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ON THE INFLUENCE OF THE POSITION OF THE BODY ON THE POSITION OF THE HEART AND ON INTRACARDIAC PRESSURE.

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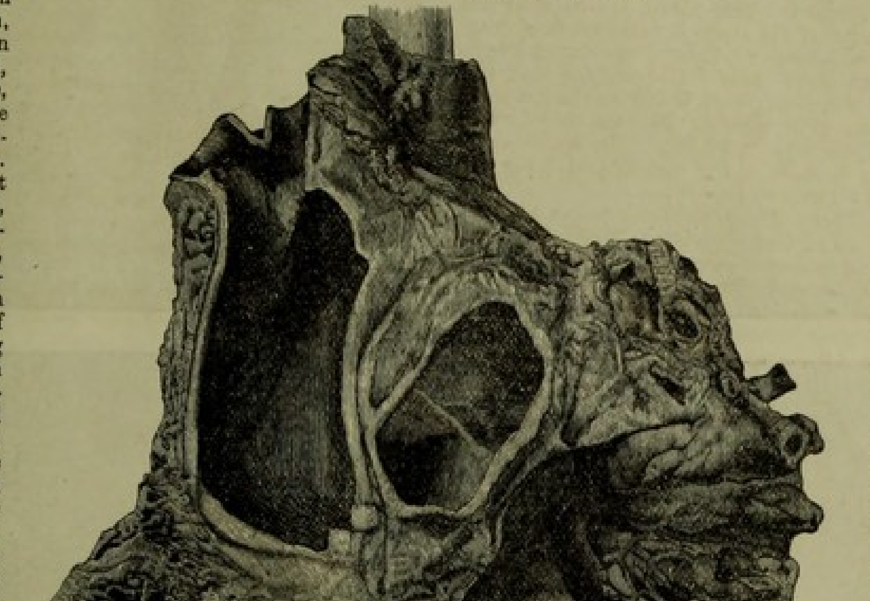
The following account is a brief statement of the results which have been obtained, and the suggestions to which they have given rise, in the course of a somewhat prolonged but by no means complete investigation into the effect of variation of bodily position on the position and movements of the heart in the thorax, and on the blood-pressure in the auricles.

In the healthy man in the erect or sitting position, the heart of course lies on the diaphragm—suspended, however, a little by its base, which is attached by the great vessels and the structures on the spinal column. Owing to this arrangement of the parts, it would seem, therefore, probable that variations in bodily position, or in the position of the diaphragm, might act through gravity on the suspension of the heart, either lengthening it, by allowing it to fall from its attachment, or shortening it, by pushing it up and back, as it were, on its base, and thus would affect the thin-walled auricles situated at the base, favouring, or rendering more difficult, their dilatation. Hence the blood-pressure in the auricles and in the great veins would be diminished or increased respectively; and this, favouring or impeding the filling of the heart in diastole, would produce the effects on the circulation which are daily evidenced by the orthopnœa of cardiac disease, or the cardiac oppression of upward diaphragmatic pressure, etc.—effects hitherto attributed to pulmonary influences, and to interferences with respiratory movements.

First comes the question, Does the heart change its position at all during variation in bodily position? and, if so, to what extent? It is, of course, well known that the forcibleness of the apex-impact against the chest-wall varies thus in the healthy adult man. It is felt most easily by the hand placed on the thorax when the body is lying prone and a little on the left side, and least when lying on the back and right side, the vertical position coming between these two extremes. Moreover, it is rendered less evident during the descent of the diaphragm in forcible inspiration, and also during a voluntary contraction of the diaphragm, with the glottis closed, probably by the tightening up of the pericardium attached to the central tendon.

In animals, as dogs, with a deep narrow chest, the apex-beat is felt least distinctly when the dog is lying on its back, and more distinctly, now on one side, now on the other, as the animal is rolled from side to side, owing, probably, to the V-shape of the thorax. In some animals, especially rodents, the diaphragm is transparent throughout the greater part of its central tendon, and through it direct observations of the movements of the intrathoracic viscera can be made. The first thing that strikes one, in looking at the under surface of the diaphragm in the rabbit or guinea-pig, is that, unlike man, the bases of the lungs are capable, during deep inspiration, of expanding over the whole surface of the diaphragm; and, as the pericardium is a thin loose membrane attached at only one point to the central tendon, they meet beneath the heart, obscuring it from view. Thus it happens that, in these animals, the action of the diaphragm in descent is very materially to widen the bases of the lungs, without materially acting on the heart.



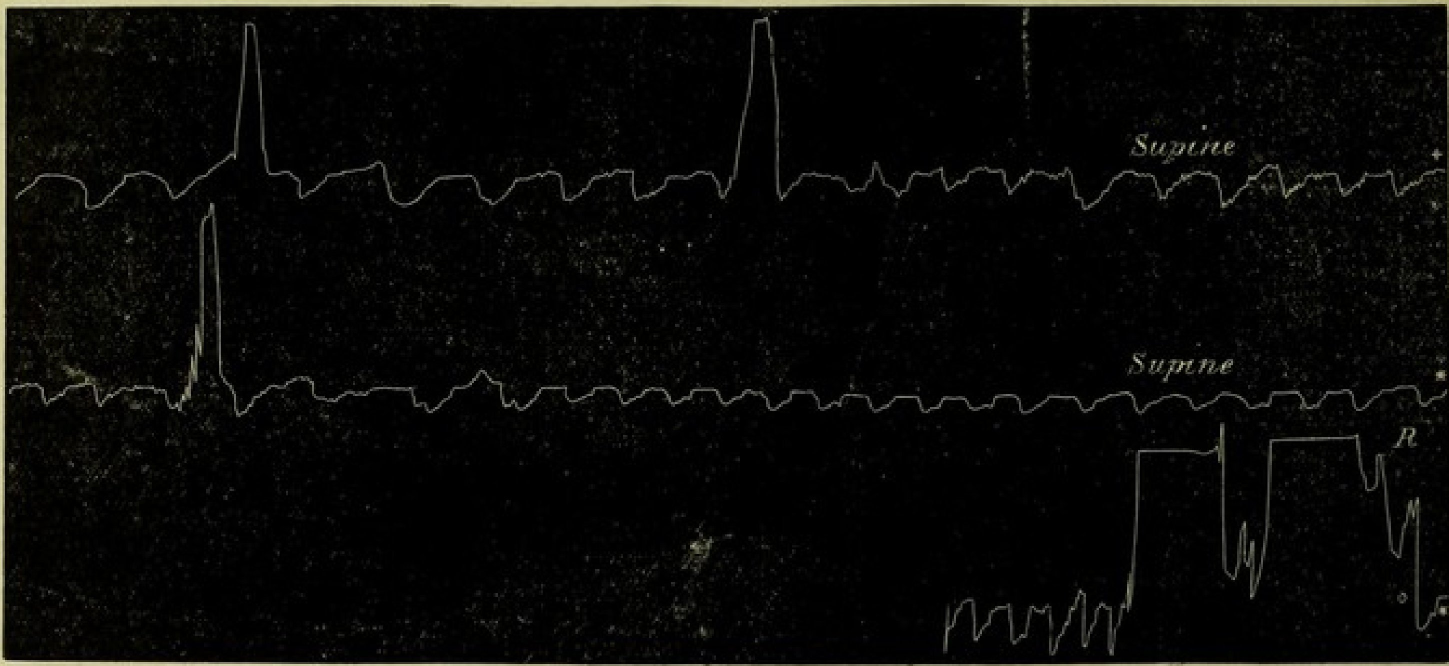
Engraving from photograph of vertical section of heart. Piece of wood passed down œsophagus shows its relation to left auricle and pulmonary artery.

But careful observation of the surface of the left ventricle visible (during expiration) through the diaphragm in the diamond-shaped area between the bases of the lungs, shows that this varies with the position of the animal. Thus, in the normal standing position, it is to the left of the middle line, and only separated from the thoracic wall by a small portion of lung; whereas, when the animal is placed on its back or right side, this ventricular surface approaches the middle line, and recedes from the chest-wall. These changes in the position of the ventricle can be also felt through the diaphragm.

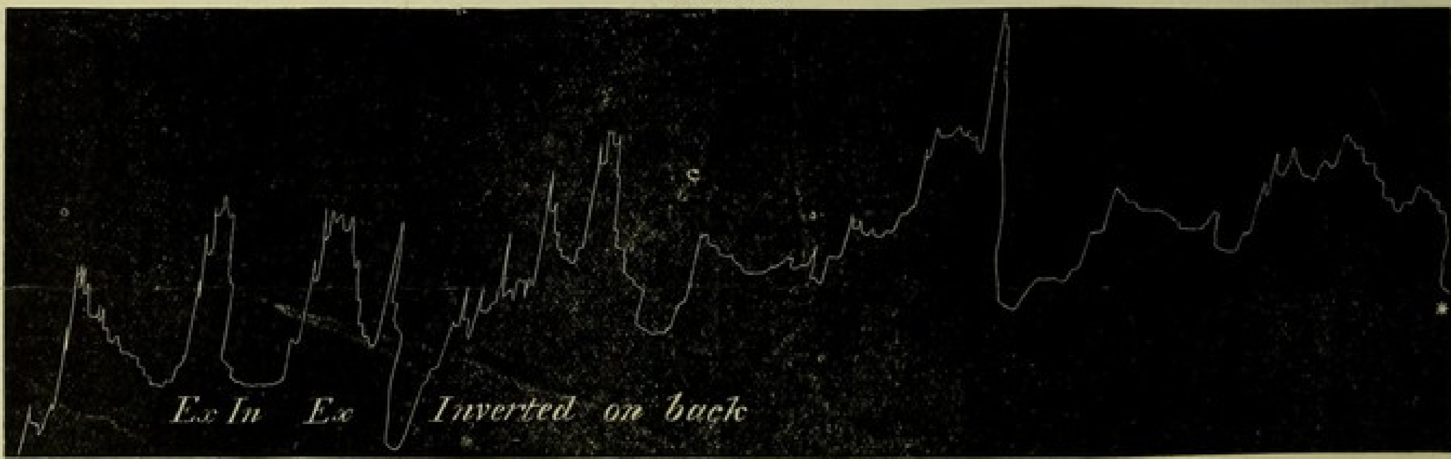
The next evidence as to variation in cardiac position is obtained by investigating, by means of the following instrument, the changes which occur at the base of the heart, as registered through the œsophageal wall. A tracing of the cardiac movements is obtained by means of an air-tampon, made by surrounding the lower end of a gum-elastic catheter, or œsophageal tube, perforated with holes, with a bag of thin India-rubber tissue, connected by tubing with an air-tambour, fitted with a lever, which writes on smoked paper stretched on a revolving drum in the usual way.

The tampon is passed down the œsophagus until the cardiac movements are most distinctly seen, showing that it rests against the base of the heart (*see* photograph), and the whole apparatus then slightly distended with air.

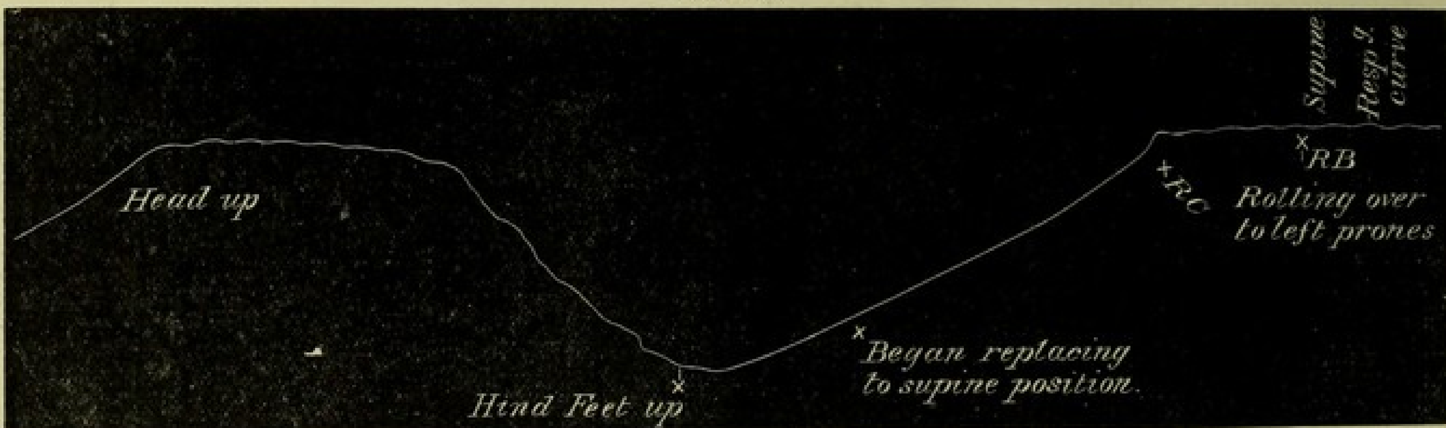
The graphic record thus obtained is somewhat complicated, for, in the anæsthetised animal, there is to be seen, first, a well marked and sudden rise, maintained at the same level for about one or two seconds, and then followed by a sudden fall. These large waves, which recur at irregular intervals, are due to the contractions of the œsophagus itself. The respiratory curve is next in size, consisting of a rather rapid rise, followed by a more gradual descent. This curve, of course, varies with the degree of anæsthesia, as will be described subse-



Tracing No. 1.



Tracing No. 2.



Tracing No. 3.

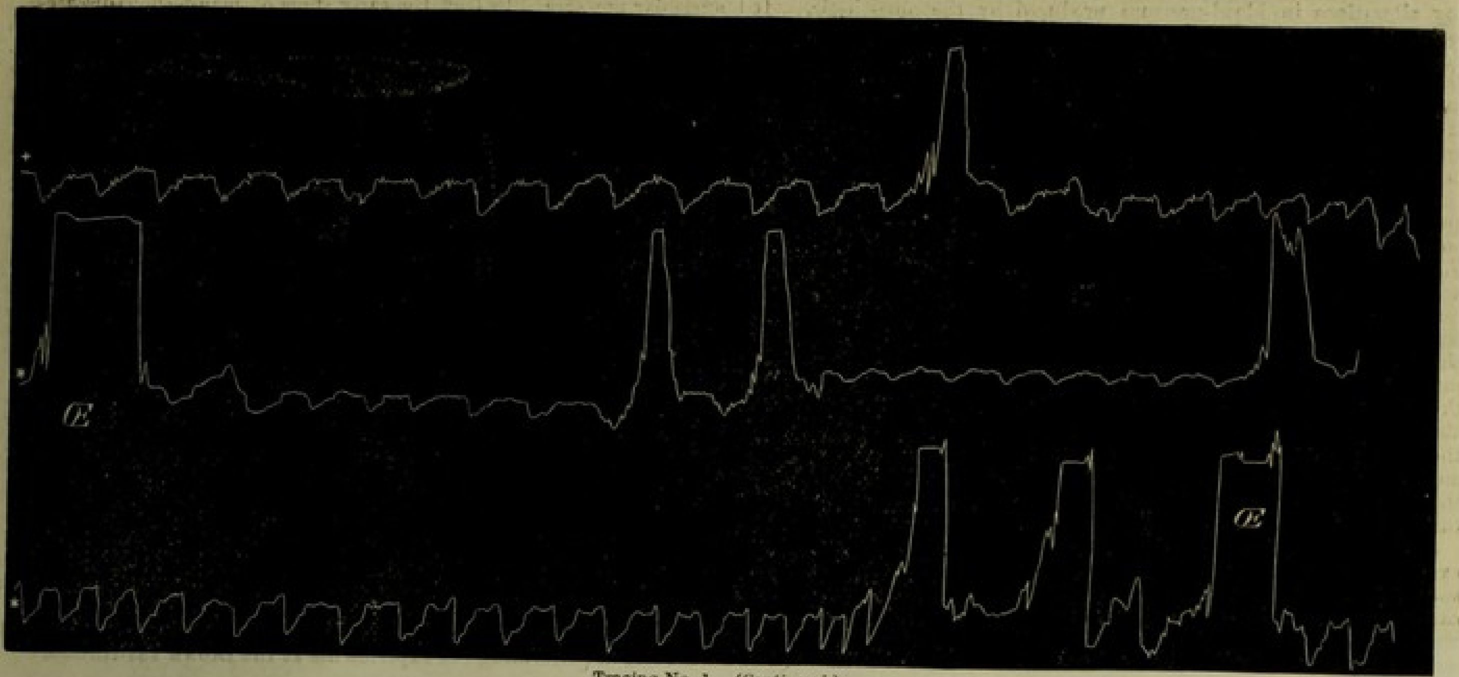
Tracing No 1.—From right to left, œsophageal tampon. Anæsthetised sheep. Shows the curves due (1) to œsophageal contraction (the tall square topped waves); (2) the respiratory curve; and (3) the smaller and frequent cardiac oscillations on the summits of the larger respiratory waves.

Tracing No. 2.—From left to right. Tampon passed down writer's œsophagus. Shows œsophageal contractions, respiratory movements, and cardiac curves. The latter more marked during expiration, and during inversion, and on back; absent in sitting and prone positions.

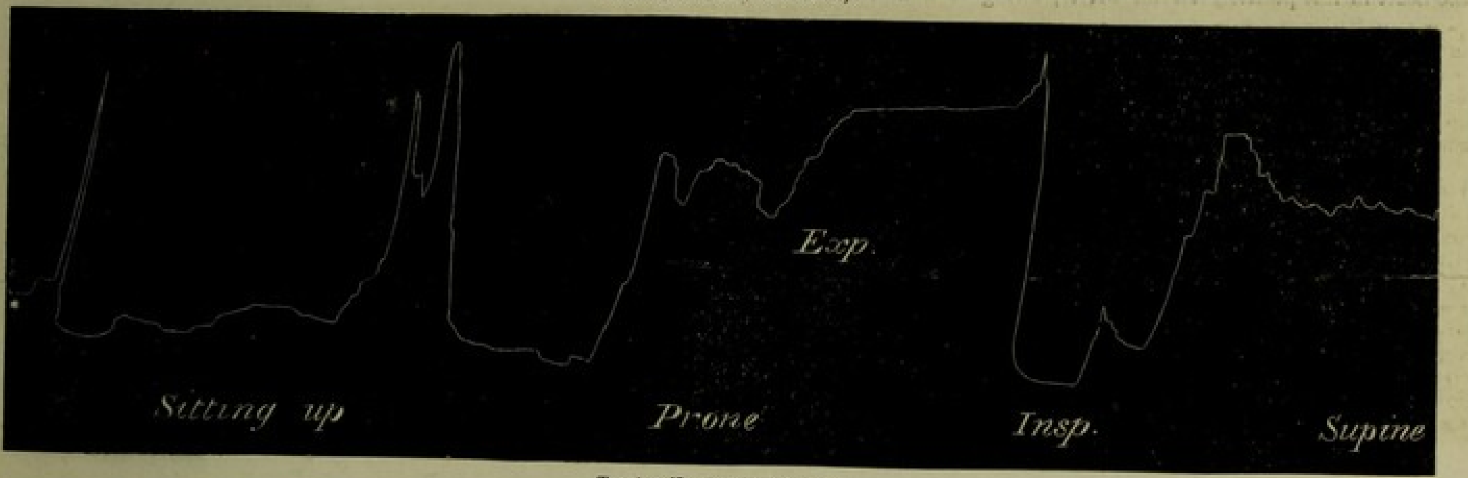
Tracing No. 3.—From right to left. Shows intra-auricular pressure-curve; falling during and after prone position, gradually rising in supine and inverted positions, and falling again when head and thorax are raised.

quently; and, thirdly, on this respiratory curve are to be seen a series of small waves, due to the cardiac beats; it is to these latter, and to their variations, that attention will now specially be directed. These cardiac waves are best shown in Tracing No. II; here the tampon was passed down my own œsophagus, without anæsthesia; and, after some practice, I was able to retain it, without any attempt at vomiting, for a quarter of an hour at a time.

In following the trace from left to right, we notice, first, that (unlike the case of the anæsthetised animal) the respiratory curve is



Tracing No. 1.—(*Continued.*)



Tracing No. 2.—(*Continued.*)

irregular; also (and this is very important) that the smaller frequent rises are more marked during expiration than inspiration, owing to the heart falling back towards the spine during expiration; further, that these cardiac curves are very marked, especially on the summits of the expiratory rise at the left end of the tracing, while I was lying on my back, with the head and shoulders depressed, and legs and pelvis raised; while they almost disappear in the sitting up and prone positions, to reappear at the right hand end of the tracing in the supine position.

Now, in interpreting this tracing, we must remember that the base of the heart is in close contact with the œsophagus, and loosely connected to it in the following way. It passes vertically down behind the left auricle, about midway between the right and left pulmonary veins, and is also in contact (the pericardium intervening) with a portion of the base of the left ventricle.

That this cardiac tracing is really due to the movements of the base of the heart, and not to pulsation in the pulmonary artery or large vessels, is shown by the fact that it varies with inspiration and expiration, and ceases entirely when the heart is drawn up a little from the spinal column by a sharp hook thrust into the apex. Now, the fact that this cardiac curve varies in intensity constantly with alterations in bodily position shows that the base of the heart (the amount of suspension, in fact, of the organ) is influenced by bodily position. The base, in fact, is pushed back or squeezed in inversion, the supine position, and in forcible expiration, while it is released in standing, the prone position, and in full inspiration.. Further, the rise of the lever in this, the "base-beat" of the heart, is synchronous (as shown by direct observation, the pericardium being opened) with the ventricular systole; showing, in fact, that, as at the apex, so at the base, the heart at systole communicates a shock to the structures in contact with it; and, as this is transmitted through the left auricle, it favours Fick's view of the function of the auricles—namely, to keep the venous flow constant, the intra-auricular pressure only rising appreciably at the ventricular systole by communication of shock and tension. At any rate, the fact of this "base-beat" being synchronous with the apex-beat seems to show that, partly by the tilting of the heart, an impulse is produced during systole at both base and apex, and that, consequently, the base of the heart does not descend or pass forward from the spine during systole, to any great extent, in consequence of the elongation of the large vessels, as has been supposed.

Having thus proved that the heart moves on the base in the thorax as the body alters its position, we have next to consider whether this movement of the heart exercises any influence on the intracardiac blood-pressure, and if so, to what extent.

A flexible tube, filled with solution of carbonate of soda, was passed down the external jugular vein of a dog (fully narcotised with ether) into the commencement of the right auricle, and connected with the tambour system above described, also filled with the solution.

Tracing No. 3 shows the results obtained, starting on the right, with the animal lying on its back. As it is rolled over to its left side, the intra-auricular pressure gradually falls, as shown by the descent of the lever; this fall continues for a little time after the animal is replaced, but rapidly rises when the animal is held with the hind parts raised, and falls again when the pelvis is lowered, and the fore part of the body is elevated.

This effect varies constantly with bodily position, and is not due to any alterations in blood-pressure produced by the anæsthetic. It occurs, too, after the inferior vena cava has been ligatured, and is not therefore due wholly to reflux of venous blood. It occurs also in the dead human heart, as I have found by means of a like instrument, passed not only into the right auricle, but also into the left auricle. It seems, therefore, certain that it is due to the mechanical effect of gravity acting on the heart, which falls back, compressing its base in the way described above.

This fact, namely, that the intra-auricular pressure, and consequently the circulation, is affected mechanically by alterations in bodily position and respiration, has, I think, important bearings. First, physiologically. The heart, slung as it is from the great vessels above, and in man resting on the diaphragm below, has, it must be remembered, no power to fill itself, for the pressure in the great veins is slight, or often a minus pressure. This filling is due, of course, chiefly to the aspiratory influence of the thoracic movements of inspiration, and partly to the elastic tension of the lungs acting on the thin-walled auricles, while the above facts would suggest that it is also partly due to the fall of the heart, since it follows the descent of the diaphragm in inspiration, thus allowing its base to fill by the mechanical aspiratory influence of its own weight. The alterations in the arterial circulation known to exist in the standing or lying postures may be partly produced by cardiac gravity.

Secondly, pathologically. This mechanical theory seems to me to explain the peculiar position of cardiac dyspnœa. The patient who suffers from backward venous pressure—from any disease, in fact, cardiac or pulmonary, which impedes the filling of the auricles—naturally sits up in bed, turns on his left side, or bends a little forward, not only because respiration is thus more easy, but also because the heart in this position can fill better, owing to diminished intra-auricular pressure. In fact, the early stage of many such diseases is impeded cardiac diastole, which is thus mechanically overcome. Also it has been found that, in the feebly-acting heart of partial chloroform-syncope, the best treatment is to roll the patient gently on to his left side, in a semi-prone position. Inversion (Nélaton) acts at first beneficially, of course, by increasing the blood-pressure in the anæmic central nervous system; but, if long continued, its heart-impeding effects soon become manifest.

Further, the peculiar cardiac embarrassment produced by upward pressure of the diaphragm, from whatever cause is thus explained by its acting, not only on pulmonary respiration, but also directly on the position of the heart. From the anatomical relations of the base of the heart, the right pulmonary vein passing behind the right auricle, being connected to it by pericardial folds, to reach the left auricle, any overdistension of the right side would excite unequal pressure on the pulmonary veins, and thus perhaps suggest an explanation of the more frequent occurrence of pneumonia on the right side.

The death of animals, especially sheep when "cast," accompanied, as it is, with all the signs of pulmonary and cardiac engorgement, may be partly due to the supine position acting unfavourably on the heart, as well as on the lungs and the diaphragm; for in quadrupeds, it must be remembered, the heart is more vertically slung from the spinal column, and they never, for any length of time, lie on their backs. This difference between man and animals in the mechanical effect of position on the heart, owing to the erect position in the former is a problem of considerable interest, especially when looked at as a process of development.

In conclusion, I have to thank Professor Victor Horsley for his great kindness in performing the experiments at the Brown Institution.