ON
THE CAUSES
OF THE
VACUITY OF THE ARTERIES
AFTER DEATH.

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COMMUNICATED BY

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Read Dec. 7th, 1819.

THE Harveian Doctrine of the circulation of the blood, may, I think, be divided into two parts. The first is the course of the blood; the second the explanation of the causes by which it is moved in that course. The arguments advanced by Dr. Harvey on the first of these points, the course of the blood, must, I think, convince every candid enquirer that the blood is conveyed from the heart by the arteries, and returned to it again by the veins. But the illustrious discoverer has not been so fortunate in the second part of his great undertaking. In maintaining that the projectile power of

being of a different colour from that discharged, the ventricles of the heart propels the blood through the whole of the arterial and venous canals, and, after having discharged this office, opens the auricular chambers by means of the returned blood, he lays claim to effects which are not warranted from the supposed causes, and which are inconsistent with the established laws of hydrostatics ; laws by which the blood, as well as every other fluid, must be governed. But this part of the doctrine of Harvey, admitting it to be philosophically correct, must be rejected in its present application as affording no satisfactory solution of the phenomena. The followers of Harvey, adopting as the foundation of their argument his doctrine of a *vis a tergo*, have enlisted the arteries into the aid of the heart, and contend that the blood is circulated by the combined agency of these powers ; but the difficulty is not removed by the supposition ; it is only shifted to another part of the system, and the phenomena are not better explained.

It has often created surprize that a doctrine so simple in appearance as the circulation of blood, and pointed out so plainly as we now suppose by facts of daily occurrence, should have been reserved for the discovery of modern times. The knowledge of the circulation seems to have been retarded by one remarkable phenomenon. The arteries, which are now known to constitute the channel of the blood for one-half of its course, were uniformly

found to be devoid of that fluid after death. That vessels in which no blood was to be found by the most careful examination after death, should be the constant receptacles of it during life, is a supposition that would scarcely suggest itself to the anatomist ; and, if suggested, would soon be rejected from the list of probable conjectures. The arteries were supposed to be the recipients of a vital aerial fluid. One fact indeed of frequent occurrence seemed to be at variance with this belief ; and, if the effect of it had not been defeated by an hypothesis, it must, we would suppose, have led to the truth. An artery, when wounded, was constantly observed to discharge blood from the living frame. But the ancient physiologists, unwilling perhaps to degrade the arteries from what they conceived to be their more refined office, and conceiving it impossible, that if these vessels contained blood during life, they could be deprived of it by death, contended that the discharge of blood from a wounded artery was no proof that the vessel contained any blood before it was wounded, but that the injury and pain given by the wound drew blood from other quarters into vessels which contained none before ; and that the impetuosity and obstinacy of the discharge arose from the conflict between this foreign intruder and the native aerial spirit. What gave greater plausibility to this supposition was, that the blood shed by the arteries, from the veins, seemed to be not the natural pro-

duct of the body, but the factitious result of this imagined conflict.

The condition of the arteries after death was urged confidently by the opponents of Harvey as an insuperable objection to the doctrine of the circulation, upon its first promulgation ; and was unquestionably one of the greatest obstacles found in the path of the discoverer ; and, after all, the explanation given by this celebrated man of the powers by the operation of which the arteries are found empty after death, is most unsatisfactory. He says that the left ventricle, in the last struggles of life, continues to propel after it has ceased to receive blood, and that, by these final propulsions, the blood at the time in the arteries is driven into the veins ; and he further asserts, in support of this explanation, that the arteries of animals, who have been killed by submersion in cold water or by mephitic air, will be found to contain blood after death as well as the veins. But there can be nothing more evident, than that the heart, by these abortive impulses, could only drive blood through the more remote portions of the arterial system by some impinged medium ; and that this medium, which, upon the hypothesis of Dr. Harvey, could only be blood, must still remain in the arteries. But defective as this explanation is, it has the further imperfection of being built upon an hypothesis that is altogether destitute of proof. This

hypothesis is, that the heart continues to propel after it has ceased to receive blood. The heart on the contrary is generally found full of blood after death. The converse, therefore, of what is maintained by Dr. Harvey would appear to be the truth, that the heart retained the capacity of receiving blood, after it had lost the power of discharging it. The statement also by which Dr. Harvey has supported his opinion, has not been confirmed by observation. The arteries of animals which have been killed suddenly by submersion in cold water, or by any of the ways enumerated by Dr. Harvey, have been found equally empty of blood with those of animals killed by lingering disease. Into such a labyrinth of error and evasion will men of the most powerful minds be led when they attempt to shape nature to a conformity with their opinions.

No new light has been thrown upon this subject by the followers of Harvey ; and in general it may be observed that after the lapse of two centuries, and though a thousand volumes have been written, and thousands of animals slaughtered to elucidate the subject, the doctrine of the circulation has descended to our times nearly in the same state in which it came from the hands of the original discoverer.

Mr. George Ker, an ingenious and learned surgeon in Aberdeen, struck with the defectiveness

and inapplicability of the explanation given by Dr. Harvey and his followers of this remarkable phenomenon, as well as of many others, has in a late publication boldly denied the doctrine of the circulation of the blood altogether, and become the acute, strenuous, and most confident advocate of the opinions of the ancient physiologists respecting the condition of the blood in the living system, and the uses of the arteries.

All the objections urged by Mr. Ker against the circulation had been stated by myself as objections, not against the doctrine of the circulation itself, which I believe to be founded on a basis never to be shaken, but against the causes assigned for the accomplishment of that effect, at least two years before the appearance of Mr. Ker's work, but unquestionably without the knowledge of that gentleman. The causes which I have ventured to assign to the motion of the blood, will, in process of time, I trust, be found to have a real existence in nature, to be adequate to the effects assigned to them, to have been fitly applied, to afford a plain and satisfactory explication of the various phenomena, to answer fully all Mr. Ker's objections, and, in a word, to vindicate a theory, which does so much honor to our country, from all future opposition.

The objection principally dwelt upon by Mr. Ker, the emptiness of the arteries after death, did

not pass unnoticed, as may be seen on reference to the enquiry into the causes of the motion of the blood ; but as I had not then had an opportunity of submitting my opinions to the test of experiment, I did not state them with that confidence which I even then felt in their truth. I have lately had that opportunity, and I now propose to state the result.

The chief, if not the whole, of the movements of the animal machine seem to be the effect of two powers acting either conjunctly or separately. These are elasticity and irritability. The elasticity of the parts which possess this property is inherent in the structure, and is independent of life. Irritability, which is the property of the muscular substance, is the concomitant of life, and ceases with it. The movements, which are the usual result of a combination of those powers, will not wholly cease at death. The elasticity will still continue to operate ; and the result will be different, either from that which would be produced by their combined agency, or from that which would arise from their synchronous destruction.

The motion of the blood seems to be the result of the contractions arising from the irritability of the heart and arteries, and of the resilience arising from the elasticity of the arteries and of the lungs. One class only of these powers is destroyed by death. The resilience of the lungs and of the

coats of the arteries possess then an uncontrouled operation.

The resilience of the lungs removes a part of the pressure of the atmosphere from the internal surface of the chest, and perhaps from the internal surface of the vessels by which they are penetrated. To restore to the parts within the chest an equality of pressure with that of the substances without it, the adjoining liquid and less fixed parts of the body will be pressed through every channel that offers into the chest. What is called a vacuum will in effect be made in the chest by the elasticity of the lungs. There will therefore be a draining from all parts of the body towards the chest, to fill up this vacuum. As thus the causes which return the blood to the heart continue to operate, after the heart, the great engine by which it is discharged, has terminated its labours, a greater quantity of blood will be necessarily collected in the neighbourhood of the heart after death, than existed there before it.

Various circumstances may intervene to fix the channels in which the blood will flow in its course towards the heart after death. The arteries are powerfully elastic, and when their coats are relieved from the distending force of the heart, become of a diminished calibre. Valves stationed at the roots of the arteries prevent the return of blood from these vessels into the chest. After the small

part of the aortic system intervening between the heart and the confines of the chest shall have been, as it usually is found to be, filled with blood, the blood in the rest of this system will sustain no diminution of pressure on the side of the heart.

No obstacle exists in the way of the blood in its course to the chest through the veins. No valves are stationed at the roots of these vessels, and the blood finds an unobstructed course from the roots of the cava into the auricles, from that possibly into the right ventricle and into the pulmonary arteries, and thence into the pulmonary veins. The heart, particularly the auricles and the large venous trunks, the coats of which being inelastic and easily dilatable, being all placed within what may be called the vacuum of the chest, will be distended to their utmost capacity. The additional blood requisite for this purpose can be drawn only from the veins. The place of the blood taken from one part of the venous system will be supplied by that from another. The termination of this process will be the emptying of the arteries into the veins.

If the preceding argument be correct and founded upon true principles, it would follow that, were the elastic powers employed in the motion of the blood disengaged before the muscular powers had ceased to act, or synchronously with that event, a distribution of the blood would

be found to exist after death different from that which is now usually observed. The blood would not be found so extraordinarily accumulated in the right auricle, and in all the veins belonging to the system of the cava within the chest, and at the approaches to it; and the arteries and capillary vessels would contain the proportion which upon the supposition of the Harveian theory must have flowed in them before death. I have not been able to devise any method of annihilating before death the elastic influence of the arteries, and therefore some allowance must be made in the phenomena which are to be brought into view for that cause; but I have been successful in removing from all influence after death the elastic power of the lungs, by far the most efficient, by the manner in which the animals were killed in the following experiments. Death was in these cases effected by inducing a previous collapse of the lungs, which was done by making openings into the chest of the living animal, and exposing the external surface of the lungs to the free access of the air.

In the first experiment made with this intention, an opening was made about an inch in length between a pair of the ribs on each side. I expected that sudden death would be the effect of these openings; but in this respect I was disappointed, and at first not a little perplexed. This disappointment I experienced particularly in the case of a large dog. This animal, as I supposed, after

the collapse of the lungs, by pressing up the diaphragm by means of the abdominal muscles as far as possible, and then by a rapid and forcible contraction of the intercostal muscles, accompanied by a rapid and forcible contraction of the diaphragm, was enabled to rarefy the air contained between the external surface of the lungs and the chest to such a degree as to occasion a partial dilatation of the lungs, and an imperfect expansion of the heart. Thus life was painfully prolonged for nearly twenty minutes. The sufferings sustained by this animal for so long a period prevented a repetition of the experiment on any other animal in the same manner. The result was in other respects satisfactory. Though the death was tedious, it was ultimately produced by the collapse of the lungs. I had previously performed the same experiment upon a rabbit and a cat. In these the death, though not sudden, was neither so tedious, nor to appearance so distressing as in the case of the dog.

The same appearances were, on dissection, exhibited by all. The muscles were remarkably red ; and, when an incision was made into them, they poured out blood. The membranous parts exhibited the blood-vessels as if they had been fully and nicely injected ; forming anastomoses which appeared like a netting made of red threads. I was particularly struck with the coats of the intestines ; instead of exhibiting the usual pale smooth

surface without the vestige almost of a single blood-vessel, they appeared to be composed of a red colored netting, the meshes of which varied greatly both in dimension and in form. The liver was like red morocco. The flesh of the rabbit, which is usually white, was in this case of a reddish color, and all the dissected parts became wet with effused blood. The heart contained little blood. When the chest was opened, and the large vessels it contains were divided, a small quantity of blood only was effused, not much more indeed than from the other parts of the body. The aorta and large arteries, in all the instances, were pale externally, while the accompanying veins were of a blue color. A part of the descending aorta, above the bifurcation of the iliacs, after its extremities had been secured by ligatures, was cut out, and was found to contain a small cylinder of blood generally coagulated. So it appears that the white color of the arteries did not arise from this being empty of blood, but from the want of transparency of their coats. With respect to the vessels, which the stomach, the intestines, and the membranous parts exhibited in so beautiful a manner, I do not pretend to say what part of them may have been arteries. Supposing, however, that these carcasses exhibited the distribution of the blood as it really existed in life, it is very evident that the blood, not only of the larger arteries, but of the smaller vessels, whether they be arteries or veins, must, in conse-

quence of death produced in the usual way, be emptied into the large veins. I think it probable, however, that what are called the capillary vessels, may, in consequence of this mode of killing the animal, be found to contain more blood than the share that belonged to them during life; for the elasticity of the coats of the arteries, the effect of which, as I before stated, I had not been able to devise any plan of counteracting, by contracting the bore of these vessels, would propel a part of the blood that was flowing in them at the moment of death into the vessels, the coats of which were inelastic and dilatable.

For the purpose of comparing the appearances of two animals of the same kind, killed in different ways, two rabbits were killed on the 20th of September 1819, one of them by causing the lungs to collapse before death, the other after a different manner. In the case of the first of these rabbits, the belly was opened freely from the scrobiculus cordis nearly to the pelvis, and the lower surface of the diaphragm exposed to view. An opening, fit to admit my two fingers, was made through the muscular part of the diaphragm on each side. The sound of air rushing through the orifices, announced the collapse of the lungs. As the animal possessed no power of contracting the openings made in the diaphragm; as its struggles would probably tend to widen them still more; and as therefore the capacity of dilating the lungs, even

in the smallest degree, no longer remained, the animal instantly died. The appearances exhibited by the dissection of this rabbit, were precisely similar to those already described of the bodies of animals killed by the previous collapse of the lungs. The vessels, particularly of the intestines, stomach and mesentery, were very distinct and full of blood, forming frequent anastomoses with each other, in the way already described. The flesh was reddish, and when cut into, bled. The heart and vessels about it contained only a moderate quantity of blood ; for scarcely any blood was found, after the division of the vessels, to have been effused into the shell of the chest. The other rabbit was killed by thrusting a sharp instrument between the vertebræ of the neck. It died instantly, and was immediately opened. Scarcely was the vestige of a blood-vessel to be observed on the surface of the intestines or stomach, which had a pale appearance, excepting where they were tinged by the colour of their contents. The membranes scarcely exhibited any traces of vascularity. The flesh was white, and when cut into, appeared to be dry, discharging at some parts a drop or two of blood. The liver was of a dusky brown colour. The trunks of the veins were swollen and rounded ; whereas in the other rabbit they appeared flat, and to contain a thin layer of blood. A considerable quantity of blood was found in the shell of the chest, after it had been opened, and the large vessels it contains divided.

A few days after, a sheep was killed in the same manner as the first of the above-mentioned rabbits. When the openings were made through the diaphragm, the sound of air rushing into the chest, announced still more plainly the fatal collapse of the lungs, and the last expiration. The animal, after making a few heavings with the chest, became lifeless. Several other sheep had been killed at the same place at that time, and there was an opportunity of comparing the carcase of this animal with those of the others. Scarcely any traces of the smaller vessels were observable in the stomach, intestines, peritoneum or mesentery of the other sheep, while in the same parts of this animal they appeared in great abundance, and as injected with red wax. The appearance was so remarkable as to strike the butchers, and the persons whose attention I directed to it, with surprise. The colour of the fat was browner than usual. The muscles of this animal being at all times red, did not exhibit so marked a difference as in the case of the rabbits, but when cut into they discharged blood. The larger arteries, where I had an opportunity of seeing them, contained a small cylinder of coagulated blood. The flat and tape-like appearance of the large veins, which I had observed in the rabbit killed in the same manner, was in this case very remarkable.

The results of these experiments I think fully

warrant the conclusion, that the difference of the distribution of the blood after death from that in which, according to the Harveian theory, it must exist in the living system, arises chiefly from the elastic power of the lungs ; and that the emptiness of the arteries and of the smaller vessels observed after death, admits of a satisfactory explanation from the supposed operation of this cause, combined with that of the elasticity of the arterial canals.

Before I conclude this paper, I am anxious to express my hope that some benefit may result to anatomy from the examination of animals killed by the collapse of the lungs ; in particular a better chance seems to be promised by it of tracing the vascular system to its various terminations. According to the Harveian doctrine, the blood must flow from the minute and ultimate branches of the arteries into the corresponding branches of the veins. But the knowledge of the manner in which the vessels form the communication necessary for this purpose, is still a desideratum in medical science ; and, as in all the ordinary modes of death, these vessels are always deprived of their contents ; and, as in these circumstances, the knife of the anatomist and the microscope, though directed by all the colourings which the art of injecting can supply, have been found incapable of bringing this union into view, it was likely to have remained so. But the exa-

mination of animals in which the smallest vessels contain at least their full proportion of the red fluid that filled them before death, seems to hold forth the hope of some more satisfactory knowledge being attainable in this dark and mysterious part of physiology.

Liverpool,
October 22, 1819.