appears to us, lead to the error, of regarding in the light of a cause, what may more rationally be regarded as one of the several effects, attributable to a totally
“Hand-Book of Physiology.” By Dr. W. Kirkes.
Third Edition page 139.
different and common source — by a strange perversion of the ordinary sequence observed in such phenomena, it is asserted, that the “general acceleration of the circulation, during active exercise” may be referred to the effects of muscular pressure! A most remarkable statement — is it not more consistent with reason, and ascertained facts, to attribute the acceleration of the circulation in such cases, to the increased action of the heart, brought about sympathetically, when the functional activity of the nervous system, is called into play, or excelled; as it is, in all muscular exertion, and especially in such a condition as we understand by the phrase “active exercise”.

From the preceding remarks, it will be inferred, that we cannot see sufficient proof, in support of the belief, that muscular pressure, accelerates the
circulation; and the phenomena observed after the operation of venesection, simply show, that when the patient is made to grasp something firmly in his hand, the muscles set in action by so doing, exert a pressure on the deeper veins; and thus, force the blood from them, into those veins more superficially situated; now since it is a superficial vein, which is opened by the operation; it follows, that the blood will flow with increased energy from its wound, during the action of such pressure; and moreover, that if the patient be made to convert the steady muscular pressure, resulting from a grasp, into an in-terminating pressure, by alternately grasping and relaxing; it also follows, that the stream, which was formerly continuous, will now be intermitting; the steady flow, being converted into a succession of jets: but these facts, after what has been urged, cannot be said to carry with them any proof of the conviction, that the
absolute velocity of the blood, would be accelerated under similar conditions of pressure, in a system of unidivided tubes, in connection with such an apparatus as the living heart.

In conclusion it is right to add, that the influence of the nervous system, which governs alike, all the functions of the living organism, could not be regarded in the special sense of an immediate cause of the circulation; any more, than of any other process, in the body; and therefore, even its more immediate relations to the present subject, have not been considered, in this confessedly imperfect attempt, indeed it is perhaps some apology, for the imperfections of this paper, to explain, that we had completed two thirds of another, on the "Mercurial, and Non-Mercurial treatment of Tritis," which it was our original intention to send in, as a Thesis; hoping, as we then did, that there at least remained, a meet for
its completion; but a notice at the University gate, warned us that the time was passed: as a dernier resort, we were compelled to adopt the subject of a dissertation, read some years ago, before the Medical Society of this city; it is almost needless to observe, that this paper, is but slightly altered from the original; and can lay no claim, either to originality, or any other high order of merit. Such as it is, we submit it to the impartial critic, neither expecting praise, nor dreading just censure; confident in the belief, that neither will be awarded unjustly.

James, George, Garrard, Grant.

June 18th, 1859.