The causes of the Circulation.

Although this is a subject which has ever received great attention from Physiologists, and about which a great amount has been written, I hope I shall be pardoned for having chosen it as the subject of my dissertation, because I think that there are some points upon which sufficient stress is not laid, or which are classed by some Physiologists amongst the "Vital" phenomena, which is tantamount to a confession either of total ignorance, or very indefinite knowledge of these phenomena. My object therefore is to discuss briefly those ascertained and hypothetical forces, and the immediate agents which generate, modify, or adapt them, to the propulsive and ultimate distribution of the blood through the tissues; a condition so essential to the more complex organisms in particular, that almost coincident
dealt with its cessation, the manifestations of life cease.

If there is any one subject which more than another requires method and systematic progression from one point to another, I think it most decidedly is the one in question, for without it we can neither arrive at any definite conclusions nor make what we write intelligible to others.

Beginning then with the blood in the right auricle of the heart, we shall follow it on its passage through and from that organ into the arteries, thence through the capillaries and its return to the right side of the heart, by the veins. The heart, consisting of its four muscular cavities and a beautiful adaptation of valves, has not inaptly been likened to a forcing pump, but here we must not allow ourselves to be led into the idea, too apt to insinuate itself, and which has taken possession of the minds of many - viz. that the heart exercises any suction power.
its expansion is more muscular relaxation. 
"all organic action is contraction" therefore since con-
traction has the effect of expelling the blood it cer-
tainly cannot also have the effect of sucking the blood 
in by dilating the cavities of the heart. Some main-
tain strongly that the physiological action of respiration 
materially influences the circulation through the 
heart; but since inspiration is not synchronous with 
the diastole - nor expiration with the systole of the 
heart, I think the main force of this argument 
is destroyed, but we shall speak of these again 
at the same time, they are neither of these required 
to account for the phenomena of the circulation. 
The venous blood having filled the right cur-
auricle - during its state of relaxation or diastole - it is 
forced by the contraction of the auricle with the ventri-
cle - any great regurgitation into the veins - during 
the curricular contraction - being prevented by the
valves with which they are furnished. The ventricle thus distended contracts and so immediately after the auricle that the one contraction appears to be a continuation of the other; simultaneous with this systole of the ventricle is the contraction of the fleshy columns attached to the auriculo-ventricular valves—thus drawing them away from the walls of the ventricle; the blood now passing behind these valves, and pressed by the contracting chamber, bunches the flaps together, and thus occludes the auriculo-ventricular orifice—is thrust into the pulmonarv artery; the moment the systole has ceased the pressure exerted by the elastic walls of the artery tending to force it back as well as on toward the capillaries—by this means closes the semilunar valves—and so effectually prevents any regurgitation into the ventricle. And now the blood traverses the pulmonarv organs—but here a variety of
forces come into play in the attraction of the blood cells for oxygen - that of the tissues for the blood - and some chemical forces of which I am afraid we know very little, some of these we shall speak more at length of hereafter. It is almost unnecessary to add that in the left side of the heart, at which the blood arrives from the pulmonary organs - it is subjected to a mode of pro- pulsion identical in principle with that of the right side of the heart which we have just noticed. And here the question very naturally suggests itself, why does the heart contract in the manner I have described? Throughout, the entire muscular structure of the heart an immense number of small ganglia of the sympathetic system are scattered - which act as so many centres or organs for the production of nervous power - and are connected by
nerve fibres—which enables them to act simultaneously. The blood undoubtedly acts as the chief exciting cause of the reflex—or I should rather say continuous-action contraction.” But this is not alone the cause of its contraction, for the heart will contract when entirely empty, and placed in vacuo, but may not the something whatever it may be which supports or suspends it, act as a stimulus, for if it is owing to nervous influence it must have a cause commencing somewhere whether we call it reflex or continuous action.

It is to be hoped that the recent researches of Mr. Brown and others may throw light upon this most important subject and the benefit thereby derived be infinite. But again the presence of blood in the heart is not of itself sufficient to cause contraction—for in a heart main-

stimulus was present, contractions do not take place. We have abundant evidence that the heart is affected by the nervous system, both cerebro-spinal & sympathetic, sudden destruction of the brain & cord cause instant cessation of the heart's action—as will also a severe blow upon the full stomach, but both the brain and cord may be gradually removed without materially influencing the heart's action (arterial). Section of the vagi nerves but triflingly affects the heart's action, but excitation of them more especially of their roots excites or accelerates it.

This nerve is also most probably the medium of communicating the influence of the different emotions of the mind, anger, fear &c. to the heart.

Remedies originally narcotic become secondarily sedative, since they diminish the capability of the nerve thine to transmit the nervous
force— and in this way the influence of the
brain being checked or impeded, their adminis-
tration is followed by diminution in the number
of its pulsations or contractions. Unfortunately we
have no means of estimating the comparative
degree in which these two agents viz. the blood's
presence & the nervous system— influence the heart's
contractions. And now the blood is expelled
from the left ventricle, the force which the latter
events upon the blood has been calculated by Valentine
to equal one fiftieth of the weight of the individual
which in a man weighing 11 stones, would
be about three pounds; that exerted by the right
ventricle, being thought to be about half of that
exerted by the left. Now if four ounces are expelled
at each contraction then according to the laws of hy-
drostatics— there will be a similar amount of pressure
upon every four ounces of blood in the body, and
susposing the whole quantity to amount to 30 lbs.
the pressure exerted will equal 360 pounds: but in

disease this pressure being I suppose too obstruction
may be increased to the amount of 12 pounds upon
every square inch; but even this falls short of the pres-
sure of the atmosphere by three pounds: upon the same 
extent of surface. Now although a power equal
to that exerted by the left ventricle may be
sufficient to propel the blood through the sys-
temic circulation — 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 driven to the conclusion
that the propulsive power of the heart would
alone be sufficient to drive the blood through
the three systems of blood-vessels and consequently
to maintain the current of the circulation.

Hence then though the heart in man, and
in all animals which possess one may be regarded as the chief—it is by no means the only source of the power by which both the systemic and pulmonary circulations are sustained.

This would appear to be negatived by the assertion that on applying a ligature to—or other pressure upon—the main artery of a part the circulation beyond the point of obstruction is instantly arrested, other facts also may seem to point to the same conclusion, but we can bring in much stronger evidence in favour of other forces, both peculiar to the vessels themselves—which exert a general & local action on the circulation, and equally distinct proof of the existence of an influence exerted by the tissues upon the current of blood—appearing to arise from those changes by which constitute nu-

trition & secretion—in which the vessels appear to be passive agents; such for instance seems to be
the interpretation of the fact that whilst any variations in the heart's action affect the whole system, there are many variations in the circulation which being very limited in their extent cannot be attributed to such central disturbances and must therefore be dependent on causes purely local (Carpenter). To determine then the nature of these influences the phenomena of the circulation in each system of blood tubes must be investigated and this leads us to the consideration of the blood's passage through the arteries. During the contraction of the left ventricle, a certain quantity of blood (from 4 to 4½ ounces) is pumped into the aorta and its branches which are already full; now if these vessels were a series of non-elastic tubes the force of the heart's would be accorded to the laws of the propagation of pressure this fluid be transmitted without loss along the whole columns of blood in the arteries, at one and the
some moment, and as a result of this - the blood would be subject to great varieties of velocity, rushing with great rapidity during the ventricular systole and then relaxing into a state of pause or repose during each diastolic interval - in short an interrupted current would ensue. But such is not the case since in consequence of the irremediably elastic and extensible character of the arterial walls (due mainly to their middle coat) that soon is obtained for each fresh injection of blood which exceeds the quantity simultaneously expelled from the opposite extremity of the vascular system. In thus yielding to the force of the heart at each successive impulse - the arteries so dilated are now in a position (in virtue of their elasticity) to repay - as it were - to the blood the force expended in their dilatation. The instant that the ventricular
systole has ceased and the diastole begins. The arterial walls recoil & contract when their contained blood—tending to propell the blood in both directions—but its backward movement is effectively prevented by the semilunar valves, necessarily the mass of blood is forced onwards to the capillary system. The ultimate result of this is that the jerking impulses which would otherwise arise from the heart action alone—is converted into a more continuous and uniform flow. It can no longer be doubted that the smaller arteries possess this the agency of their middle coat (consisting of muscular muscular tissue) a power of contractility, does this influence the arterial circulation? Now unless it possesses a kind of vermicular or peristaltic action commencing at the aortic extremity—and thence passing towards the distal
extremity — or indeed it had the power of alternately contracting & relaxing — coincident with the diastole and systole of the ventricles — neither of which we have grounds for believing we must reject this as an agent in the propelling of the blood.

In shorter words — what I mean is this that the calibre of these vessels does not alter with each beat of the heart — of course it is subject to very material alterations from different causes — as is sufficiently evident in congestion of any superficial part — the nervous system being the medium of influence in most cases. Most probably the function of this middle coat is to regulate the supply of blood sent to each part — according to its requirements — or to adapt the size of the vessel to the amount of blood passing along it to the tissues, but in the large arteries their dilatation similar to that of the heart may be owing to relaxation
and this alternating with their contraction acts very much in the same way as the heart as by their relaxation they do not meet the entrance of the blood. Dr. Carpenter on ascribing to the muscular coat of the smaller arteries the function of regulating the supply of blood sent to a part by adapting their caliber accordingly and dependent upon peculiar circumstances at the time says "If this hold is the enlargement of the uterine or mammary arteries at the epochs of pregnancy and lactation" and then adds as a still more convincing proof that "the enlargement and strongly increased pulsation of the Radial artery, when there is any active inflammation of the Placenta" Dr. Hill very properly admits the incapacity of the Heart to effect these changes "since this is commonly unaffected" but states further that "it must therefore be by a power inherent in themselves that their dilatation &c." Now independent of this being a hasty conclusion, it is totally at variance with the now-
almost universally admitted explanation; Dr. Billings states that all organic action is contraction; now how can contraction—ever supposing that they were of themselves the agents of it—effect their dilatation? What is the cause then of their dilatation? the past inflamed, or the mammary gland command to secrete milk— or the uterus receiving the womb—require a greater supply of blood—than when these circumstances are otherwise—and so exert a greater attractive force upon the blood. These conditions are communicated to the nervous centres and they in their turn regulate the condition of the arteries, for if such major jest changes are effected in the act of breathing—and they can only be through the nervous system—how much more will the unconsciously acting principle of intelligence, regulate affairs which involve the welfare of the individual and the perpetuation of the species.

This I think is the most feasible explanation of
the phenomena above alluded to. This attractive force is exerted chiefly at the capillaries, the one I alluded to before, but in addition to this we have a selective force exerted by the tissues - which appears to be in abeyance in inflammation probably because if it was exerted the necessary elements for carrying on the subsequent changes would not be present. It may be asked here what proof have we of an attractive force existing at all?

Let us look for a moment at the circulation in plants - in them a prompt circulation of fluid takes place with such rapidity that it finishes before it the fluid above. This is assisted by the attractive force exerted by the leaves and may be demonstrated most satisfactorily by placing the cut surface of the upper portion of a vine which has been cut in two in water - an active absorption or circulation of water will take place as long as the changes - the result of the effect of light - go on in the leaves - but which is checked.
by the removal of the plant into a dark apartment; the elaborated sap also containing all the elements essential for the nutrition & various secretions of the plant circulating in the under surface of the leaves and bark until ascend towards the stem, even against gravity, in a dependent branch. The existence of this force is still more strongly indicated by the fact that a complete circulation is kept up in many of the lower animals in which no central organ of nutrition exists— as in some of the Polyphemus & Articulata. In the sponge also the remarkable currents of water which flow through the various channels that penetrate its substance are maintained without any special propelling organ whatever.

The late Dr. Houston has recorded a case of an acardiac fetus which had grown to a considerable size and had its tissues well developed, without any connexion with the twin fetuses, which (it is reasonable to infer) must have been
affected by a circulation exclusively its own.

The phenomena of asphyxia show that an attractive
exists between the blood and the oxygen of the atmos-
phere, for when the access of air to the lungs is prevented
the circulation ceases at the pulmonary capillaries as
evidenced by the post mortem appearances on its being
again admitted the circulation recommences.

I think that these facts will be sufficient to prove
not only that an attractive force exists but is also essu-
ient to the maintenance of the circulation; the heart being
undoubtedly the principal agent (but insufficient of itself)
in maintaining it, but it is regulated and modified
partly by the elasticity of the walls of the vessels partly
by their contractility - influenced chiefly or we might say
entirely by changes in the nervous system or resulting from its
action - produced in various ways - perhaps most frequently
by the ventricle nerves acquainting the nervous centre
with the state and requirements of the parts which they
supply, and last but not least by the operation of a force, viz. that of attraction - the existence of which I have already proved. To what extent this influences the circulation in the normal state we cannot even conjecture, but certainly is increased in the so-called phenomenon of inflammation, and this brings me to speak of another force of whose existence we have equally strong proof: viz. - a selective force; for how can we otherwise explain the fact that cells precisely the same in structure, secret from capillaries also the same in structure - though the same basement homogenous membrane (at least until the end of the most powerful microscopes, our histologists have not detected any difference) - in the case of the kidney at one portion the fluid - at another the solid ingredients of the urine, in the liver, the elements of bile, in the salivary glands - saliva, &c. and in the villi of the intestines, the constituents of the whole of these secretions - but if the nature of this selective power we know nothing, it
is either destroyed or suspended in inflammation.

The capillary circulation is also more particularly affected by alterations in the chemical state of the blood - as take place in asphyxia, and Dr. Reid states "that the blood, when imperfectly oxygenated, is retarded in the systemic capillaries, causing an increased pressure on the walls of the arteries."

The circulation through the veins is continuous - a fact frequently demonstrated when resection was fashionable, but now seldom witnessed - and it may also be observed in the transparent parts of a few animals with the aid of a microscope. The whole capacity of the venous system is considerably greater than that of the arterial; the former is usually estimated to contain in a three times as much blood as the latter, in the ordinary condition of the circulation; and when we consider the proportion which the veins in almost every part of the body - bear to the arteries - we shall not be incredulous.
on that point—hence we have the rapidity of the movement of the blood in the two systems differing materially—and having an uneven ratio to their respective capacities. The veins are furnished with a series of valves (except in the lungs—brain—I abdominal viscera) and these effectively prevent regurgitation upon the capillaries—they are single in small veins—the free edge of the flap closing against the opposite wall of the vein; in the larger trunks they are double—and in a few instances are composed of three flaps.

The movement of the blood through the veins is chiefly effected by the vis-a-tergo— proprioceptive force which results from the action of the heart & arteries upon the blood; this is shown by the immediate cessation of it when these forces are suspended.

Muscular action exerts considerable influence upon the venous circulation—each contraction expelling a certain amount of blood from the vein—which
refill during their relaxation to be again compr-
essed by their next contraction. That the general
muscular movement is an important agent in
maintaining the circulation—at a point above that
at which it would be kept by the heart &c.—appears
from several considerations:—the pulsations are
very much quickened by violent effort—accelerated
by moderate action—and diminished in frequency
by rest; but here we must not forget that the part
performing these movements undergoes a various
amount of changes in its composition—and requires
a proportionate amount of blood to supply the elements
necessary for these changes.—Therefore a proportionate
amount of blood is attracted to the part according
to these requirements—and not determined as already
stated by many; so that muscular movement
does not affect the various circulation alone—but the
other sections of that process also.
The venous circulation is much more liable than the arterial to be influenced by gravitation; particularly noticeable where tonicity of the vessels is deficient. There are other two forces—talked of by some as effecting the circulation—in the suction power of the heart which we have described already. And 2nd the effects of respiration movements. But it appears to me that if inspiration favours the flow of venous blood into the thorax it will impede the flow of arterial from that cavity, and vice versa with expiration. viz. if it favours the flow of the arterial blood from the thorax it will equally hinder the influx of venous.

I have already alluded to the influence of the nervous system—but we do not possess sufficient accurate knowledge to judge of the amount to which it influences the circulation—and what we do know is sometimes contradictory.

James Irving.