ON CERTAIN MOLAR MOVEMENTS OF THE HUMAN BODY PRODUCED BY THE CIRCULATION OF THE BLOOD. By J. W. GORDON.

A PERSON standing erect in a perfectly easy posture on the bed of an ordinary spring weighing-machine, and maintaining, as far as possible, perfect stillness, will be found, if the instrument is delicately adjusted, to impart a rhythmic movement to the index, synchronous with the pulse and according to the following rule:—At each occurrence of systole in the heart, the needle will be vigorously deflected toward the zero point of the dial, and in the intervals of systolic action will return by a slower movement to the starting point; this point nearly coinciding with the point at which the needle would rest if the subject were laid horizontally on the bed of the instrument. The return of the needle is effected by a series of secondary vibrations which appear to bear an appreciable but imperfect analogy to corresponding features in the sphygmograph.

This phenomenon may very easily be verified, but in repeating the experiment it should be borne in mind that the following are desiderata:—That the skeleton of the subject be brought as nearly as possible into contact with the instrument and that the hip- and knee-joints be so disposed as to secure the *maximum possibile* of rigidity in a perpendicular direction. It does not appear that this phenomenon has heretofore been anticipated by any process of theorising, or turned to any useful account. It may therefore be permitted me to point out what may prove to be its phenomenal cause and practical consequences.

As to its cause—When the heart is contracting it propels blood in all directions; but the greatest column is propelled downward, along the aorta, almost in the direction of the axis of the body. If, therefore, we disregard all blood that is propelled upward, and make a compensating abatement from that which is propelled downward, there will remain a certain mass of blood which at each contraction of the heart is forced

vigorously downward, and which therefore must give rise to a recoil in the opposite (*i.e.* upward) direction. Indeed, the case is precisely analogous to that of a ball propelled from a gun, and in both cases the vis inertiæ of the body propelled is the principal cause of the reaction. It is worthy of remark that the analogy is not vitiated by the fact that in the one case the body propelled does and in the other case does not get free of the system to which it originally belongs. For, take the case of the gun: Here the reaction is set up while the ball is still in the barrel; as soon as the ball passes the muzzle, and the confined gas behind it is set free, it can communicate no more motion to the gun. Suppose then a target of sufficient strength attached to the gun and held at a short distance in front of the muzzle. In this case the ball will never get free of the system to which it originally belongs, but its opportunity of generating recoil will not be impaired by this arrangement, although the recoil will be almost immediately checked. This is precisely what occurs in the human body. The projected mass of blood is checked in its course, not indeed by any rigid diaphragm, but by the elastic walls of the arteries through which it flows. But *so long as it is actually in motion the analogy to a gun is complete.*

This raises another point. Whether there is any actual reflux of blood in the principal arteries, or whether the flow is continuous, but variable, is not assumed in the above proposition, for the motion there referred to is relative. For example; assuming that the inward flow of blood in the venous system compensates the outward flow in the arterial, it will be evident that the mean, *i.e.* actual, velocity of the venous flow must lie between the extreme velocities of the arterial flow[1]. When, therefore, the velocity of the arterial blood is such as only to compensate (or produce momentum equal to that produced by) the venous flow, this blood would be said to have no relative motion; when it falls below this speed there is a relative reflux, and a recoil is produced in the opposite direction. If therefore the vascular system be con-

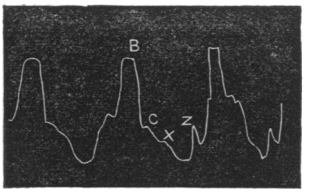
[1] More accurately—the momentum generated in the venous system must lie between the momentum generated by the extreme velocities of the arterial flow; for if the area of the venous system : area of arterial system = 9 : 4, the arterial flow at its slowest might conceivably be quicker than the venous.

nected with a weighing-machine by means of tolerably rigid supports, we ought to have an observable effect produced on the weight of the body, whenever the posture is such that the blood which flows through the descending aorta has a virtual velocity in the direction of gravitation.

With these facts in view probably my readers will concur in referring the phenomenon to the cause suggested here. It remains to discuss the best method of deriving a sphygmograph from the motion thus caused. The most obvious method of effecting this is to allow the index of a weighing-machine, such as is described above, to trace out a figure in the ordinary sphygmographic manner. By such a process Fig. 1 has been produced; of which it may be remarked that the second deflection behaves in such a manner as to leave but little doubt of its being a representation of the dicrotic wave. With less certainty the third deflection may be referred to the tricrotic wave.

Fig. 1.

Fig. 2.



In Fig. 1 the downstroke which is immediately succeeded by a long upstroke is synchronous with the systole: the next downstroke is the second deflection referred to in the text. The upstrokes are to be regarded merely as indicating the instrumental tendency to restore equilibrium.

In Fig. 2 the letters bear the same significance as in Dr Galabin's figures. Vide infra.

It has, however, been found possible to substitute for this process one much more satisfactory in every respect. It will be obvious that if the subject be placed in a horizontal position, the internal movements which in the perpendicular position caused the weight to vary, will now tend to produce horizontal motion; and if the body be free to move will actually produce a movement, the observation and registration of which will be a matter of delicate measurement only. By employing the horizontal position several important advantages are gained, *e.g.* much greater proximity of the skeleton to the supporting framework

can be secured; and the resulting figure conforms to the ordinary sphygmographic type, whereby the task of analysing it is greatly simplified. Accordingly Fig. 2 was produced in the following manner. A frame constructed in the lightest possible form, of sufficient size to allow the body of the subject to be disposed at full length upon it, was swung by four ropes from a trestle of appropriate size, and substantial structure. This frame was fitted with sliding supports, upon which the body was sustained by contact at those parts where the soft tissues are thinnest, *e.g.* the spine towards its extremities, the sacrum, ilia, and scapulæ. The body thus supported hammock-wise has a movement corresponding to that observable by means of a weighing-machine, and, with a sphygmograph adapted to the circumstances, yielding figures like the one already referred to.

It will be observed that the curve so obtained is remarkably conformable to the type which has been ascertained, by experiments made under special circumstances, to be characteristic of the aortic flow. If Fig. 2 be compared with the aortic tracings which illustrate Dr Galabin's paper on "Transformations of the Pulse-wave," *Journal of Anat. and Phys.*, Vol. x. p. 297 (see especially figs. 42 and 46, Pl. xiv.) the correctness of this statement will be obvious. I would especially call attention to the small rise *Z* preceding the main up-stroke.

It would seem therefore that the production of a sphygmograph from the aortic flow in a human subject under perfectly normal conditions is a matter of no difficulty. Moreover, the process which, though indirect, yields results of astonishing delicacy, is capable of being most extensively and instructively varied.