ON THE
PHYSICAL PHENOMENA OF LIFE.

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VITAL HYDRAULICS.

THE body of every animal is the seat of an internal movement, which results from the action of physical causes upon the fluids contained in the organised parts of the animal. Thus, if we select any of the mammalia, as an example, we find an hydraulic apparatus, arranged with such admirable skill and design, that the most scientific mechanic could scarcely produce a clumsy imitation of it. The term "circulation" has been appropriated to the course of the fluid which this machine is destined to put in motion, for the purpose of distributing to each organ the materials necessary for its growth and support. The study of this important phenomenon is well worthy the attention of physiologists, and it will be presently seen what various results emanate from the most simple actions, which are themselves produced by a multitude of different agents; yet how erroneous or imperfect are the ideas generally entertained on the action of the various compartments which enter into the composition of this hydraulic machine. The illustrious Harvey, no doubt, threw an immense light on the subject, by demonstrating the passage of the blood, through the lungs, from the right to the left side of the heart, and its subsequent return to the right cavities of that organ, after having traversed the whole body; but several points connected with the mechanism of the circulation escaped his notice. We advance but a small way by having determined the apparent results produced in the mass, by any mechanical apparatus; we must descend to the details of its structure and study the play and purpose of each particular piece in the machine. How few physiologists have pursued this method.

The history of the circulation embraces the study of a number of questions which require for their explanation a very considerable knowledge of the physical sciences. But, before we attack the more complicated facts, we should endeavour to make ourselves master of those which are simple; this is the only method of examining and embracing the whole subject.

Take any living animal, and make a punctured wound into any part of its body, a small quantity of fluid immediately escapes; the liquid continues to flow for a certain time, then its course becomes more slow, and at length it ceases. Make a large incision, and the fluid escapes in greater quantity; the force of the current is considerable, and it takes a much longer time

to diminish, not ceasing altogether until the fluid coagulates, and closes up the opening of the wound. What is daily seen with regard to the external surface of the body, may be equally observed in its interior; hence, then, a first fact which is well established, viz., all the tissues of the living subject are constantly traversed by a current of fluid.

Open the dura mater of an animal, between the occipital bone and atlas, and then incise the little transparent pouch which presents itself to view; a limpid fluid immediately escapes, and is projected to some distance. The wound thus made soon heals up; the disturbance which was occasioned by the evacuation of the cerebro-spinal fluid is calmed, and the order of the economy restored. Repeat the experiment after the lapse of some time; incise the cicatrix, and a fluid exactly similar to that seen during the first experiment flows and escapes in nearly equal quantity. How, then, does it happen that after having drawn off a serous fluid, you afterwards discover a new deposit of it? We must admit that it has been carried to, or placed in, that particular spot by some special mechanism.

Is a more striking example required? Let the eye be emptied by a puncture; in twenty-four hours afterwards the eyeball is again filled, and distended by a new fluid. This fluid is necessarily derived from some source or other; it is not formed all at once; it has been transported by some particular agency; but what is this agency, or from what source is the fluid derived? these questions will be examined by and by. Daily experience, moreover, demonstrates an internal movement of fluid in our economy. What is "thirst" except an instinct which warns us to replace the liquids that are constantly escaping from the body.

This perpetual renewal of fluid is a condition necessary for the support of life. How long can an animal live, if completely deprived of drink? A dog, submitted to absolute abstinence, lived twenty-three days; we tried to support other dogs exclusively with solid food, but they all died. Hence the introduction of new fluid is necessary to the existence of a living body. But by what mechanism is the fluid put into motion? Is it by the law of gravity, or of capillarity? Are our organs capable of imbibing fluids, like a sponge? Yes, in many instances. Several medicinal substances are introduced into the economy by means of the porosity of our membranes, a property which likewise explains the phenomena of pulmonary transpiration, absorption, and exhalation. But is there no other force by which the fluids of the body are circulated? Yes; this is performed by an admirable assemblage of organs. We commonly designate by the names "vessels," "arteries," "veins,"

"capillaries," &c., a number of membranous "tubes," destined to carry the blood to every point of the body. The word "tubes" seems preferable to the anatomical terms, for it has the advantage of attaching our ideas to the laws of physics,—the only ones which can throw light on the questions we are about to examine.

Taking a general view of the circulatory apparatus, we find a *central hydraulic machine* (the heart), which serves as a reservoir and pump for the fluid (blood) destined to move through every point of the body; *discharging tubes* (arteries) which carry the fluid from the central machine; and *carrying tubes* (veins) destined to re-collect the same fluid when deprived of some of its qualities, and mixed with certain foreign materials. These tubes are not of equal diameter throughout; they gradually decrease in calibre as they recede from the central organ, and present a continued succession of cylinders, the most minute of which are finer than hairs. The latter constitute an intermediate class of tubes called capillaries. But a fluid contained in a machine cannot be moved without the action of some mechanical cause.

In some cases, gravity is the power employed; thus, by means of reservoirs situate in elevated stations, water is carried to a great distance. In other cases, hydraulic wheels, moved by falling water, are employed; in a great many instances steam is forced against a piston. Everybody is acquainted with the manner in which mechanics have availed themselves of the force of the winds to favour the ascent and course of fluids; but we find nothing analogous to all this in the animal body. Gravitation may, indeed, effect something, but the essential force by which the human hydraulic machine is put in motion is muscular contraction; hence, in the study of vital hydraulics, we must consider two points:—

1st. The moving force, a *vital agent*, whose mechanism will probably always remain a mystery; and,

2nd. The play of a central machine, and of tubes traversed by currents of fluid, which is subject to the ordinary laws of hydrodynamics. The analogy between the organic and common mechanical pumps, is, indeed, very great. In both machines the direction of the currents of fluid is regulated by similar contrivances. The orifices of an hydraulic tube are closed, or left open, according to circumstances, by the disposition of its *soupapes*; now, whether they be living membranes, or simple plates of metal or copper, the action of these *soupapes* is essentially the same; the passage of the fluid is free, or interrupted, according as they may be open or shut, and it is in vain that we look for anything in their mode of acting except a mechanical phenomenon.

In the human heart we find the orifices of

all the great tubes furnished with membranous folds, and which, in the language of the schools, are denominated "tricuspid, mitral valves," &c. It would be desirable to substitute the term *soupapes* for these expressions, because it leads the mind at once to physics, from which science it has but too great a tendency to wander.

The two principal tubes which communicate with the central pump are furnished with valves, but the latter, instead of being composed of a single plate, are formed of three isolated plates. Is this a superfluity? or was not the constructor of our hydraulic machine most profoundly versed in mechanical knowledge? Assuredly the admirable unity of design which presides over the action of this machine, and the prodigious results, obtained by the most simple means, excel all that the most scientific natural philosopher could have imagined. The object desired could not have been obtained by a single valve. Now, let us suppose the orifices of the tubes furnished with only one, this would certainly oppose the reflux of fluid as long as the tube conserved its habitual diameter; but the tube is elastic, it is capable of considerable dilatation, and, in this latter case, a single *soupape* would accomplish its function in a very imperfect manner. On the contrary, by the ingenious mechanism of three valves (*soupapes*), which touch one another at the centre, the course of the fluid through the tube is regulated at every degree of its dilatation. We must not, however, push the analogy between living and dead machines too far. The former exhibit certain conditions of the deepest interest to the physiologist. Thus, a common pump will act equally well, no matter what may be the nature of the fluid which passes through it; but the contrary is observed with respect to the animal hydraulic machine. This depends, partly, on the nature of the tubes, and, partly, on the specific nature of the contained fluid, which harmonises perfectly with the physical properties of the living tubes, and without which the machine itself could not continue its functions. It has been already mentioned, that the human machine is constantly traversed in every direction by currents of fluid; but what is the nature of this liquid? Its characters are excessively complex, and even the most skilful chemists find a difficulty in determining its composition.

This fluid is remarkable for its viscosity, a property which cannot be increased or diminished without producing serious consequences.

The tendency of the blood to coagulate is also another property which exercises an immense influence in the animal economy. Thus, let blood be drawn from the arm, and the fluid be collected in any vessel; the blood at first appears as a homogeneous

fluid, but it soon separates into two portions, the one solid, formed of fibrine and colouring matter, the other liquid, and composed of serum. But it may be asked, why does the blood continue fluid in the vessels of a living animal? Why does not any accidental retardation of its course produce a tendency to solidification? This, undoubtedly, depends on some agency of physical causes with which we are as yet unacquainted. When first viewed the blood seems to form a uniform mass, but if submitted to the microscope it presents myriads of small bodies of a lenticular shape (and not globular, as was formerly thought), floating in the midst of limpid serum. These little lenticular bodies are constantly rolling, one upon the other, and traverse tubes more delicate than the finest hairs, with the greatest facility. There is no product of science to be compared with these wonderful mysteries of our organisation, the whole of which is governed by a harmony of design, and an *ensemble* of actions, whose results alone we can attempt to analyse.

GLANDERS,
PRODUCED IN A MARE,
BY THE INOCULATION
OF MATTER TAKEN FROM THE
BULLÆ AND PUSTULES OF THE
MAN—PROST.*

TRANSLATED FROM THE FRENCH OF M. RAYER,
By T. H. BURGESS, M.D.

ON the evening of Prost's death (Feb. 12, 1837), M. Vigla gathered upon watch-glasses, a certain quantity of the sanious matter issuing from the gangrenous bullæ situated beneath the ear, and some pus from a pustule on the forearm, and also from an abscess on the back and shoulder. M.

* Prost, whose case has been already noticed in an English journal, in the form of extracts, taken from M. Velpeau's "Clinique," although in so very brief a manner as to warrant me in giving the full details of this interesting case as published in M. Rayer's work. The following is an outline of Prost's case, as given by M. Rayer:—A groom sleeping in a stable, and near an animal affected with acute farcy glanders; typhoid symptoms; subcutaneous abscess; pustular and gangrenous eruption upon the skin; pustular eruption in the nasal fossæ and larynx; small abscess in the lungs; gangrenous eschars on the glans, terminating in death; inoculation of a horse with the matter taken from the pustule and bullæ of Prost, followed by the development of glanders, as may be seen by the subjoined report of the proceedings.

Leblanc inoculated, in my presence, and in the following manner, a foundered mare, (which, although thus rendered unfit for service, still did not present any other symptom of disease) with the different portions of matter.

1st. At the right nostril, he inoculated the pustular matter by three punctures, of which two were within the nostril and one external; the two first punctures gave rise to a weeping of blood, but the other produced scarcely any.

2nd. Upon the conjunctiva of the right eye he applied a small quantity of the matter taken from the pustule.

3rd. At the internal and superior part of the right buttock he inoculated the pus taken from the abscess by three punctures.

4th. At the internal and anterior surface of the right axilla he inoculated with pus taken from the abscess by three distinct punctures.

The left side of the animal was inoculated in a similar manner.

1st. The left nostril was inoculated with the matter of the gangrenous bullæ by three punctures, of which one was within the nostril. The puncture gave rise, like those on the opposite side, to a slight weeping of blood.

2nd. To the left eye he applied the humour of the gangrenous bullæ.

3rd. The internal and anterior surface of the axilla of the left side was inoculated with the matter of the gangrenous bullæ by three distinct punctures.

4th. The internal surface and superior part of the left buttock was inoculated with pus by three punctures. In fine, the entrance of the nares and vulva were highly impregnated with pus.

I have observed (adds M. Rayer) the effect of these different inoculations with M. Leblanc, who kept a diary of the proceedings.

The following are my observations:—

On the 13th and 14th, no appreciable change could be observed in the state of the parts inoculated. On the evening of the 15th, at 7 o'clock, slight circular and circumscribed efflorescence and swelling around the punctures on the right buttock; at the centre of the swelling a depression was observed, corresponding to each puncture; painful tumefaction in the region of the left buttock where the punctures had been made, and the matter of the bullæ inoculated. This unœdematous and hard swelling, extended a little below the punctures but not above. The circumference of the punctures of the wings of the left nostril were a little tumefied; there oozed a small quantity of serous liquid from the internal wing. There was also effused a little serosity from the punctures of the internal wing of the right nostril; but the circumference of the punctures was not at all swollen. The