illuminated surface. Having experimented with the extinction of light at other parts of the retina, he finds that it obeys the same law. Since a large and a small area having the same actual illumination appear to be of different brightness, an investigation was made of the relative luminosities of the two, and it was found that the two were connected by a very simple law.

The reduction of the intensity of a coloured ray to extinguish all colour was next measured with areas of different dimensions, and it was shown that again the intensity of the reduced light was connected with the size of the spot by a simple expression similar to that of the extinction of all light, but the exponential coefficient differed, indicating that light and colour were not connected together in the manner which might be expected.

The author then deals with the question of colour fields, and finds that all colour fields are of the same form, the extent depending solely on the illumination and the area of the surface the image of which falls on the retina. He finds that there is a connection between the intensity of the colour and the extent of the field which can be expressed by a formula, as also can the connection between the size of the spot of illuminated surface and the extent of field. He gives the curves of illumination for equal colour fields, and the curves of extent of field for every colour in the prismatic spectrum. Finally he makes an investigation into the relative sensitiveness to light of various points in the retina, and shows that there are "iso-lumes" or fields of equal sensitiveness which appear to be of the same form as the colour fields.

He points out that there are difficulties in reconciling these results with either the Young or Hering theory of colour vision, and suggests a modification in the accepted theory of light and colour which may explain the connection between the two.

"On the Mechanism by which the First Sound of the Heart is Produced." By Sir RICHARD QUAIN, Bart., M.D., F.R.S. Received April 29,—Read June 3, 1897.

It is a well-recognised fact that the action of the heart is accompanied by the emission of certain sounds, which are described as the first and second sounds of the heart. These sounds, which were observed soon after Laennec had discovered the use of the stethoscope, have been compared to the sounds produced by the utterance of the words lŭbb-dŭp. They have been studied with interest by the physicist, the biologist, the pathologist, and the clinical physician, by the latter especially, inasmuch as the changes produced by disease in the character of these sounds become of material assistance in the

diagnosis and treatment of diseases of the heart. An explanation of the mechanism by which phenomena so distinct, so constant, and so remarkable are produced, has been sought for by many observers amongst the classes just mentioned.

The *second sound* is the result of the sudden tension of the semilunar valves, caused by the resistance which these valves offer to the retrograde flow of the blood from the aorta and pulmonary artery respectively into the ventricles on the cessation of systole. The sound is similar to that produced when a piece of tape or ribbon is suddenly made tense. It is needless to say more here on the subject of the second sound and its causes, for the explanation just offered is, I believe, almost universally accepted.

The cause of the *first sound* is, on the contrary, still a subject much discussed and undecided. Many explanations have been offered at various times of this phenomenon. Professor Michael Foster, to whose admirable exposition of the mechanism of the circulation I am deeply indebted for guidance in working out the subject of this communication, observes that "this sound presents many difficulties in the way of a complete explanation."* The difficulties result from the number of events which occur simultaneously with the systole of the ventricle and the occurrence of the sound. It seemed to me to be desirable, amidst such differences of opinion, to solve if possible a problem which has its special interest and its special importance. Two of the most striking events which take place during systole, namely, the closure of the auriculo-ventricular valves and the muscular contraction of the ventricular walls, are regarded by many authorities as the sources from whence the first sound proceeds. The result of my investigations, on the one hand, leads me to the conclusion that neither of these explanations is satisfactory; and, on the other hand, enables me to indicate what I believe to be the real explanation of the phenomenon.†

A. The action of the auriculo-ventricular valves is not the source of the first sound of the heart.

The mechanism of these valves (the mitral and tricuspid) and their action do not possess the elements necessary for the production of such a sound. The action of the valves commences when the blood, pressed from behind by the contraction of the auricles, flows into the ventricles. It is there reflected from the walls of these cavities, and presses on the lamellæ of the valves, which are thus

* 'Text-book of Physiology,' 6th Ed. (London, 1893), p. 239.

† I have to acknowledge with thanks the assistance rendered me in arranging my notes of this memoir by my valued friend, Dr. Mitchell Bruce, during my recent severe indisposition.

brought face to face into close apposition, and are so far closed by the mere pressure of the blood from behind. As soon as the ventricles are filled with blood the systole commences. The apex of the heart approaches the base. At the same time the musculi papillares contract, and by means of the chordæ tendineæ, attached to the margin of the valves, prevent the laminæ of the valves and the blood from being pressed backwards into the auricles. In this action—the simple apposition of the laminæ of the valves, and the closure of the orifices by means of the musculi papillares and chordæ tendineæ—there is no such tensive force exercised as would be sufficient to produce the loud and characteristic first sound of the heart.

Further evidence on this point may be found in another direction —namely, in the fact that the first sound can be heard independently of the existence and action of mitral and tricuspid valves. Aware of the fact that in some of the lower animals, more especially in the reptile class, the auriculo-ventricular valves exist in but a very rudimentary form, I obtained permission to examine some of these creatures in the Zoological Gardens, and spent many hours on many occasions in the investigation, assisted by my valued friend Dr. John Sibbald, who was at that time my clinical assistant at the Brompton Hospital, and who is now Senior Commissioner in Lunacy in Scotland. Having examined many animals, we finally decided that the python (*Python solurus*) afforded the best illustration of the occurrence of the first and second sounds of the heart. In the heart of that animal, of which I present two drawings, copied by permission from a preparation in the Hunterian Museum, it will be seen that the structures which represent the auriculo-ventricular valves are formed by a continuation of the septum of the auricles; they are merely muscular flaps, destitute alike of musculi papillares and chordæ tendineæ, and are without means of producing valvular tension. I may here add that in an animal of a totally different class, namely, the kangaroo, the sounds were distinctly recognised, though the valves, as seen in the second drawing (copied also by permission from a specimen in the Hunterian Museum), are very rudimentary in character.

Objections will no doubt suggest themselves to the view above expressed. For example, the clinical physician will say, "I am in the daily habit of hearing a distinct murmur accompanying the systole in cases of diseased heart, and apparently replacing the first sound. On examining the heart after death I find the auriculo-ventricular valves diseased, a condition with which I therefore connect the murmur." It will at once be seen that we have here to deal with morbid sounds totally different in character, and totally different in the seat and mode of production, from the first sound of the

heart. To make the explanation more simple, I will confine my observations to two principal forms of mitral disease associated with systolic murmur, namely, first, imperfection in structure with distinct regurgitation, and, secondly, induration, roughness, and irregularities on the mitral valve.

(*a*) In mitral regurgitation consequent on disease affecting the margins of the valves, the auriculo-ventricular orifice remains imperfectly closed; and when systole of the ventricle takes place, a portion of the blood is driven backwards towards the auricle, the remaining portion being sent forwards in its normal course towards the orifice of the aorta. The murmur which is produced by the retrograde flow of blood, permitted by the diseased valve, is heard at the apex of the heart; but at the same time the healthy first sound may almost always be recognised at the base of the heart, over the aortic valves.

(*b*) In a second form of disease of the mitral valve, there may be roughness, induration, or other irregularities from the presence of deposits on the external surface of the laminæ which meet the current of blood going towards the aorta and flowing parallel with the surface of the valves. A murmur is there produced audible at the apex, but also accompanying the current of blood towards the base, where it can be heard, often masking by its loudness the first sound. It is quite remarkable how slight the roughness or irregularity may be on the laminæ of the valves which produces a loud and definite murmur. These murmurs, striking and characteristic as they are, are merely accidental complications which occur at the moment of the systole of the heart; but they are unconnected with, and have no relation except in point of time to, the healthy first sound, which may be heard apart from, and independently of, them.

The weight of evidence, then, is clearly against the possibility of the structure or the functions of the auriculo-ventricular valves being the source from whence proceeds the first sound of the heart.

Two other phenomena occur synchronously with the systole of the heart, and consequently with the occurrence of the first sound. They are—(*a*) *the contraction of the muscular walls* of the ventricles, and (*b*) *the propulsion and movement of the blood* from the ventricles into the arteries. I shall first consider the supposed share which muscular contraction has in the formation of the sound.

B. The muscular contraction of the walls of the heart during systole is not the source of the first sound of the heart.

The sound produced by muscle during its contraction was first described by Dr. Wollaston.* He compared it to "a sound which

* 'Philosophical Transactions,' 1810.

resembles most nearly that of carriages at a very great distance passing rapidly over a rough pavement."* It is very difficult to conceive the slight, soft, rolling sound produced by muscle in action being convertible into the loud, booming first sound of the heart. Yet the theory is accepted. If muscle during contraction could produce so marked a sound, we should expect to find that the powerful muscles of the neck attached to the base of the skull and those attached to the jaw (being through the bones of the skull in direct relation with the hearing apparatus) would give us some striking evidence of the production of muscular sounds when they are thrown into strong action. It is reasonable, too, to believe that such muscular sounds must occur and be heard, if they exist, during the movements of the athlete or the boxer as well as during the performances of the *danseuse.* But there is nothing of the kind. I have failed to hear such sounds when listening to the powerful contraction of the biceps, or on listening to the contraction of the shoulder muscles of a strong cart-horse struggling with a heavy load in ascending a hill. I could hear no other sound save the soft, rolling sound described by Dr. Wollaston. Still many observers have argued that the contraction of the walls of the heart differs from the action of the skeletal muscles, and that it is this peculiar form of contraction which causes the first sound. They have adduced so many observations in favour of this doctrine that it will be necessary to examine them. But before doing so, for the sake of making my argument more clear, I desire to point out that there is another event which occurs simultaneously with the systole of the ventricle. This is the propulsion of the blood from the ventricles and its impact against the column of blood resting on the semi-lunar valves.

With a view to showing how large a share the sound of muscular contraction has in producing the first sound, observers have cut off altogether the supply of blood from the cavities, and on listening during the contraction of the heart have heard a systolic sound. Such were the old experiments of Ludwig and Dogiel, represented as confirmed by Krehl† and by Kasem-Beck.‡

The conclusions which have been drawn from these experiments are disproved by those conducted by my friend Professor Halford, and described in his essay on "The Action and Sounds of the Heart," published by Churchill (1860). He writes: "Large dogs

* It is interesting to note that Dr. Wollaston, in examining the sound produced by the muscles of his leg, made use of a wooden rod to convey the sound to his ear. He may be thus said, in a measure, to have anticipated the principle of mediate auscultation discovered by Laennec in 1816. The muscular sound which we now recognise is that accurately described by Wollaston.

† 'Du Bois-Reymond's Archiv,' 1889, p. 253.

‡ 'Pflüger's Archiv,' vol. 47, p. 53.

were obtained, and, as in my preceding experiments, the heart was exposed, and the circulation kept up by artificial respiration. A stethoscope being applied to the organ, sounds were distinctly heard. The superior and inferior venæ cavæ were now compressed with a bull-dog forceps, and the pulmonary veins by the finger and thumb; the heart continuing its action, a stethoscope was again applied, and neither first nor second sound was heard. After a short space of time, the veins were allowed to pour their contents into both sides of the heart, and both sounds were instantly reproduced. On the veins being again pressed, all sound was extinguished, notwithstanding that the heart contracted vigorously. Blood was again let in, and both sounds restored. I have thus frequently interrogated the same heart for upwards of an hour, and always with the like result" (p. 25).

These experiments of Professor Halford must be accepted as sufficient to refute the view of the German observers just quoted. Another source of fallacy in making experiments of this kind is that a very slight stroke of the muscle or ventricle against the end of the stethoscope is sufficient to produce a very loud and distinct sound, resembling the first sound. If the palm of the hand, for instance, be pressed gently over the ear, and the back of the hand be touched by a finger of the opposite hand, it will be felt how slight a stroke is sufficient to produce a very distinct sound. Observers (Ludwig and Dogiel) have recognised the difficulty of isolating muscle from the instrument conveying the sound, and they have placed the empty heart, still contracting, in a jar containing defibrinised blood or warm water, from the side of which a neck is projected, covered by a thin layer of india-rubber. At each contraction of the heart a distinct sound, resembling the first sound of the heart, was heard. But the flapping of the heart against the water was quite sufficient to produce the sound which was conveyed to the ear; and I cannot see in such an experiment sufficient evidence of the sound of muscular contraction being the cause of the first sound of the heart.

Experiments of another kind have been employed to show that the contraction of the muscle is a source of the sound. Hürthle* and Einthoven† show graphically that the first sound begins with the very beginning of the systole, before the ventricle has got power "to open the valves." This observation is entirely consistent with the view I am about to propose. The moment the ventricle begins to contract, the impact of the blood against the semi-lunar valves commences, producing the commencement of the sound, not when the valves are thrown open. The valves being connected with the fibroid

* 'Pfluger's Archiv,' vol. 60, p. 263.
† *Ibid.*, vol. 57, p. 617.

ring surrounding the base of the heart, with which also the muscular walls are continuous, the sounds are conducted to the apex.

Pathology confirms this view. It was observed by Dr. Stokes that in the course of typhus fever the first sound of the heart gradually disappears. After death it is found that the walls of the heart are softened; and this morbid state has been accepted as a proof that muscular contraction is the cause of the first sound. The real explanation is that the impulse of the heart is so feeble that it is unable to produce the sound at the valves. The correctness of this view is confirmed by the fact, recorded by Dr. Stokes, that the last point at which the sound disappears is over these valves, and that it is at the same point that the returning sound is first heard.

With the object in view of further investigating this subject, I requested my friend, Dr. Alexander Morison, to study the heart of a turtle recently killed by holding it close to the ear as one holds a watch when testing for deafness, and also by pressing it gently against the ear. With this intention, I gave him an introduction to the proprietors of the "Ship and Turtle" tavern, where he had the fullest opportunity of carrying out the investigation.

Dr. Morison writes to me:—"An opportunity was afforded me of examining the hearts of two large turtles immediately after they were killed. The heart removed from the body was easily provoked into active contraction by a gentle tap with the finger, the contraction being sufficient to expel blood from the cardiac cavity. On placing the ear close to the heart whilst thus contracting, no sound could be heard; on placing the ear lightly on the heart whilst contracting, no sound could be heard. So far, therefore, as a turtle's heart is concerned—no other that I know of has more vigour of contraction after removal from the body—muscular contraction, as a cause of cardiac sound, must be excluded."

These facts and observations are, in my opinion, sufficient to prove that the contractile action of the muscles of the heart is not capable of producing the first sound of the heart.

Having thus endeavoured to show that the cause of the first sound is independent alike of auriculo-ventricular action and of muscular contraction of the walls of the heart, I proceed to consider a third event, the most striking and important of all those which occur during the systole of the heart, that is, the propulsion of the blood contained in the ventricles into the pulmonary artery and the aorta, and herein to indicate what seems to me to be the agency by which the sound is produced.

C. The first sound of the heart is caused by the impact of the blood driven by the action of the muscular walls of the ventricles against the block produced by the columns of blood in the pulmonary artery and aorta which press upon the semi-lunar valves.

I would adopt the explanation suggested by my valued friend, the late Dr. C. J. B. Williams, that "sound is a phenomenon resulting from resisted motion." We hear it in the whistling of the wind in the rigging of a ship; we hear it when the waves break upon the shore; we hear it when the blacksmith strikes the anvil with his sledgehammer; we hear it in the gentle sounds of the Æolian harp, and in the whispers emitted by the vocal chords when the air passes over them from the trachea. Let us examine the condition of the circulation with regard to this particular point, namely, resisted motion.

In this inquiry I have derived most important assistance from the admirable and elaborate researches of Professor Bell Pettigrew, F.R.S., first, on "The Arrangement of the Muscular Fibres in the Ventricles of the Vertebrate Heart," published in the 'Philosophical Transactions' of the Royal Society, 1864, and, secondly, on "The Relations, Structure, and Functions of the Valves of the Vascular System," published in the 'Transactions' of the Royal Society of Edinburgh, 1864. These refer especially to the left ventricle, but, at the same time, it is to be observed that what applies to this ventricle applies, only in a lesser degree, to the right ventricle. Dr. Pettigrew explains the manner in which the column of blood, projected from the heart into the aorta, is formed by the union of three columns, an arrangement which results from the mechanism of the heart as fully described by him. These columns ultimately unite into one before reaching the orifice of the aorta. The columns have a spiral motion, which is the result of the spiral arrangement of the *musculi papillares*, of the spiral arrangement of the fibres composing the walls of the ventricle, as well as of the spiral shape of the left ventricular cavity itself. These points, illustrating the character of the flow of the current, are shown in the blood-cast from the interior of the left ventricle of a horse which, by permission of the President of the Royal College of Surgeons, I am able to submit to your examination.

By this spiral, or what might be called "rifle," motion, the blood is seen to be directed against the segments of the semi-lunar valves, which are thereby hastily thrown apart, the spiral current being continued for some distance within the aorta. The beautiful rifle mechanism here described is constructed with the definite objects of giving precision to the direction of the moving body against a given point, and of securing greater velocity and force in that body—the moving column of blood. We have, in fact, here represented in

nature—a matter of the deepest interest to the biologist—the mechanism of the comparatively modern rifle.

The resistance to the stream of blood issuing from the ventricle is offered by the block formed by the column of blood resting on the aortic valves. These in their action are described by Dr. Pettigrew as "closed by a spiral movement, by which these valves are wedged, and, as it were, screwed, more and more tightly into each other"; the movement here—the spiral movement—being caused by "the direction of the sinuses of Valsalva, which curve towards each other and direct the blood in spiral waves upon the mesial line of each segment."*

We find that various estimates have been given of the absolute propelling power of the ventricles and of the resistance of the column in the pulmonary artery and in the aorta respectively. For example, Professor Michael Foster says:—"If we take 180 grams as the quantity in man ejected at each stroke at a pressure of 3·21 metres of blood, this means that the left ventricle is capable at its systole of lifting 180 grams 3·21 metres high, *i.e.*, it does 578 gram-metres of work at each beat." †

Different estimates of the propelling force are given by physiologists, and the estimates of the resistance vary more even than the estimates of the propelling power. It will therefore suffice to say that authorities are substantially agreed that the driving power and the resistance are in the proportion of 4 to 3, the really important point for our present purpose being the relation they bear to each other.

In the motion thus described and the resistance we have all the elements for the production of a sound; and a sound being produced, we ask what it is. The reply must be: the first sound of the heart, the cause of which we now seek.

If it be admitted that sound is a result of resisted motion, we have in this instance a remarkable illustration of movement and resistance. The movement of the blood with all the force, precision, and velocity of a rifle or spiral movement, is directed against a fixed and definite resistance, the moving power and the resistance being capable of definite measurement and found to be quite sufficient themselves to explain the source of the sound of which we are in search. This

* 'Transactions of the Royal Society of Edinburgh,' vol. 23.

† As an illustration of the great mechanical force exercised by the muscular walls of the heart, Professor Michael Foster says that "the work of the whole heart during the day would amount to 75,000 kilogram metres, which is just about the amount of work done in the ascent of Snowdon by a tolerably healthy heavy man" ('Text-book of Physiology,' by M. Foster, M.A., M.D., London, 1893).

Professor Haughton, F.R.S., in his learned and most interesting work on 'The Principles of Animal Mechanics,' says that "the daily work of the left ventricle is equivalent to lifting 89·7 tons through 1 foot" (Longmans, London, 1893).

explanation was first suggested to my mind many years ago by the occurrence of a case of disease in which the aortic valves, being completely broken down by disease, became inadequate to their function. A murmur of such intensity was produced that it was audible at 2 or 3 inches from the wall of the chest without any intermediate communicating body. With a view to determine how far this murmur might be conducted along the course of the circulation, I examined the femoral artery. There I found that the murmur was not conveyed to the ear, but a sound precisely resembling the first sound was heard, a sound caused by the pressure of the stethoscope resisting the motion of the blood in the artery, which, the valves being destroyed, thus received the full force of the ventricular contraction. My attention was thereby directed to the obstruction offered by the aortic valves in health to the blood in leaving the ventricle. I felt the case to be so interesting that I submitted it to a meeting of the Harveian Society; and my observation is recorded in the Minutes of the meeting April, 1852.

From that time to the present I have taken every opportunity of investigating the subject. Observations have been made on the course of the circulation in the femoral artery under like circumstances by Duroziez, Moulie, von Bamberger, and others. These observations, however, have had reference more especially to the diagnosis of disease of the aortic valves, and I mention them here only as indicative of interesting investigations having been made on the femoral artery in cases of diseased aortic valves. The observers named make no special reference to the first sound of the heart in health.

Objections may be offered to the explanation of the first sound of the heart here brought forward, founded on the fact that this sound is heard more distinctly at the apex of the organ, a point removed from the seat of the valves. The observation is perfectly correct, but the explanation is simple. The muscular walls of the heart are connected, as above described, with the fibroid ring which is intimately associated with the semi-lunar valves. The sound produced at these valves is communicated to the apex of the heart through the fibroid ring and the muscular walls, which at the moment of systole are tense and firm. The sound thus conducted reaches that portion of the heart which is uncovered, and which is in contact with the walls of the chest. But, on the other hand, when opportunity offers it has been found that the sound in question is heard over the aortic valves more distinctly than in any other situation. A remarkable case of this kind has been related by M. Cruveilhier, who was invited to see an infant just born presenting a complete case of ectopia of the heart. He says, "On examining the heart thus exposed, both sounds were

distinctly heard over the base, and *not* at the apex." He remarks, "We must not forget that one element of the sound, that produced by the shock of the heart against the chest-wall, is absent."*

Another point of interest is that which has already been alluded to in the case of typhus fever, as described by Dr. Stokes, namely, that the sound disappears last over the semi-lunar valves, and also that the returning sound is first heard in the same situation.

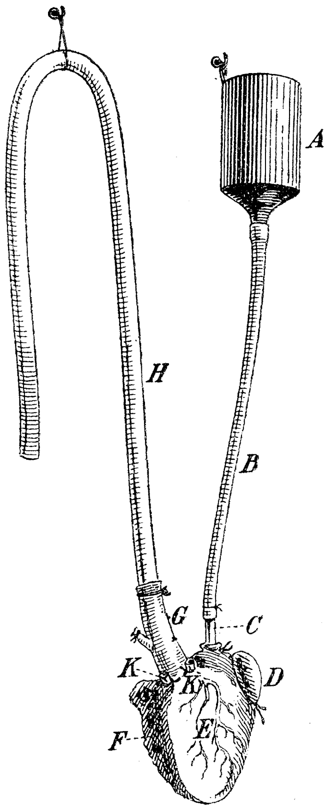
It is also an object of great interest to compare the *characters* of the two sounds in relation to the seat of their origin at the semi-lunar valves. In the first sound we have the character of propulsive force and sustained action, softer and more prolonged than the second sound, which is sudden, sharp, and short, as if produced by an abrupt mechanical disturbance. These distinctions, which may be readily recognised in various degrees by careful observation, serve to convince us that the sounds are both produced at the same point: at the semi-lunar valves, each by its own single and simple agency.

D. Lastly, sounds resembling the first (and second) sound of the heart can be produced artificially in accordance with the view contained in the preceding communication.

The experiment is thus made: a sheep's heart of good size (or that of a calf) may be used. It must be carefully cleared from pericardium, leaving the large vessels and pulmonary veins as far as possible intact. The orifices of the pulmonary veins must be laid into one, so as to permit a sufficient opening into the left auricle through which to divide the attachments of the mitral cusps and the musculi papillares in the left ventricle, taking care in doing this not to injure the aortic segments when detaching the cusp that lies next them. The coronary artery must next be ligatured, and also the innominate artery where it springs from the aortic arch. The right auricle and ventricle should be removed. Through the opening made by laying into one the orifices of the pulmonary veins a bone nozzle should be passed. It is well also to ligature the auricular appendix and any points from which water may issue when the ventricle is filled. To the posterior orifice of the nozzle rubber tubing should be attached, communicating with a source of water supply, placed on a higher level; and another portion of rigid gutta-percha tubing, about 3 feet long, should be introduced into the aorta (see diagram, fig. 1). If now the ventricle be filled with water by means of the tube in the left auricle, the water will of course pass into the ventricle and thence up the aorta, a portion of the water resting upon and closing the aortic sigmoid valves.

* 'Gazette Médicale,' p. 488 (1841).

Fig. 1.—Diagram to illustrate Sir Richard Quain's theory of the mechanism causing the first sound of the heart.



A. Receptacle for water-supply connected by means of tubing B with bone nozzle C tied into the left auricle.
D. The left auricular appendix ligatured after escape of all air from the heart chambers.
E. The left ventricle of the heart.
F. The site of the right chambers of the heart which were removed after ligature of the coronary arteries KK.
H. Tubing connected with the aorta G and containing water representing the aortic column of blood.

If further the ventricle be compressed periodically in imitation of systolic contraction, and allowed to relax in imitation of diastolic relaxation, a sound closely resembling the first sound of the heart will be produced when water is propelled from the ventricle into the aorta, and another closely resembling the second sound when propulsive movement ceases, and the sigmoid valves again close under the superincumbent weight of water in the aortic tubing. As the fluid

rises in the gutta-percha tube, the pressure on the valves increases, and the sound becomes more marked; when the fluid on the other hand diminishes, the sounds become less distinct. If the heart be placed horizontally, the sounds become wobbly. The terminal piece of small diameter of a binaural stethoscope gently placed over the aorta at its commencement is most suitable for observing the cardiac sounds in this experiment.

The experiment here described, when first suggested by me, was submitted, with the assistance of Dr. Sibbald, to my lamented friend the late Dr. Sharpey, and to Sir James Paget, who were quite satisfied that with the increase or diminution of the column the sounds closely resembled those of the heart in man, and that they became more or less distinct in proportion to the quantity of fluid contained in the tube.

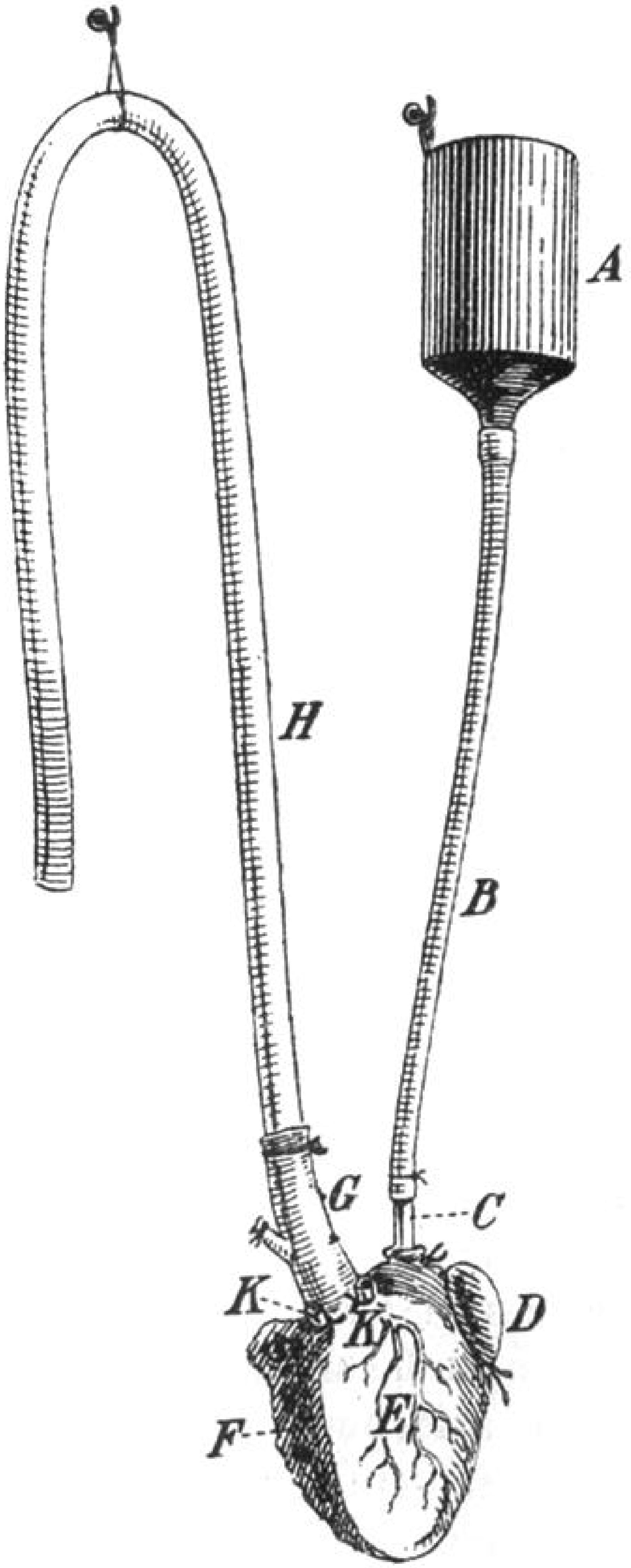
In conclusion, I may say that I was moved to undertake and continue this inquiry by a desire to obtain a solution of what seemed to be an insoluble problem, and also by a belief that a correct explanation of the cause of the first sound of the heart would be of practical value in the study of the clinical phenomena of diseases of this organ.

I would wish further to add that the explanation of the cause of the first sound of the heart given in this communication, being so different from that hitherto accepted, may seem calculated to create difficulties in the diagnosis of valvular diseases of the heart. Closer consideration will show, however, this not to be the case, but that, like all accurate knowledge, it will be found to simplify, and not to confuse. It will afford an explanation of the relations of certain morbid phenomena which are at present unintelligible, such, for example, as that a systolic murmur may be heard at the apex whilst the first sound is audible at the base free from murmur; and it will serve to encourage a closer study of the relation between muscular contraction of the walls of the heart and the tension of the vessels of the system.

"Mathematical Contributions to the Theory of Evolution. On the Relative Variation and Correlation in Civilised and Uncivilised Races." By Miss Alice Lee, Bedford College, and Karl Pearson, M.A., F.R.S., Professor of Mathematics and Mechanics, University College, London. Received April 9,—Read June 3, 1897.

1. The following numerical data were calculated in the hope of reaching some general ideas on the comparative variation and com-

Fig. 1.—Diagram to illustrate Sir Richard Quain's theory of the mechanism causing the first sound of the heart.



A. Receptacle for water-supply connected by means of tubing B with bone nozzle C tied into the left auricle.

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F. The site of the right chambers of the heart which were removed after ligature of the coronary arteries KK.

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