

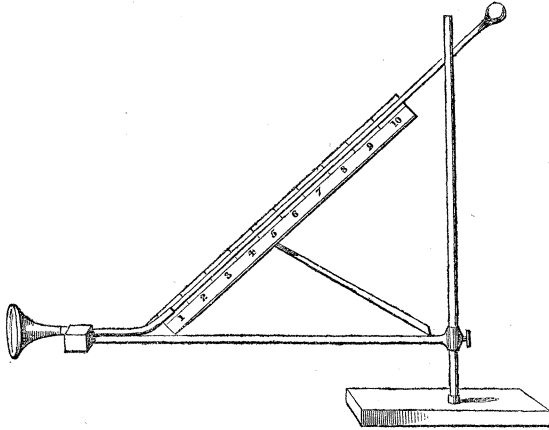
equation given by the pendulum experiments, the mean specific gravity of the earth is found to be 6.566. Adverting to the excess of this number above those given by the Schehallien and the Torsion-rod experiments, the author remarks that it is very difficult to assign the causes or the measures of error in either of the experiments, but expresses his belief that the result of the present experiment may compete on at least equal terms with the others.

A paper was also read, entitled "A Description of a new Sphygmoscope, an Instrument for indicating the Movements of the Heart and Blood-vessels; with an Account of Observations obtained by the aid of that Instrument." By S. SCOTT ALISON, M.D., Licentiate of the Royal College of Physicians, London. Communicated by G. O. REES, M.D., F.R.S. Received January 12, 1856.

The sphygmoscope (fig. 1) consists of a small chamber containing spirits of wine or other liquid, provided with a thin india-rubber wall, where it is to be applied to the chest. At the opposite extremity the chamber communicates with a glass tube, which rises to some height above the level of the chamber. Liquid is supplied to the instrument until it stands in the tube a little above the level of the chamber. The pressure of the column of liquid in the tube acts upon the elastic or yielding wall of india-rubber and causes it to protrude. This protruding part or chest-piece is very readily affected by external impulse; it yields to the slightest touch, and being pushed inwards, causes a displacement of the liquid in the non-elastic chamber, and forces a portion of liquid up the tube. The protruding wall of india-rubber is driven inwards when it is brought in contact with that portion of the chest which is struck by the apex of the heart, and a rise in the tube takes place. When the heart retires, the india-rubber wall, affected by the pressure of the column of liquid in the tube, is pressed back, follows the chest, and permits the liquid to descend. The degree to which the india-rubber wall is forced in by the apex of the heart is denoted by a corresponding rise in the tube, and the amount of protrusion of the india-rubber

wall which takes place when the heart retires is denoted by a corresponding fall in the tube. The tube is supplied with a graduated

Fig. 1.



Sphygmoscope.

scale to denote the rise and fall with exactitude. The glass tube is provided at the top with some contrivance, such as a brass screw and collar, to prevent the egress of the liquid when the instrument is not in use, or a bulb with an orifice may be supplied. When employed, the glass tube is left open to permit of the passage of the air to and fro.

The sphygmoscope is mounted upon a stand. The chamber and tube are fitted to a horizontal arm, which is made to move up and down so as to carry the instrument to the desired height. The base is so made as to secure the requisite immobility.

The glass tube is a foot or more long, and the round bore is about the one-eighth part of an inch. If the bore be much larger, the movement will be inconsiderable; if much less, capillary attraction will interfere and prevent free motion.

When the instrument is to be employed, mounted upon its stand, it is placed upon a firm table with the chamber projecting beyond it. The person whose heart is to be examined is seated upon a firm chair, with his chest erect and free from motion. The protruding india-rubber wall of the chamber or chest-piece is delicately made to touch the fifth intercostal space so as to receive the blow of the apex

of the heart. The liquid in the tube is now observed to be in motion. With persons in ordinary health, the liquid rises and falls about an inch. This rise and fall, after taking place three or four times, is followed by a much longer rise and fall to the extent of three or four inches, due to the advancement and retirement of the wall of the chest during the acts of respiration. The shorter rise and fall are again repeated and are again followed by the longer rise and fall caused by the motions of the chest. During the longer rise and fall due to respiration, the beat and retreat of the heart are still to be recognized by brief interruptions in the rise and fall of the liquid. When difficulty is experienced in obtaining the shock of the heart sufficiently strong to give an appreciable rise and fall, the examinee should make a moderate expiration, and then hold his breath and incline the chest somewhat forward. When the action of the heart is feebly felt at the præcordial region, it may be necessary to apply the instrument to the naked chest; but this is not necessary in the great majority of cases, and it will generally suffice to make the shirt and waistcoat fit tight to the skin. In many trials the sphygmoscope has succeeded in indicating the movements of the heart through the tightly buttoned coat. Thin persons are very favourable for examination; on the other hand, the corpulent less readily affect the instrument.

The movements of the heart, though best indicated at the fifth intercostal space, are to be denoted at other parts of the chest, and in some examples of disease and of large and powerful heart, even in the epigastric region. The moving arm proves convenient in applying the instrument to these parts. In many persons with no very excited heart, it is sensibly acted on at the scapular and infra-dorsal regions.

By means of this instrument the observer can ascertain the frequency of the beats of the heart, but as this can be effected in most cases with accuracy at the radial artery, no particular advantage is gained from it in respect to this point.

The duration of the impulse of the heart upon the chest is well measured by this instrument: the time occupied by the rise, is the time occupied by the impulse. A slow rise after a rapid rise shows a slow beat after a rapid one, and *vice versâ*, a slow fall after an ordinary fall, shows a slow retirement after an ordinary one. An

intermittent pulse is marked by an imperfect rise, followed by an ordinary fall, and then by a long rise. The rise is sometimes slower than the fall, which is occasionally found to be abrupt. This is observed when the heart, by reason of its great size, and of the somewhat bent back posture of the thorax, suddenly falls away from the walls of the chest.

The movements of the auricles under ordinary circumstances are not indicated by the sphygmoscope, though when it is placed over them, the liquid in the tube is moved upwards and downwards; but as these movements are synchronous with the movements upwards and downwards of another instrument placed at the apex, it may be inferred that the ventricle is the cause of them all. In some examples of greatly excited heart, as in phthisis, the instrument has revealed movements which seemed to proceed from the auricles; but further observations are required to settle this point, as well as the question whether the movements of the aorta, in a state of excitement, communicate any influence to the instrument.

The instrument, placed upon the heart, indicates strokes of that organ which are so feeble as to have no corresponding pulse at the wrist.

No pause whatever in the movement of the liquid has been at any time observed when the sphygmoscope has been carefully placed so as to receive the full beat, and fall back with freedom. This would go to show that the heart, however slow, is in constant motion, and, contrary to the belief of many physiologists, enjoys no pause. There is certainly no pause in the descent of the liquid, which takes place when the heart retires from the thoracic walls, in the middle of which movement it has been said a very short pause is to be observed in living animals having the heart exposed.

The force with which the heart beats at the fifth intercostal space may be ascertained by closing the upper extremity of the glass tube, and observing the extent to which the enclosed air is compressed.

When the heart is excited, the liquid in the sphygmoscope rises and falls more than usual; but the rise and fall of the excited enlarged heart is much the same as the rise and fall of the excited normal organ. For the most part the enlarged heart gives movements to the instrument when placed upon the ribs and sternum, whilst the

normally sized heart affects more exclusively when it is placed upon the fifth intercostal space.

The sphygmoscope indicates with exactitude both the absolute and the comparative influence upon the heart, of food, cordials, stimulants, and tonic medicines. It does the same in respect to depressing causes, such as hunger, cold, and sedatives.

With the aid of this instrument the fact is demonstrated, that the action of the heart may be great when the pulse is small,—that the heart may strike the instrument with force when the pulse scarcely affects the liquid of the hand-sphygmoscope. It affords a remarkable proof that the pulse is one thing and the heart's action another, and teaches that the pulse is only an approximate sign of the state of the heart. It is found also, that while cold at the surface and extremities may depress the pulse, the heart may remain little enfeebled, or even become excited, and that warmth and friction applied to the extremities may cause an excited pulse without there being any accompanying increased force of the heart.

The influence of respiration upon the action of the heart is manifested, in some degree, by the instrument placed over the region of the heart. If the breath be stopped after an ordinary expiration, the movement of the liquid is seen to be increased. If a very long and forcible inspiration be made and the breath then suspended, the movement is somewhat reduced; but when the respiration is again allowed to take its normal course, the movement is seen to be increased for a short time.

The sphygmoscope rises during the first sound of the heart and falls at the second.

The sphygmoscope reduced (fig. 2), deprived of its stand, having a level elastic wall instead of protruding one, and having a glass tube with an almost capillary bore, forms a remarkably delicate indicator of the pulse*. It is so delicate in its impressions that it

* Since this instrument was contrived, the author has learned that a sphygmometer of much the same construction was invented some twenty years ago by Mons. le Docteur Hérrison, and that a memoir upon it was presented to the Institute of France. The liquid employed was mercury—too heavy to indicate feeble impulses, and the moveable wall was of gold-beater's skin, which is inelastic. It may be added, that M. Magendie reported against the practical application of the invention.

is appreciably affected by the regurgitant wave in the jugular veins, and by the wave in arteries greatly smaller than the radial. From its nicety in manifesting the beat of the blood-wave, it is very valuable, and is called the hand-sphygmoscope.

By means of this hand instrument applied to the arteries, a comparison is readily made between the time of the beat of the heart and the rise of the arteries under the influence of the blood-wave. This instrument is much more delicate than the finger in such an inquiry. The impressions made upon the fingers of two hands fail to be conveyed with sufficient nicety to the mind to tell with certainty the relative time of the beat of the heart and arteries. Except in cases of extreme slowness, the sensations obtained from the two hands impressed at nearly the same time, do not admit of a distinct difference in respect to time being made out. It has been to this very defect that the erroneous idea, that the beat of the heart and the beat of the pulse are synchronous, or nearly so, has owed its origin and continuance.

The hand-sphygmoscope, placed upon the radial artery, shows a rise of the liquid while there is a fall in the sphygmoscope placed over the heart. As the liquid in the one instrument starts from below, the liquid in the other starts from above, and as the liquid in the one reaches the top of its ascent, the liquid in the other reaches the bottom of its descent, to renew their opposing course. The movements in the two instruments at the same instant are always opposed, and the whole time occupied in the movement of one instrument in one direction appears to be occupied by the movement of the other in the opposite direction. The movements *alternate* with as much apparent exactitude as the arms of a well-adjusted balance. When the lapse of time between the beat of the heart and the pulse at the wrist was first observed, suspicion of disease of the aorta was entertained, but the subsequent examination of many persons proved that this alternation was natural. In some twenty persons subjected to examination, the complete alternation has been made out without the shadow of a doubt. These persons were of all ages above childhood, and had the pulse of different degrees of rapidity from 60 to 100.

Fig. 2.



Hand-sphygmoscope.

Hand-sphygmoscopes placed upon the carotid, the brachial, the radial, the femoral, and the dorsal artery of the foot, rise at the same instant, and fall at the same point of time.

These facts prove the existence of two great laws not previously enunciated,—1st, that the heart's beat alternates with the pulse at the wrist; 2ndly, that the pulse of arteries beyond the chest takes place in all parts at the same instant, and without any appreciable interval.

The pulse, it appears, occurs during the retirement of the heart from the thoracic walls, and the collapse or fall of the arteries takes place during the impulse of the heart. During the rise in the hand-sphygmoscope placed over the arteries, the second sound of the heart has been distinctly heard, and during the fall, the first, softer and more prolonged sound has been easily distinguished.

The horse has been subjected to examination, to learn the relative time of the beat of the heart and arteries, but the respiratory movements and the motions of the animal have hitherto restricted the application of the instruments. However, it has been most distinctly ascertained, by the hand placed upon the heart and upon the plantar artery, that between the beat of these parts there is a decided interval. The slowness of the action of the heart in the horse renders this experiment less open to error than in man. In these experiments upon the horse, Mr. Mavor, the eminent veterinarian, gave his valuable aid.

The sphygmoscope forms a good pneumoscope. It delicately measures the rise and fall of the chest in respiration. It likewise declares the relative duration of inspiration and expiration, and may thus prove useful in the detection of incipient phthisis, and other pulmonary diseases. When the liquid has attained its highest elevation at the end of inspiration, it immediately begins to fall; but when it has reached the lowest point at the end of expiration, it remains there some instants. The ascent is slower than the descent. After the fall of an ordinary expiration, a forced expiration gives a second fall.

The sphygmoscope may be employed without a stand and is then more portable (fig. 3), but from the want of a fixed basis, and from the motion of the ribs on which it must rest, its manifestations are less extensive and satisfactory. It may be maintained *in situ* with an elastic band placed around the thorax. When em-

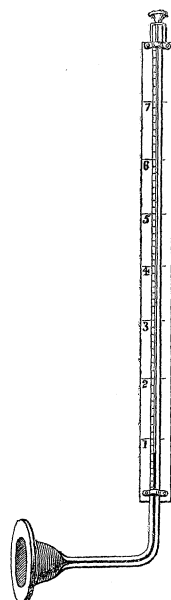
ployed without a stand, as it must rest upon the ribs, the elastic wall of the chamber should be plain, and not protruding.

The hand-sphygmoscope is an exceedingly delicate instrument, but requires great care and nicety in its construction. It may be made by taking about an inch and a half of a gutta percha tube, half an inch in diameter, slightly widening one extremity of it to make a chamber large enough to hold a small horse-bean, and fastening with thread a piece of thin india-rubber, or of Bourgeaud's india-rubber bandage, securely over it for the elastic and moveable wall. The liquid is now supplied, and the glass tube, with a very fine flat bore, say $\frac{1}{10}$ th of an inch, and provided with a ring of india-rubber, obtained by cutting off a small portion of a fine india-rubber tube, for a "washer," is now inserted and the instrument is ready for use. The hand-sphygmoscope discovers the blood-wave in regurgitation of the jugular veins; it responds to the radial of the newly-born infant; it rises and falls with the movements of the brain of the infant, though some months old, as that organ rises and falls under the influence of its arteries. There is no doubt that, applied to the fontanelles before delivery, it will inform the obstetrician whether the fœtus be dead or alive, and, in cases of difficult labour, supply important evidence for his guidance.

The hand-sphygmoscope applied to the radial artery, and to the fontanelles of a dying infant three months old, has indicated to the author the influence of respiration upon the circulation. During inspiration, the column of liquid in the tube was found to fall as if sucked down, and during expiration to spring again.

In practical surgery, the hand-sphygmoscope may possibly be employed with advantage, for it will rise with the wave or fluctuation of liquid tumours. It may be placed where the fingers cannot reach. The rise in the instrument is greater in liquid than in æriform tumours on account of the compressibility of air, and the fall is more rapid and decided when the contents of the tumour are liquid.

Fig. 3.



Portable Sphygmoscope.

For the most part, the hand-sphygmoscope is best applied simply with the aid of the fingers. It is delicately held between the tips of the thumb, fore- and middle-fingers, the nails resting on the examinee. The elastic wall is on no account to be pressed down with a dead weight upon the vessel. It is to be nicely lowered to the level of the artery when collapsed. When the artery rises, it will strike the elastic wall, and as the chamber is fixed by the fingers, the entire blow is communicated to the liquid and it rises in the tube. During the retirement or collapse of the artery, the elastic wall resumes its level condition and draws the liquid down the tube. This motion of the liquid allows the instrument to be employed though the open end of the tube be dependent. When it is desired to avoid the varying pressure experienced when the instrument is held between the fingers, some such apparatus as was invented by Dr. E. S. Blundell, or an elastic band suitably applied around the wrist, will be useful.

The sphygmoscope is for several purposes rendered more convenient of application by interposing, between the chamber and the glass tube, a piece of india-rubber tube of suitable bore and length. In this way the comparison of the beat of the heart and the pulse of an artery is much facilitated, for the glass tubes of the two instruments employed may be brought parallel and close to each other, so that the opposite motions of the liquids in the two tubes are, by near contrast, rendered easier of observation. In employing this adaptation, care must of course be taken that the india-rubber tube is of the same calibre and length in both instruments.

It is hoped that the sphygmoscope will aid in the acquisition of additional knowledge of the movements and condition of the heart, the situation of which within a case of bone, wisely provided to secure it from injury, has this disadvantage for the physiologist and physician, that the action and condition of the organ are with difficulty made out. By means of the sphygmoscope, that small amount of movement which is manifested at the exterior of the chest may be rendered more appreciable to our senses, and more available for physiological and curative purposes; and perhaps information may be obtained by this instrument which has hitherto been procurable only by the practice of vivisection.

Park Street, Grosvenor Square, London;

Jan. 12, 1856.