Mechanical theory of the predominance of the right hand over the left : or, more generally, of the limbs of the right side over those of the left side of the body / by Andrew Buchanan.

MECHANICAL THEORY

OF

THE PREDOMINANCE

OF

THE RIGHT HAND OVER THE LEFT;

OR, MORE GENERALLY, OF

THE LIMBS OF THE RIGHT SIDE OVER THOSE OF THE LEFT SIDE OF THE BODY.

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Professor Bennett
from the Author

TO THE

PRESIDENT AND MEMBERS

OF THE

UNIVERSITY MEDICAL SOCIETY,

AND TO THE

STUDENTS IN THE CLASS OF PHYSIOLOGY

IN THE

UNIVERSITY OF GLASGOW,

THIS MEMOIR,

WRITTEN IN THE HOPE OF CONTRIBUTING TO
THEIR INSTRUCTION,

AND FIRST SUBMITTED TO THEIR JUDGMENT, IS NOW

Respectfully Dedicated,

WITH BEST WISHES,

BY THEIR VERY SINCERE FRIEND,

THE AUTHOR.

PREDOMINANCE

OF

THE RIGHT HAND OVER THE LEFT.

Read before the Philosophical Society, March 12, 1862.

The use of the right hand in preference to the left must be regarded as a general characteristic of the family of man. There is no nation, race, or tribe of men on the face of the earth, at the present day, among whom this preference does not obtain; while, in former times, it is shown to have existed, both by historical documents and by the still more ancient and authentic testimony of certain words, phrases, and modes of speaking, which are, I believe, to be found in every spoken language. A custom so universal cannot, I think, be supposed to be a mere human institution, by which I mean a conventional arrangement founded on utility or expediency, and maintained by example and precept. The object of this memoir is to show, on the contrary, that the custom is adopted in obedience to physiological laws, and that it depends on causes lying deep in the human organization.

I. Phenomena to be Explained.—Let us first endeavour to ascertain the facts to be explained, without any thought of the explanation; and, with that view, let us compare the two sides of the body, and more especially the limbs, in reference to their structure and the uses we make of them.

When we look at the right arm of a full-grown man, and compare it with the left, we at once see that the former has the advantage over the latter in point of size. We discover, also, without difficulty, a corresponding inequality in the lower limbs, and we may say generally in the two sides of the body, considering the number of tissues that are common to the limbs and trunk. On more minute examination we find the inequality to be chiefly due to the greater development of the muscles of the right side, which are brawnier, and have stronger tendons. But other tissues participate in this increased development: the bones in particular are, according to Haller, larger and heavier, and have their

processes more prominent and strongly marked, furnishing a more powerful leverage to the muscles.

When we compare men with each other in these respects we find the inequality just noted most conspicuous in those that take much muscular exercise. It is more strongly marked, for instance, in the husbandman or the blacksmith than in the clerk or the shopman, while it is least of all apparent in those that lead an indolent and inactive life.

Among women there is less inequality of the two sides than among men. But the diversity occasioned by age is the most striking. The inequality which is so marked in the man is less perceptible in the stripling, and still less so in the boy. In the child it is still more faint, and during infancy and the fœtal state it is no longer to be discovered.

With respect to the use which we make of the limbs of the two sides, here, as everywhere else throughout the wide domain of physiology, we find action corresponding closely to structure. The tendency to use the right hand, or, which is nearly the same thing, the habit of using it, as well as its superior strength and efficiency, or what we emphatically call *dexterity*—these are always proportionate to the development of the muscular system. This, at least, holds true of adults and of young persons, and even of children of vigorous frame; but among the less vigorous we often see a habit of using the right hand which we could not have inferred from the condition of the muscular system, and which is manifestly a voluntary habit, acquired by precept and example, or the desire to avoid the imputation of awkwardness, or, as the French name it, *gaucheté*, which we associate with the use of the left hand.

As to infants, again, it will, I think, be admitted by all observant persons that they exhibit no tendency to use the one hand in preference to the other, as they employ indifferently the nearest hand to clutch at any object within their reach. Even in childhood the two hands are often used indiscriminately. This is more especially the case with weakly children, with whom it requires great attention to make them relinquish the bad habit of using the left hand, which it is supposed they have contracted. But this is a mistake, and an error in physiological training founded upon it. Nature intends all the limbs to be equally exercised during the weakness of infancy and childhood, and it is wisest to allow the development of all the parts of the frame to proceed in the natural way without interference. It will be shown below that as soon as a child acquires such a degree of vigour of muscle and firmness of bone as to enable it to put forth the whole strength of its body—then a mechanical advantage necessarily accrues to the muscles of the right side, and the child becoming conscious of the

superior power of those muscles, soon learns spontaneously to call them into action; but until that feeling arises naturally, and prompts to the use of the muscles of the right side, it is to do violence to nature, and to dwarf the left side of the body, to enforce upon a child the use of the right.

It thus appears that the preferential use of the right hand is not a congenital, but an acquired attribute of man. It does not exist in the earliest periods of life, but shows itself sooner or later thereafter, according to the development of the muscular and osseous systems.

To the general rule, however, that men prefer the right hand to the left, there are, as to most others, certain exceptions. Some individuals continue during boyhood, and even during their whole lifetime, to use the left hand as readily as the right, and with a strength and endurance little, if at all, inferior. Such persons we call ambidextrous. But in some men a still greater anomaly prevails, for they are truly left-handed. In them the left hand takes the place of the right, being more highly developed and stronger, as well as superior in the address and efficiency which we name dexterity in the other hand.

Among some nations of antiquity the custom seems to have prevailed of cultivating the use of the left hand on account of its utility in war. Thus we read in the Old Testament (Judges xx. 15, 16,) that in the tribe of Benjamin, out of 26,000 men that drew sword there were 700 chosen men left-handed, of whom every one could sling stones at a hair-breadth, and not miss. This gives a proportion of nearly 3 per cent. (2·69) of left-handed men; and as this is a proportion much greater than obtains in other communities of men, it is obvious that the great number must have been the result of education; and it may be inferred, without improbability, that the majority of them must have been ambidextrous, rather than left-handed. No training, indeed, could ever render the left hand of ordinary men equal in strength to the right, all that can be done being to diminish the inequality. A person really left-handed, or having the left hand stronger than the right, is much more rare, and the proportion of such men in all communities is probably nearly the same. What that proportion is I do not know. Among my own schoolfellows and companions in boyhood I recollect only one whom I regard as having been truly left-handed. But there were several who were ambidextrous. Among boys personal prowess and the *virtus bellica* are held in high repute, and they often cultivate the use of the left hand from the idea that it makes them good fighters. This is quite analogous to what takes place in the rude ages of human society, and serves to illustrate the doctrine that, just as it is shown in physiology that the human organism, in the course of its development,

exhibits a series of phases comparable to those observed in the bodies of animals scientifically arranged in a zoological scale, so it is shown in history that the human mind passes through certain stages of development which find their antitypes in the progressive stages of advancement of human society.

II. Explanatory Hypotheses.—The hypotheses which have been formed to explain the inequality in size and strength of the two sides of the body may be divided into two classes, according as they assume increased nutrition or increased muscular action to be the primary differences between them. If it can be shown that the right side of the body is better nourished than the left, then will the muscles participate in that better nutrition; they will therefore be more fully developed and stronger than those of the opposite side; and, as a consequence, they will be more frequently exercised, which will still farther increase their nutritive development. But, again, if it can be shown that, from any cause distinct from increased nutrition, the muscles of the right side are more frequently called into action than those of the left, then, just as in the former case, will the whole phenomena be easily explained, for it is a well-known law which regulates the nutrition of the muscular tissue, that it is the more developed the more frequently and energetically the muscles are exercised.

A. **Higher Nutrition.**—Those who advocate the hypotheses of the former class, and assume that increased nutrition of the right side is of primary occurrence, regard that increased nutrition, either as springing immediately from a law of development of the muscular tissue of the right side, or as resulting in a secondary way from the condition of certain other organs capable of influencing nutrition.

It is quite conceivable that a law of development might directly influence the condition of the muscles, as of any other tissue, on the right side of the body, rendering them larger than the corresponding tissues on the left side. It is not more difficult to conceive this than the known physiological fact, that while in most other animals the organs of generation are developed symmetrically on both sides of the body, in birds they are developed on the left side alone. But it is not enough to show that this hypothesis is not repugnant to the laws of nature. It must be shown also to be in accordance with them; and here the argument fails; for a law of nutritive development would most probably have been apparent from a very early period, even in the embryo, and become gradually more manifest as growth advanced; or it would have been linked with particular periods of life, as is the case with the genital organs in both sexes at the period of puberty, and in the female also at the cessation of childbearing life. But the unequal

development of the muscles on the two sides of the body is neither congenital nor linked with any particular period of life, but is manifestly contingent, both for the period of its appearance and for its progress, on the functional activity of the muscles.

The same arguments are opposed alike to the hypothesis by which the phenomena are referred to the origin, size, or distribution of the blood vessels, whether arteries or veins, on the two sides of the body. It is, besides, very difficult to see how at any period such causes could produce the effects ascribed to them. So far as any difference could result from the different modes of origin of the arteries, it would be confined to the upper limbs; and no explanation is thus given of the difference of the lower limbs. As to the influence of the veins, it might have been passed over in silence had it not been deemed worthy of a special notice and exposition by Dr. Barclay. His views may be gathered from the following notes, taken from his lectures:—"The veins of the left side of the trunk and of the left inferior extremity cross the aorta to arrive at the vena cava; and some obstruction to the flow of blood must be produced by the pulsation of that artery. From this circumstance Dr. Barclay endeavours to explain why man, as well as other animals, use the right side of the body, particularly the extremities, more than the left. All motions produce obstruction of the circulation, and obstruction from this cause must be more frequently produced in the right side than in the left, owing to its being more frequently used. But the venous circulation on the left side is retarded by the pulsation of the aorta, and therefore the more frequent motions of the right side were intended to render the circulation on the two sides uniform." An admiration for his Teacher little short of veneration did not prevent the pupil by whom these notes were taken from appending to them the following criticism:—"This is substituting a final for an efficient cause, and, besides, does not apply to the upper extremities."

B. Precedence in Exercise of Muscles.—The hypotheses of the second class have this antecedent probability in their favour, that they are simple and adequate, in the principle on which they are founded, to the explanation they are intended to give. Let it be supposed that the two sides of the body were, by their original constitution, perfectly equal; then, so long as there was no tendency to use the one side more than the other, the same equality would subsist between them: but if at any time a tendency were to arise, from whatever cause proceeding, to use the one side in preference to the other, there would occur also immediately thereafter a gradual increase in the nutritive development and power of the muscles of that side; but the feeling of increased power

thus engendered would increase the tendency to call into action the more highly developed muscles, which would be followed by a farther augmentation of their development and power; and thus, these two causes reciprocally augmenting each other, out of the mere tendency to use the one side, there would arise a confirmed predominance of that side over the other. The two sides of the body, and the tendency to exert them, may be not unaptly compared to the two limbs of a syphon and the current of water passing through them. If the two limbs and two columns of water within them be of the same length, the water requires to be impelled to pass through either of them; but if the one be made a little longer than the other, the current of water sets spontaneously in the direction of the longer limb.

It follows from what has been said, that, to explain the greater power and development of the muscles of the right side of the body, it is only necessary to assign a sufficient reason why, among mankind generally, those muscles should be more frequently called into action than the muscles of the left side.

Passing over, as devoid of all evidence in support of it, the supposition that there is any law of innervation, or any peculiarity in the size, structure, or mode of disposition of the parts of the nervous system, in connection with the right side, to which the greater tendency to action in the muscles of the right side could be attributed, I proceed to examine two other suppositions,—the one, that the use of the right hand is a human institution or conventional arrangement among mankind; the other, that it depends upon mechanical laws arising out of the structure of the human body.

As to the former of these hypotheses, it cannot, I think, be doubted that the voluntary use of any set of muscles, from whatever motive adopted, and although proceeding from a purely psychological cause, would, if habitually persisted in, signally influence the physical condition of those muscles both in structure and endowments. If, then, we suppose that the two sides of the body were naturally quite equal in point of muscular power, but that the right side were to be systematically and habitually used in preference to the left, the consequence would be that the right side would thereby acquire a higher power and development, that the feeling of conscious strength so engendered would confirm and render easy the habit of employing it, and that the conjoined operation of these causes would be amply sufficient to produce, in course of time, a marked predominancy of the right side over the left. To solve the whole problem, therefore, we have only to suppose that our first progenitors, moved by certain reasons which seemed to them good, showed the example of using the right hand—as,

upon different grounds, I have no doubt they did—and farther, that they inculcated the same practice upon a docile and obedient posterity.

This hypothesis, then, is a plausible one, as it affords a satisfactory explanation of some of the most important phenomena to be explained; but it does not explain the whole of them, as it would have done had it been a true interpretation of nature. In particular, it gives no explanation of the universality of the predominancy of the right hand. Uniformity in their operation is the character of physical causes; variability, of moral causes;—the former resting upon the immutable laws of physics; the latter upon human judgment, passions, and caprices, manifested in minds widely different and ever varying. If the use of the right hand were a mere conventional arrangement, founded on utility or expediency, it would have varied, like every other human institution left to voluntary control. Love of change, fancied utility, the spirit of opposition, and mere caprice, would, in every age of the world, have rendered the use of the one hand as common as of the other. If the barbarians who tatoo their faces, compress their skulls, distort their feet, and otherwise mutilate and disfigure the human frame, are, nevertheless, all of them just as unanimous as civilized nations in the preference of the right hand over the left, we may rest assured that it is not a mere matter of choice on their part which hand they ought to prefer.

The theory, then, which ascribes the use of the right hand to example and precept, and its higher power and development to the habit of using it, although plausible at first sight, as explaining some of the most remarkable phenomena, is found, nevertheless, on more minute scrutiny, to be beset with insuperable objections. Some cause subject to the never-varying laws of physical nature, and independent of all voluntary control, could alone produce a habit so nearly universal. The remainder of this memoir will be devoted to show that it is the result of mechanical laws, arising out of the organic relations of the two sides of the body, and the inclination of the common centre of gravity to the right side determined thereby.

III. Mechanical Theory.—The view which I take of the origin and causes of the predominancy of the right side is as follows:—I believe that there is no primary or congenital difference in power and development between the two sides of the body; for this is what we observe in infancy and early childhood. But no sooner does the child acquire sufficient vigour of muscle and firmness of bone to be able to put forth the whole strength of his body, than he becomes conscious that his right side is more powerful than his left. So long as he uses his limbs

as mere appendages of his body, and separately from it, he uses those of either side with a like efficiency; but when he becomes capable of making all the muscles of his frame—of trunk and limbs—co-operate in producing a combined effort, which nature prompts him to do as soon as he has strength to accomplish it, then for the first time he becomes conscious of the superior power of his right side—a power not primarily due to any superior force or development of the muscles of that side, but to a purely mechanical cause. He cannot put forth the full strength of his body without first making a deep inspiration; and by making a deep inspiration, and maintaining afterwards the chest in an expanded state, which is essential to the continuance of his muscular effort, he so alters the mechanical relations of the two sides of his body that the muscles of his right side act with a superior efficacy; and to render the inequality still greater, the muscles of the left side act with a mechanical disadvantage. The consequence is, that the muscles of the right side are called into action in preference on all great occasions where muscular power has to be put forth; and, from being more frequently exercised, they become more highly developed, stronger, and more prompt to action. The full predominance of the right side is thus ultimately established. One limb of the syphon has been made longer than the other, and the whole current sets in that direction.

With the view of establishing this doctrine I shall first endeavour to prove certain preliminary propositions with respect to the position of the centre of gravity of the body, the changes in the position of it produced by the act of respiration, and the connection between the act of respiration and muscular exertion; and I shall thereafter point out the mechanical principles which render the inclination of the centre of gravity of the body to the right side the primary cause, and at all times one of the principal causes, of the superiority of the limbs of the right side over those of the left. The whole argument thus divides itself into two parts, the proof of the first of which is chiefly experimental, or derived from general reasoning, while the proof of the second is chiefly demonstrative. But I shall add a third part, containing some evidence not strictly belonging to either of the former heads, or omitted in its proper place, not to encumber the general argument.

A. Preliminary Propositions.

1st. *The centre of gravity of the body situated not in the mesial plane, but to the right side of it.*—Borelli found the centre of gravity of the body to be situated between the hips and the pubis, or in the middle of the pelvis. His experiment was made by poising a table accurately on the edge of a triangular prism placed under it *transversely*, and laying thereupon a dead body, which he shifted upward

and downward till equilibrium was produced. This experiment could determine only the transverse plane in which the centre of gravity is placed. But to render the investigation complete, it should have been accompanied with another experiment, similarly made with a table poised on the edge of a prism placed under it *longitudinally*, which would determine whether the centre of gravity be situated in the mesial plane or to one side of it.

Weber has of late years repeated Borelli's experiment, with various precautions to insure accuracy. He found the point fixed upon by Borelli as the centre of gravity to be too low. In a man 5 feet 2·329 inches in height (1669·2 millemètres) he found it to be (87·7 millemètres) rather more than one-third of an inch above the promontory of the sacrum. However accurate this determination may be, it is liable to an objection, which applies equally to that of Borelli, that the position in which the body is placed during the experiment makes the weight of the hands and arms tell too much downward; for the hands are stretched out by the sides, and extend downward to the middle of the thighs. This is the position in which a man is laid in his grave, but what is wanted is to determine the centre of gravity in living men during a period of active exertion, in which the body is erect and the upper extremities free, with their whole weight appended to the shoulder-joints. To determine this with the body recumbent, the upper extremities should be placed on either side in the same straight line, or at right angles to the trunk of the body; the mechanical effect of which, in such an experiment, would be just the same as if the whole weight of the upper limbs were placed in the middle line of the body, at the top of the sternum. Such an arrangement would elevate the centre of gravity of the body nearly as high as the umbilicus.

But no attempt has been made, so far as I know, to determine experimentally whether the centre of gravity of the body be situated in the mesial plane or to one side of it; and in the absence of direct experiment we must have recourse to general reasoning. It cannot, I think, be doubted that in the adult the greater development of the locomotive organs of the right side will cause the centre of gravity to deviate from the middle plane, and incline to the right. In the fœtus, and for some time after birth, the vast size of the liver will give rise to a similar deviation. But in a child from one to two years of age, in whom the liver has diminished in size, and assumed the relations to the other viscera that it is afterwards to retain, but in whom the locomotive system of the right side has not yet acquired a predominancy, it is probable that the two halves of the body, separated by a vertical section from before to behind, differ very little in weight from each other;

and in that case the centre of gravity must be situated in the middle plane. Now, it is at that very age, when the child makes his first attempt to walk alone, that he begins to exhibit the tendency to use the right side of his body in preference to the left; which leads me to think that the primary cause of that tendency is the deviation of the centre of gravity towards the right side produced by inspiration, rather than that resulting from any structural difference of the two sides.

2d. *A deep inspiration necessary to every great muscular effort.*—This proposition need not detain us long. All who have studied the science of physiology know that it is essential to every great muscular effort that a deep inspiration should be first made, and that the chest should continue in the expanded state as long as the effort lasts. You know that an animal cannot run, leap, or make any other great muscular exertion if it have an open tube inserted into the windpipe, or if there be anywhere an open wound through which the external air communicates freely with the air passages, because in such circumstances the chest cannot be maintained in the expanded state. You know also the two great ends which are served by the continued expansion of the chest, accompanied as it is with a fixity of the abdominal muscles—to convert the trunk of the body into a firm basis of support for the limbs and contracting muscles, and fully to aerate the blood which is to stimulate the muscles and nervous centres during the period of their excitement. I shall advert but to a single circumstance connected with this process, because it has a mechanical significancy, and bears upon our present subject. During certain muscular efforts, as in those which we name expulsive, the included air is retained in the chest by the closure of the glottis, the slender muscles of which are enabled to withstand the force of the much more powerful expiratory muscles by a mechanism which Sir C. Bell has explained. But it is taught erroneously, as appears to me, that the same thing happens in violent exercise of the voluntary muscles, for in these the glottis remains open, the mouth and throat forming a common cavity with the chest, in which the air is retained by the compressed lips and nostrils.

3d. *Shifting of the common centre of gravity of the body obliquely backward and to the right on making a deep inspiration.*—I have endeavoured to show that in the dead body, if the upper limbs be placed so as to produce the same mechanical effect as in active muscular exertion, the centre of gravity is placed a little below the navel, and inclined to the right side. In the living body, so far as it can be said to have any fixed place, it occupies the same point when the lungs are undistended; but upon making a full inspiration, as we have just seen must always be done to prepare for any great muscular exertion, the centre

of gravity inclines farther to the right side and backward, nearly in the direction of the right heel, and it remains in this new position as long as the chest continues in the expanded state.

This problem, like that relating to the ordinary position of the centre of gravity of the body, admits of experimental proof, and I have given below (Part C., 1*st*) the only experimental evidence I have to adduce in support of it. I here subjoin some general arguments pointing to the same conclusion.

The right lung is more capacious than the left, having three lobes, while the left has only two, and it receives more air on inspiration, to the extent, as has been estimated, of about one-twelfth. If, therefore, 240 cubic inches be inhaled, which is under the highest *complement* given by Mr. Hutcheson, the right lung would receive 20 cubic inches more than the left. In consequence, the right side of the chest bulges out more than the left on inspiration, as is manifest to the eye; and the lower ribs, as they recede from the middle plane, carry with them the liver, which is firmly bound to them on the right and posterior aspects by its short and strong coronary ligament, while its other ligaments being long and lax offer no impediment to its outward motion. Now, the liver being the heaviest organ of the body, weighing nearly 4 lbs. avoirdupois, to whichever side it swings it will incline the common centre of gravity in the same direction. The combined effect, therefore, of greater expansion of the right side of the chest, and the motion of the liver, is to shift the position of the centre of gravity of the body obliquely backward and to the right, and probably also somewhat downward. The inclination of the centre of gravity to the right is not counteracted, as might at first be supposed, by any motion of the heart in the opposite direction, for the heart is firmly attached to the spine and diaphragm by the pericardium, and the expansion of the adjacent part of the lung takes place to the left of it, and often also in front. As to the stomach and spleen, they go with the liver, to which they are attached by veins and by the omentum minus, rather than follow the left ribs, with which they have no structural connection.

4th. *More general view of the utility of the act of respiration in shifting the position of the centre of gravity in subservience to the movements of the body.*—We have shown that when both sides of the chest are equally distended, as in ordinary inspiration, the centre of gravity of the body shifts obliquely backward and to the right, which, for the purpose of our argument, is the most important point to establish. But it tends to confirm and illustrate this, to show also that nature makes use of the act of respiration for many analogous purposes, shifting the centre of gravity of the body in subservience to its intended

movements. This is effected by means of the viscera attached to the diaphragm above and below, viz., the liver, heart, stomach, and spleen. These together form a mass of from five to six pounds in weight, which, as it is carried by the motion of the diaphragm upward or downward, or inclined to either side, backward or forward, cannot fail to influence the position of the centre of gravity of the body. Every energetic muscular action has a peculiar mode of respiration, which we instinctively combine with it, and the main object of which is to adapt the position of the centre of gravity of the body to the motion to be performed. Thus, in preparing for violent exertion with the right hand, instead of inflating the two sides of the chest alike, the left side is contracted and the right side distended to the uttermost, which has the effect of shifting the centre of gravity, in the direction indicated above, farther than an ordinary inspiration can effect. In using the left hand again, the left side of the chest is fully distended, while the right is only moderately distended above, and below it is contracted and inclined to the left, so as to force the visceral mass in the same direction. In preparing to leap upward, as upon a chair, the centre of gravity is elevated, the visceral mass being forced upward by the contraction of the abdominal muscles, while inspiration is made altogether by the dilatation of the ribs without any depression of the diaphragm. But in leaping down again the inspiration is chiefly made by the depression of the diaphragm, which lowers the visceral mass and centre of gravity.

Still farther, the respiratory muscles, during the continuance of any muscular effort, adapt themselves to the necessary change in the position of the centre of gravity, and thus facilitate the effort. In throwing a stone the centre of gravity advances forward and to the left, being over the right heel at the commencement of the act, and over the right foot at the end of it; and, correspondingly, it will be found that while the right side of the chest was dilated and the left contracted at the beginning of the act, it is the left side which is dilated and the right which is contracted at the end of it; even in the mouth it will be often seen that the right cheek is inflated at the beginning and the left at the end; and all these changes take place by the mere movement of the air within the chest and upper air passages, without any fresh act of respiration. It is otherwise, however, if the effort made be beyond the strength of the individual making it, for then the air rushes forth with a loud sighing noise, as we hear in the paver and the man who wields the sledge hammer; and so great is the force with which the air rushes forth, that the attempt to confine it is often followed by deplorable consequences, as I have myself witnessed.

5th. *The kind of respiration which accompanies the action of the*

limbs of the right side more favourable to sustained muscular exertion than the respiration which accompanies the action of the limbs of the left side.—The respiration which accompanies the action of the right side is free and nearly natural, while that attending the action of the left side is constrained and with much less amplification of the chest; so that the aeration of the blood and consequent excitation of the nervous system and muscles must be effected more completely in the former case than in the latter.

B. The inclination of the centre of gravity of the body to the right side confers a mechanical advantage on the limbs of the right side in their complex movements, while it is mechanically disadvantageous to the limbs of the left side in the analogous movements which they perform.

This proposition embraces the whole of the mechanical or demonstrative part of this argument. It is too general to admit of proof without being divided into several subordinate propositions; and these must be preceded by what mathematicians would name a lemma, explanatory of the principles on which we can compare together the muscular actions of the two sides of the body, so as to judge of their relative power —that is, to estimate the momentum which they respectively generate.

1*st.* The momentum imparted to the body by its own muscles, in the transition from one attitude to another, will be greater or less—(1*st.*) According to the number and power of the propelling muscles; (2*d.*) According to the mechanical disposition of the bones or passive organs of motion; (3*d.*) According as the propelling muscles are in effective action during the whole or only during a part of their range of contraction; and, (4*th.*) According as the resultant force in the direction of which the centre of gravity moves is generated by forces more or less parallel—that is, less or more antagonistic to each other.

The first mode of comparison is chiefly applicable to movements which are dissimilar to each other; for in these it is obvious that the number and strength of the muscles called into action must often differ widely. But they are foreign to our subject; for in comparing together the two sides of the body, we compare movements which are strictly analogous. In these it might at first be supposed that there could be no difference in the number of the propelling muscles on either side. It will, however, be seen below that the predominancy of the right arm over the left is mainly owing to the greater number of muscles that assist in giving it motion.

The second mode of comparison affords demonstrative evidence derived from the principles of mechanics of the relative power of the

two sides of the body. It is exemplified below with respect to the movements of the lower limbs in all their varieties.

The third mode of comparison might have been otherwise described as referring to the greater or less length of the line described by the centre of gravity under the influence of the propelling muscles. In all analogous movements the longer this line the greater is the momentum generated, although not in strict proportion. Thus a man will never spring from the ground in a standing posture so high as when slightly bent, nor in the latter posture so high as he can do if he first put himself in the stooping posture which nature and experience teach him to assume for the purpose; and in each of these cases the length of the line described by the centre of gravity, from the point at which it begins to move till the feet leave the ground, serves to indicate the momentum generated. It will be seen that this principle is applied in comparing together the lateral movements of the pelvis on the two sides.

Of the principle involved in the last mode of comparison we may take as illustrations the movements to which it is applied below. We leap farther straight forward than with much inclination to either side: but we leap farthest of all with a slight inclination to the left side; for the centre of gravity has the greatest range in that direction, under the influence of the muscles acting on the pelvis; and an additional impulse is given to it forward and to the left, by the transition of the thorax from the state of inspiration to that of expiration, which transition accompanies the act of leaping with full force; lastly, the propulsion on the right side is more powerful than on the left.

2*d*. *Comparative Power of the Lower Limbs.*—The simple movements of the lower limbs present no difference on the two sides of the body in the mechanical conditions under which they are performed. They are therefore excluded from our present inquiry, which relates only to those complex movements in which the lower limbs communicate an impulse to the whole body; and we are to compare the impulse communicated by the muscles of the one side with that communicated by the similarly acting muscles of the other side. As it is to the pelvis that such movements are immediately communicated, we shall speak of them as movements of the pelvis, and we shall consider successively the upward, the lateral, and the revolving movements of the pelvis.

a. Upward Movements.—The upward movement of the pelvis is usually the result of the simultaneous action of the two limbs; but it can be conceived to be produced by one of them only; and we have various practical illustrations of it, approaching more or less closely to the theoretical model. When we carry a weight upon either shoulder it is the lower limb of the same side that chiefly sustains the weight.

Movements effected by Lower Limbs

Upward Movements.

Fig. 1.

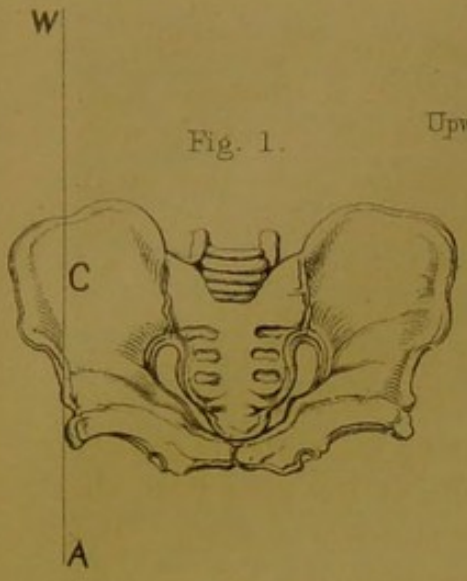
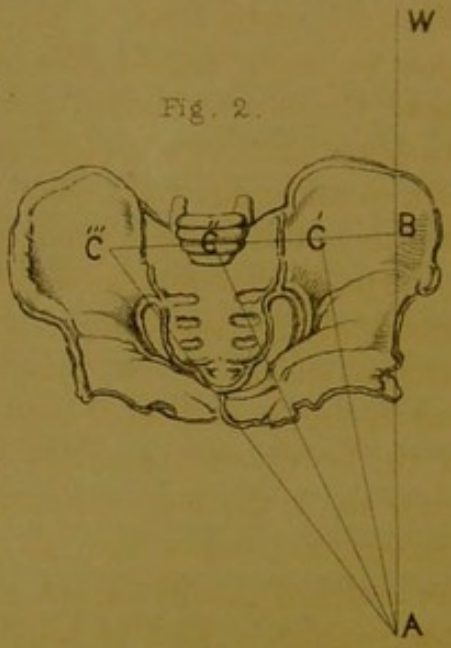


Fig. 2.



Revolving Movements

Fig. 3.

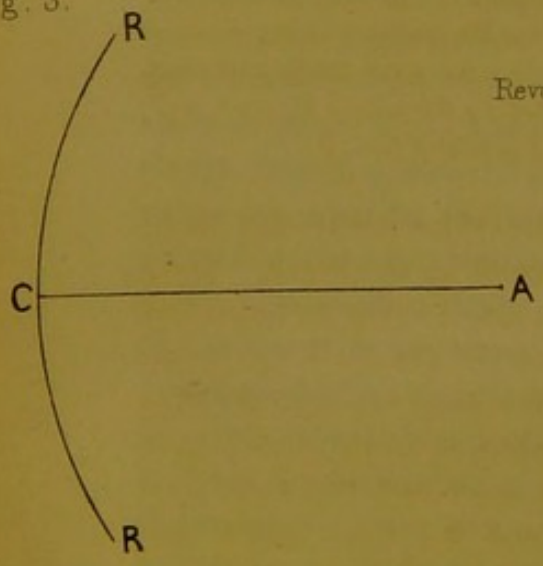
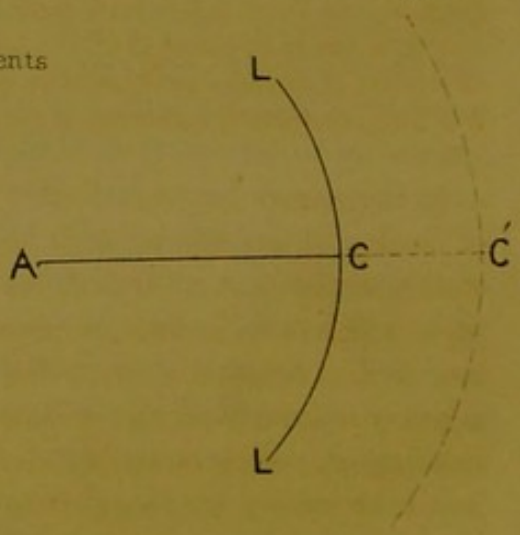


Fig. 4.



Lateral Movements.

Fig. 5

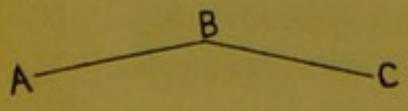


Fig. 6.

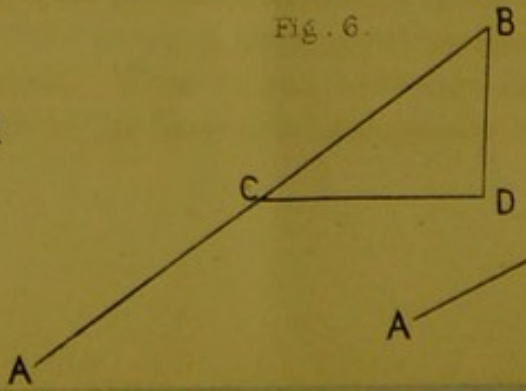
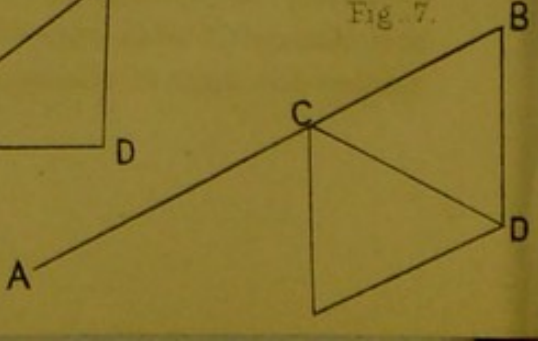


Fig. 7.



When the carter bears up the shaft of the cart upon his shoulder, or when we apply the shoulder similarly to overcome a resistance from above, the muscular action put forth originates chiefly or entirely with the lower limb of the same side. Now, experience shows that on all such occasions the right shoulder is much more powerful than the left. Neither is this result difficult to explain; for to make either limb act with the greatest mechanical effect it is necessary to make the centre of gravity of the body coincide with the line of direction of the superincumbent weight. Now, upon the right side, the position of the liver and the influence of a full inspiration readily bring the centre of gravity of the body nearly over the right foot, while, at the same time, the joints are in the most favourable position for muscular exertion. But the same two causes have an adverse influence upon the left side; for the centre of gravity cannot be made to come so nearly over the left foot without a kind of respiration and a constrained attitude, little favourable to the muscular action to be performed. (Plate I., figs. 1, 2.)

In fig. 1, Pl. I., the centre of gravity, C, lies in the line of direction of W, the resistance to be overcome, and the muscular power, A C, is applied in the most advantageous direction. In fig. 2, A B is made equal to A C, fig. 1; but the position of the centre of gravity is not at B, but at C′ C″ C‴, &c., when, to produce the same mechanical effect, an amount of muscular power must be put forth, indicated by the lines A B, A C′, A C″, A C‴, &c., continually increasing as the centre of gravity is farther from B.

It sometimes happens that the upper extremities receive the credit of muscular exertions which are in reality made by the lower. Thus, in the action just described, the shoulder appears to play an important part, while it is, in fact, no more than the end of the shaft set in motion by the muscles of the lower limbs. In the same manner, in lifting a heavy weight from the ground, the arms appear to be the most important agents, while in reality they are, for the most part, like mere inert ropes by which the weight is suspended, and the force which acts through them is derived from the lower limbs. The act of lifting a weight, although apparently so different, is quite analogous to the act last described, in the mechanism by which it is performed. It may be performed either with both hands or with the right and left singly. It thus becomes an excellent means of testing the relative power of the two sides of the body. The weight suspended by the arm from the shoulder has the same mechanical bearing as if placed upon it; and the principles explained above show that the action must be performed most effectively by the muscles of the right side.

b. Lateral Movements.—The pelvis may be impelled towards either side by the limb of the opposite side; and in any direction, transverse

from either side, or oblique from behind forward, or from before backward. To produce such a movement the limbs are separated from each other, the impelling limb being more or less bent, and the opposite one extended. On straightening the limb the centre of gravity is impelled to the opposite side with an inclination at first upward and then downward. The first half of the movement is produced by the power of the muscles alone, the second by that power acting in conjunction with the weight of the body; the resulting movement being in the diagonal line intermediate between the direction of the two generating forces.

Of all of these lateral movements that which is practically the most important, and which is also the most extensive in its range, and generates the greatest momentum, is the movement obliquely forward and to the side in a line intermediate between the transverse and antero-posterior diameters of the pelvis. The foot of the side towards which the motion is made is advanced in the line just described, while the other foot is placed sideways behind, and, as in all the lateral movements, the centre of gravity rests over the one foot at the beginning of the movement and over the other at the end of it.

When we compare the lateral movements originating on the right side with the analogous movements originating on the left, we find the former to possess a mechanical superiority over the latter. This superiority is mainly due to the position of the liver; for as this weighty viscus is situated on the extreme right, and the body advances sideways, it must manifestly be in front in the motions towards the right side, while it is behind in the motions towards the left. Now, a double mechanical advantage accrues to the right side from this cause. In the first place, to produce lateral movement, the previous flexion of the joints of the impelling limb is required; for it is by the extension of them that the impelling force is produced, and of these joints the hip joint is the most powerful. Now, from the position of the liver over the right hip joint this joint admits of being bent while the body inclines towards the left side, without disturbing the favourable position of the centre of gravity, and thus the powerful muscles of the hip joint exert their full force upon the right side. On the left side, again, from the liver being situated on the opposite side of the centre of gravity from the hip joint, the body cannot be inclined to the right without a displacement of the centre of gravity in the same direction, and thus the flexion of the left hip joint cannot take place without making its muscles act at a mechanical disadvantage.

In the second place, the centre of gravity moves farther under the action of the muscles, without interfering with stability, in its course

from right to left than in that from left to right. In either case, the weight of the body as it moves forward comes to be thrown from the foot behind to the foot in front; but the movement from right to left may be carried as far as the power of the muscles and flexion of the left limb in front will admit, for the weight of the liver behind keeps the equilibrium stable, whereas the movement from left to right is prematurely arrested, for the liver being in front renders the equilibrium unstable, as the line of direction sooner approaches the limit of the basis of support.

These arguments, deduced from the mere position of the liver, without reference to the act of respiration, are rendered more forcible by taking into account the influence exerted by the respiration on the mechanical condition of the body. (Figs. 5, 6, 7.)

In fig. 5, Plate I., the line A B C represents the direction of the lateral movements of the pelvis ascending from A to B, and descending from B to C. In fig. 6 the oblique force A C B is resolved into a horizontal portion, C D, which carries the pelvis to one side, and a portion, D B, directed upward. But in fig. 7 the direction, C D, is obliquely downward, and the force of gravity conspires to augment the impetus of the body.

In the oblique lateral movement of the pelvis we have another instance of an action performed by the lower limbs being often ascribed to the upper. This happens when a pole or other weapon is held in the two hands in the same way in which a musket is held in a charge of bayonets—that is, when the weapon is supported by the two hands horizontally in the plane of the centre of gravity, or nearly so, and in a direction obliquely forward from right to left. This is the very direction in which it has just been shown that the right limb impels the body most forcibly, and the whole of that force is communicated to the advancing weapon, which the hands merely sustain without giving it any additional impulse. This is the case when the hands are pressed close to the body, but when they are protruded forward, as is likely to happen in warfare, they give new force to the weapon.

c. Revolving Movements.—The pelvis may be impelled by one limb so as to revolve horizontally, or nearly so, upon the other; the centre of revolution in the latter being the head of the femur, or some part of the foot—the fore part of the sole, the toes, or the heel: while the movement is for the most part rendered more complicated by the ankle joint passing from a state of extension to flexion, and the hip joint from a state of flexion to extension. But in all its varieties of form this revolving movement is performed more effectively and more steadily by the impulse of the right limb than by that of the left. The reason of its being more effective is very obvious; for the centre of gravity, lying

towards the right side, and being farther impelled in that direction by inspiration, the muscles of the right side act with a longer lever and proportionally greater power than the muscles of the left side. Its greater steadiness, again, is owing to the position of the liver at the outer extremity of the radius of curvature, which, by its centrifugal power, acts like a regulator. On the left side, on the contrary, the position of the liver, at the inner extremity of the radius, tends to render the movement insecure. (Figs. 3 and 4, Pl. I.)

In figs. 3 and 4, Pl. I., A is the centre of revolution on either side, C and C′ are the centres of gravity, and R C R, L C′ L, are the directions in which the centres of gravity are made to revolve by the right and left limbs respectively; giving a mechanical advantage to the former over the latter, as A C to A C′.

3d. Comparative Power of the Right and Left Arms.—There is a much more signal inequality of power between the upper than between the lower limbs. It is also quite different in nature from that which we have described above as existing between the lower limbs. But it does not belong to the upper limbs alone, for the lower limbs participate in it, and generally the two sides of the body, although in so saying it is necessary to distinguish the two sides of the body in a somewhat different sense from that in which we distinguish them as separated symmetrically by a mesial plane.

When we compare together the simple movements performed on the two sides of the body, at the several articulations both of the upper and the lower limbs, we find no inequality between them, except what may arise from a difference of power in the muscles; for the mechanical conditions under which each joint moves on the two sides of the body are exactly the same. Thus it is with the movements of the two upper limbs in their totality, as performed at the shoulder joints; for whether these movements consist in flexion in any given direction, in rotation, or in circumduction, the mechanical conditions under which they are performed are precisely similar. The same holds of the movements at the hip joints, so long as the trunk of the body has no participation in them, but acts merely as a basis of support to the limbs. But we found it to be quite otherwise in the complex movements in which the body participates; for in these we found that the right side had a mechanical advantage over the left. Now, the same holds true of the upper limbs; for it is only in the complex movements in which the trunk of the body participates largely that the right side has a mechanical predominance over the left.

The movements in which the right arm predominates most signally

over the left are those in which it is made to describe a curve from behind obliquely forward and to the left, as in throwing a stone or other missile, or striking a blow with the fist or with a weapon held in the hand. The arm is extended more or less in these movements, chiefly according to the weight with which it is charged; but, overlooking at present all lesser differences, we select as an example of these, and of other kindred movements, the throwing of a stone of such moderate size that it can be held at arm's length without inconvenience. The arm is extended to the uttermost, and the hand holding the stone, as it revolves rapidly round the body, describes a curve, which we shall see reason to believe, in the case of the right hand, to be a cycloid. Now, while this movement is performed with ease and effectively by the right hand, it is performed much less perfectly and with difficulty by the left —the act being accompanied with a feeling of constraint and impediment, and sometimes with insecurity in the positions into which the body is apt to be thrown.

With the right arm a stone is thrown most forcibly in a direction obliquely forward and to the left. The left foot is advanced in that direction, with the ankle, knee, and hip joints fully extended. The right foot is placed behind, nearly at a right angle to the left, and with the joints just named all slightly bent, to be in readiness to give an onward impulse to the body. The head rests over the right shoulder, with the eye fixed steadily on the object aimed at; the trunk of the body, as well as the head, are thrown backward and to the right; the right arm with the hand holding the stone, is extended to the uttermost in the same direction, while the left arm is bent across the neck. This attitude and a deep inspiration, made preparatory to the muscular effort, cause the centre of gravity to rest over the right heel, without any constraint to impair the power of the contracting muscles or organs of respiration. Such a complicated arrangement would be unnecessary were the arm to act alone, merely swinging in a circle round the shoulder joint; but instead of that the whole body revolves, the arm merely participating in the movement. The axis round which the body revolves is not its symmetrical axis, but its true mechanical axis, as it may be named, coinciding with the line of direction (*linea propensionis*) —that is, with a plumb-line let fall from the centre of gravity, and produced upward. Around this axis the whole body revolves, the right side and arm advancing, while the left side and arm are carried backward,—the left arm having at the very first been brought rapidly forward, and outstretched to the uttermost on its own side, to counterbalance the right arm. Were the axis of revolution quiescent, a circular motion of the arm would be the result; but instead of this the axis moves

forward and to the left, impelled by the right lower limb, till it terminates its movement over the fore part of the sole of the left foot, or a step farther forward still, over the right foot, which has in the meantime swept rapidly round from behind to before. Now, as the arm continually revolves round this advancing axis, it will describe a cycloid in its course. There is scarcely a muscle in the human frame which does not take a part in this complicated movement—the right and left sides revolving in opposite directions, and thus co-operating in the impulse they communicate; and it is worthy of remark, that the direction in which the centre of gravity is made to move, obliquely forward from right to left, is precisely the direction in which it has been shown that the right lower limb acts with most mechanical effect, whether it retain its place behind or revolve to the front. Hence it is clear that the superior power of the right arm is not due to the muscles of the arm alone, but to numerous muscles on both sides of the body co-operating with them in a direction highly favourable to their mechanical effect. (Plates II. and III.)

Plate II. represents three successive stages in the act of throwing a stone according to the method first described above, in which the toes of the right foot remain in the same position at the end as at the beginning of the action. Fig. 1 represents the position at the beginning, fig. 2 in the middle, and fig. 3 at the end of the action.

Plate III., fig. 1, represents the attitude of the body at the end of the second method of throwing the stone above described, in which the right foot performs a semi-revolution round the left, and so advances in front of it.

Plate III., fig. 2,* represents the attitude of the Discobolus, or discus-thrower, from the well-known antique statue in the Vatican. The right arm and left leg are thrown back, to balance the upper part of the trunk, which stoops forward, with an inclination to the right; the centre of gravity is thus thrown over the right heel, and the whole body turns on its mechanical axis, as the right arm performs somewhat more than half a revolution round it in discharging the discus. The modern method of throwing the quoit is different, bearing much the same resemblance to throwing a stone in the ordinary way that the ancient method of throwing the discus bears to what school-boys call *haunching* a stone.

The mechanical conditions favourable to the right arm are no longer of advantage, or are reversed, when the same action comes to be performed with the left arm. The centre of gravity of the body has no natural tendency toward the left side, and, when a deep inspiration is made, swings away from it backward and to the right. A peculiar kind of inspiration therefore, already described, requires to be made to regulate the position of the centre of gravity; but it is of a kind less favourable to muscular effort than the ordinary inspiration, and, moreover, cannot

* For the photograph from which this engraving has been taken, and which was made from a cast in the gallery of the Government School of Art in this city, I am indebted to the kindness of Charles Heath Wilson, Esq.

Fig. 3.

Third Attitude

Fig. 2.

Second Attitude

Fig. 1.

First Attitude

Throwing Stone.

Wm White . Phot.

Maclure & Macdonald, Lith.

be maintained as the body advances forward, when the centre of gravity again inclines to the right side. There is, therefore, no longer the same harmony between the two sides of the body revolving round a common axis; the left arm, compelled to rely more on the action of its own muscles, swings round the shoulder in a course more nearly circular; and less aid is derived from the left lower limb, which has been already shown to propel the body at greater disadvantage than the right. The causes, therefore, are manifest which impede the action of the left arm, and produce the awkwardness and constraint, and the occasional instability with which it is accompanied; the kind of respiration required being less favourable to muscular exertion, the two sides of the body not balancing each other, nor revolving harmoniously round a common axis, the arm acting chiefly by its own muscles, and the lower limb assisting it less powerfully.

4th. Burdens best carried on Left Side.—I have reserved to the last the notice of the only instance I know in which there is a mechanical advantage in the use of the left side, and in which that side is in consequence used in preference to the right. Carrying or supporting burdens is the special function of the left side. Look at the women who go along with baskets of eggs or vegetables. They all carry the baskets on their left arms. The nurserymaid carries an infant on her left arm. If you ask her the reason, she can probably only reply that she was instructed to do so, or that all other nurserymaids do the same. But if you ask the same question at an intelligent mother in the humble ranks of society, she will tell you that she must keep her right arm free for the older children, and for her various household duties. Her view, then, is, that it is on account of the comparative uselessness of the left arm that it is set to sustain burdens, and so leave the right arm free for its more important duties. This is true in so far, but there is besides a mechanical cause which is overlooked. A different reason certainly must be given why the porter hoists a heavy trunk or the carter a sack of meal on his left shoulder, for the burden demands his whole strength, and the right arm acts the part of a mere auxiliary to the left.

There are two mechanical reasons for the preference given to the left side in carrying burdens; the one applying to light weights swung upon the arm, the other to heavier weights borne upon the shoulder.

In carrying a weight not heavier than can be borne on the arm, the equilibrium of the body is better maintained by carrying it on the left side; for the centre of gravity being upon the opposite side, less inclination of the body to that side is required when the weight is appended to the left; and there is, therefore, less interference with the natural play of the limbs in walking: whereas, if the weight be appended to the

right by the side of the liver, the body must be thrown very much to the opposite side to keep the equilibrium stable, and the motion of the limbs will be proportionally constrained.

The mechanical conditions under which a man bears a heavy weight upon his left shoulder are quite different, and still more worthy of admiration. The burden is in reality supported, not by the left, but by the right lower limb. The body is inclined to the right side, as described above with respect to the act of throwing a stone, so that the mechanical axis passes from the left shoulder to the right foot, and the load is placed right upon the top of it, the whole force of the right arm being employed to place it there.

In this way the muscles exert their full force effectively in sustaining the load, while the whole body is so disposed that it can revolve freely on its mechanical axis, which is of great service in adjusting and throwing off the load. But there is a still more wonderful adjustment; for the centre of gravity is so placed that the body can revolve also with ease and the full force of the muscles on another axis passing through the centre of gravity at right angles to the former. By this kind of revolution, which is like that of a wheel upon its axle, the weight can be thrown off the shoulder to the left, or over the head to the right, with as much ease as it can be thrown backward or forward by the revolution first described.

The left side may therefore be compared to a "beast of burden," the offices of which it is fitted by a special mechanical adaptation to perform. The right side is like the horse—prompt, rapid, powerful, and graceful in its movements; while the left is like the camel—less ready, and more slow and awkward, but bearing its burden indefatigably, and stooping to receive and to be released from its load. (Plate III., fig. 3.)

Plate III., fig. 3, represents a burden borne on the left shoulder at the summit of the mechanical axis passing along the right lower limb, while the body is capable of revolving either on this vertical axis or on an axis at right angles to it, and intersecting it in the middle of the loins.

To recapitulate, I have shown that the greater development of the muscles of the right side is owing to the more frequent use made of them; and that this more frequent use, although in part proceeding from their greater development, is originally altogether independent of the condition of the muscles, and due to a mechanical cause inherent in the constitution of the human frame—the position of the centre of gravity to the right of the mesial plane, and the farther inclination of it backwards and to the right on deep inspiration, essential to muscular effort; and lastly, I have explained in what way the position of the centre of gravity operates in giving predominancy to the limbs of the right side.

Fig. 3.

Burden on Left Shoulder

Fig. 2.

Throwing Discus

Fig. 1.

Throwing Stone

C. Additional Illustrations.

To these arguments, deduced chiefly from the principles of mechanical science, I shall add one or two, chiefly of an experimental kind, which address themselves to our senses or conscious bodily feelings, or to the common experience of mankind.

1. The first addresses itself to the sense of sight, and exhibits one of the marvels of the human mechanism. When the body stands erect on the two feet, while the posture is stable and secure, the various parts of the frame, if not voluntarily restrained by the action of the muscles, preserve their mobility with respect to each other, and yield lightly and gracefully to the slightest impulse, like a tree fast rooted in the ground, while its branches quiver in the breeze; or like a ship held fast by its moorings, while it rocks lightly on the waves. A floating body is indeed the best similitude. A light boat floating in the water changes its position with every change of its centre of gravity, such as would be occasioned by a person in it moving from one place to another. A cart or waggon resting on dry ground would be quite uninfluenced by a similar cause; but we see an approach to it in a well-hung carriage, the springs of which yield in correspondence with the position of the persons within it. Now, the human body, placed as we have supposed, is supplied with numerous delicate springs that connect its several parts, as between the toes and bones of the feet, and at the ankles, knees, hips, and joints of the spine; and so lightly and delicately is it poised, that every movement of its centre of gravity produces involuntarily a perceptible change in its position. Thus it oscillates with the act of breathing; when the centre of gravity shifts during inspiration, it inclines to the right side, and it returns to its former position during expiration. This oscillation is best seen in our own persons, because its correspondence with the conscious acts of inspiration and expiration serves to guide the eye of the observer. It may be seen in a looking-glass, or on the shadow of the body fitly thrown on a screen or wall. My attention was first attracted to it in a different way. Looking from my own window at a light in the house opposite, I was amusing myself listlessly by bringing the bar of the window opposite into such a relative position that it might conceal the light at once from both eyes. I succeeded in doing this, but remarked at the same time that the light appeared from time to time. Further observation satisfied me that the appearance of the light corresponded with the act of inspiration, and that it always appeared at the right side. It immediately occurred to me that this phenomenon might be connected with the arduous problem which Dr. Barclay had first taught me to investigate, and which I had ever since pursued with such little success; and arguing from the

observed phenomenon upwards to its cause, and from the cause, when once established, downwards to its effects on the movements of the body, I became persuaded that I was on the right road. Such, at least, was the embryo idea conceived last spring. It has since gone through exactly a nine months' process of evolution, and I now leave it to you* to decide whether it is to be regarded as a mere abortion or shapeless monstrosity, or, if more happily organized, and fitted for independent life, it is to become stronger as it grows older, till it can at length assert its place among the genuine doctrines of physiology.

2. A second argument addresses itself to a peculiar internal sensation, the precise nature of which it is for physiologists to determine.

Let any one compare the strength of his right and left arms while the lungs are in the unexpanded state; let him then make a full inspiration, and he will feel the power of his right arm increase with every cubic inch of air which he inhales, till it attains its maximum, when the inspiration is completed. In the left arm, again, he will perceive little change, so that the disparity between the two arms is increased by inspiration. Or, again, let any one, when the power of his right arm is at its maximum, blow out his breath, and the power will gradually dwindle down to the standard of the left arm.

As to the sensation by which we become conscious of the increasing or diminishing power of the right arm in the preceding experiments, it is manifestly of the same class as those intrinsic sensations which serve to indicate to us certain conditions of our internal organs—as a hungry stomach, a parched mouth, or a distended bladder. It is most closely allied to those sensations which indicate to us the conditions of the muscular system; but it is not identical with what has been called the muscular sense, for it merely gives to us a consciousness of possessing strength, and not of actually putting it forth, of which the muscular sense is the measure.

3. There is less inequality between the two sides of the body in women than in men, which is owing partly to the strictly symmetrical arrangement of the generative organs within the pelvis, and partly to the slenderness of the waist and less breadth between the shoulders. But in civilized society, and more especially among the higher ranks, it is mainly owing to the style of dress which, by contracting the waist, renders useless the apparatus provided by nature for adjusting the centre of gravity in accordance with the movements of the body.

4. After studying the kinds of inspiration which accompany the action of the right and left hands respectively, change the action of the

* These words are to be understood as addressed to the medical students of the University, before whom this paper was first read.

hands without altering the kind of inspiration, when the action of either arm will be signally weakened and impeded.

5. In leaping forward with the whole strength, the body deviates in its course towards the left, for when the whole strength is put forth, an expiration is made, and the centre of gravity inclines from right to left: something must also be ascribed to the superior strength of the right foot.

6. Many dogs, but not all, and never at full speed, run diagonally forward with the right shoulder in advance. Birds fly straight, but walk diagonally, which last is probably connected with the lateral disposition of their eyes. Crabs and lobsters advance obliquely.

7. It may be asked, If men use their right hands not from habit but from a mechanical necessity, how it happens that some men use their left hands rather than their right? It seems to me probable that many such cases, as in the left-handed slingers of the tribe of Benjamin, are merely cases of ambidextrousness, where the habit of using the left side, in whatever way begun, has given to the muscles of that side such a degree of development as enables them to compete with the muscles of the right side, in spite of the mechanical disadvantages under which they labour. There is an awkwardness in the muscular efforts of such men which seems to indicate a struggle against nature. There are, however, unquestionably, as I believe, men who use their left limbs with all the facility and efficiency with which other men use their right. Pathological anatomy furnishes us with a complete explanation of this anomaly in certain cases. There are men born who may grow up and enjoy perfect health, in whom the position of all the thoracic and abdominal viscera is reversed. There are three lobes of the left lung and only two of the right, the liver is on the left side, and the heart on the right, and so forth. Now, individuals so constituted must use their left limbs most effectively from a mechanical necessity, just as other men use their right. There are other malformations and pathological lesions, particularly those occurring in early life, which must materially influence the relative power of the two sides. Such are diseases of the right lung, contraction of either side of the chest from pleurisy, enlargement of the spleen, particularly when, as often happens, it is accompanied with a diminished size of the liver, distortions of the spine, with consequent displacement of the viscera, and many others.