ON A NEW FORM OF STETHOSCOPE IN ITS RELATIONS TO THE THEORY AND PRACTICE OF AUSCULTATION.

By W. H. SPENCER, M.A., M.B. Cantab.,
Physician to the Bristol Royal Infirmary.

I.

LAENNEC, in 1816, applied a well-known acoustic fact to the investigation of intrathoracic disease. He placed one end of a quire of paper, rolled very tight, against the chest of a patient, and placed his own ear against the other end; he heard, as he himself expresses it, the beating of the heart much more clearly than if he had applied his ear directly to the chest. That experiment marked the dawn of auscultation. Thence the development of the new method of physical exploration was rapid and vigorous, so that, in not much more than fifty years, a science of physical signs, abstract and applied, has grown up and reached tolerably voluminous dimensions. Laennec applied a principle by means of an instrument; and, though his apprehension of the principle was imperfect and his original mode of applying it was rude, both principle and mode remain at this day, the one only more clearly apprehended, the other, in all essential features, very much what Laennec and his contemporaries left it. The principle was conceived by Laennec as a property of matter whereby it conducts sounds; stated in the language of modern science, it is, that sonorous vibrations are transmitted through an elastic medium, under certain circumstances, with little or no loss of intensity. The original mode of applying the principle was modified by Laennec himself, then by Piorry, and, in later times, by a host of competent as well as of incompetent persons. New arrangements, entirely unlike Laennec's mode or the many modifications of his mode, have been devised and adopted with more or less success. Yet, in that form of stethoscope most universally used and relied upon at the present day, behind modifications of doubtful value, relating chiefly to shape, size, and fashion—we see the rolled quire of paper, only become a more or less shapely cylinder of wood or similarly light and rigid material, adapted at one end to fit the chest and at the other end to fit the ear.

The acoustic principle is fundamental to the whole art of auscultation; it is the condition upon which auscultation, however practised, becomes possible at all. Is, then, the mode of applying the principle adopted from Laennec, and used with little modification to this day, also fundamental? Is it a means whose singularly perfect adaptation to the purposes of auscultation the progress of science during sixty years has not been able to gainsay or improve? Or, is the form of the stethoscope really unimportant? Are a well-trained ear and a prescient understanding the conditions upon which successful auscultation depends?

Rather, I think, it must be acknowledged that, from causes it would not be difficult to set forth—chiefly a too limited encouragement of the study of physics as a part of a general education, and a too well encouraged bondage to clinical traditions—the scientific character of the stethoscope has not kept pace with the progress of physics, and, in consequence, auscultation has not attained that degree of development which it might otherwise have been expected to attain. Some may be disposed to conclude, because Laennec with his instrument brought auscultation almost to its present state, and because, with only the modern modification of Laennec's stethoscope, it has been found possible to acquire a high degree of skill in the diagnosis of chest-diseases, that, therefore, the mechanical conditions of auscultation are sufficiently fulfilled. But the state of our clinical knowledge and needs does not justify such a conclusion; the relations between physical signs and diseased processes are not so well understood (however our knowledge may satisfy the exigencies of routine) that we can afford to ignore the possibility of imperfection in our acoustic appliances. The skill of the best diagnosticians may depend very much more on natural perfection of the organs of hearing and on clinical acumen, on personal qualities, than on fitness in the stethoscope as a means to an end. This much, at least, must be admitted, that, whatever it may be, the stethoscope in any of its present forms is not a scientific instrument of precision, adapted to fulfil the conditions of its highest value as an aid to diagnosis and research. Yet, though we may be far from realisation of the ideal held out to us by science, I take it we shall not err if we make that ideal the goal of our efforts and desires. These, and many such considerations, have influenced me, and I think also justify me, in attempting to improve the construction of the stethoscope. I have now to describe what I have done, and to compare my work with what those who have preceded me have done.

I propose, first, to discuss my stethoscope from the clinical, that is the practical, point of view. Its form and mechanism shall be described

in so far as these are related to the clinical uses which it is designed to serve, and some illustrations of its use shall be given. I will then discuss the instrument from the acoustic, that is, the scientific point of view; and this must be at some length, for I hold that a scientific character, if it can be rightly claimed, will constitute the highest praise.

Consideration of what accurate diagnosis demands, and what clinical experience has shown to be necessary in the application of auscultation to the physical exploration of the chest, leads, I think, to the conclusion that three chief practical conditions are involved in the successful practice of auscultation by means of an instrument. The conditions are these: 1. Accurate communication between the organ of hearing and circumscribed areas of the chest, under varied circumstances of position of areas relatively to the auscultator; 2. Admission of sounds from any area to both ears of the auscultator simultaneously; 3. Rapid and complete substitution of sounds from any area for sounds engaging the ears from any other area. Examination of different forms of the stethoscope brings out the fact that each of these conditions, singly and in turn, has been recognised and its realisation attempted; yet, not one of the forms hitherto devised has succeeded in fulfilling any one of the conditions with completeness of mechanical adaptation; moreover, in every case, acoustic conditions which are cardinal to accuracy of result have been more or less infringed. It is hardly perhaps surprising, then, that no attempt has been made to construct a stethoscope that should combine them all. It might be expected that Laennec and his contemporaries would ignore, in the construction of their stethoscopes, conditions which only a fuller experience than theirs could suggest; but it is, to my mind, highly significant that the form most universally preferred in the present day, for all clinical purposes whatever, should be as completely innocent of all recognition of these conditions as are its discarded prototypes.

Let me briefly notice one or two forms of the stethoscope, in support of what I have said, as well to gain a standard wherewith to compare the practical features of my instrument. The *uninaural rigid stethoscope*, as the form most universally adopted, claims the first notice. This form does not pretend to recognise any of the conditions of which I have spoken. Its use might not inaptly be compared with that of the low powers of a microscope, or the finder of a telescope. The relations of my instrument to this form may be represented as similar to the relations of high powers to low powers in a microscope, or the relations of a telescope to its finder. Admitting that, from the acoustic stand-point, this form does answer tolerably well its purpose, regarded solely from the practical side, it has, as every one knows, certain disadvantages, which are often a source of discomfort both to patient and to auscultator, which sometimes falsify its teachings and sometimes hinder its use altogether. To remedy some of these disadvantages, and to provide for the first of our conditions, Dr. Golding Bird and others devised stethoscopes in which the rigid stem of the ordinary form is replaced by a flexible tube. Acoustically, these forms are vastly inferior to the form they are intended to supplant. Still further to obviate disadvantages, and particularly to provide for our second condition, Dr. Leared, in 1851, and, four years later, Dr. Cammann of New York, each independently designed a form generally well known as the *biaural stethoscope*. Differing only in details, the English and the American forms consist essentially of a very short tubular and rigid stethoscope, furnished with two tubes, partly flexible, which pass to the two ears respectively of the auscultator. Sounds are conducted from any one point of the chest to both ears simultaneously. The biaural feature is admirable; but in the construction of the instruments, a regard for the laws of acoustics appears to have been sacrificed to a desire to augment the loudness of sounds. These stethoscopes create sounds in themselves; and what sounds they conduct from the chest are reinforced by resonance to such a degree that differences in the character of sounds cannot, in many instances, be apprehended at all, and in other cases only with much difficulty and after much practice. The effect produced reminds one of the child's toy-resonator, a sea-shell. Dr. Scott Alison has designed a stethoscope which is particularly intended to fulfil the third of our conditions, to provide for an urgent and fundamental requirement of diagnosis. It is designed to enable the auscultator to compare sounds generated at different parts of the chest, and is, therefore, called the *differential stethoscope*. It consists of two flexible and tubular uniaural stethoscopes, connected together by a joint for adaptation to the two ears at the same time. Sounds are conveyed from any two points on the chest-wall, the one set to one ear, and the other set, separately and independently, to the other ear. The instrument is not, therefore, biaural in the sense of our second condition. The principle of action claimed for this stethoscope appears to me to rest upon a physical impossibility. If it were possible to close one ear at will, the other ear remaining open to receive sounds, the principle might, perhaps, be made available in practice: even then, the value of the stethoscope would depend on the auscultator hearing equally well with both ears, which is by no means always the case. Assuming equality in the two

ears, the instrument can only reveal the fact, when it exists, that of two sounds or sets of sounds one is louder than the other.

No form of stethoscope, then, had been devised which combined in itself the means to fulfil all three conditions: no stethoscope could be easily applied to different points on the chest-wall whilst patient and auscultator retained their relative positions, or readily accommodated itself to the comparison of sounds originating at different parts, and, at the same time, transmitted sounds with accuracy to both ears simultaneously. It thus became my aim to devise a stethoscope which should fulfil all three conditions with scientific completeness, and should also be simple and handy in use.

It might be expected that the realisation of such an aim would begin in an attempt to modify and combine existing forms; and so it was. I had in view, at first, to remedy acoustic defects that marred the binaural and differential stethoscopes, and to engraft upon one of these forms those features of the other that relate to our practical conditions; to combine the two in one, and to make the product a faithful conductor of sounds. It was whilst engaged in considering how this should be done, that I discussed the matter with my friend Mr. P. T. Main of St. John's College, Cambridge; and he, with characteristic acumen, made suggestions which, carried out, realised the combination of the two forms, and originated two of the most important features of the *compound binaural stethoscope*—viz., the commutators, and the feature of the two collectors each communicating with both ears. It is unnecessary to detail all the numerous and complicated steps that have, after much labour and many failures, culminated in the stethoscope now introduced to the profession. It is to be noted, however, that the real element of difficulty—which has doubtless proved to be the insurmountable difficulty hitherto—lies not so much in any inherent character of the conditions themselves, as in the necessity that exists to fulfil each condition in concert with the other two. The instrument being threefold as to its functions, must be so constructed as to permit concerted action of its parts in the combined exercise of its functions.

Concerning form and details of construction, our three practical conditions shall be the heads for description.

First, as to the mode in which accurate communication between the ears and the area to be examined has been made, and so made as to suit those contingencies of position of area and auscultator that are met with in practice. The mode adopted to compass the first condition is, in

general terms, to interpose between the tympanic membrane and the chest-wall a flexible column of air. The medium of communication is air: it is enclosed in two long tubes, having a smooth interior, and throughout of the same calibre as that of the auditory canals. The air in the tubes is practically insulated from its enclosing envelope; the walls of the tubes neither modify the sounds conveyed by the air, nor do they aid, to an appreciable extent, in the conduction of sounds.

The insulated columns of air in the tubes are brought into direct continuity with the columns of air in the auditory canals by adapting the ends of the tubes (through two ivory ear-pieces, A) to fit closely against the external openings of the canals; they are also brought into contact with the chest-walls by means of sound-collectors, of the usual shape (C), fitted to the other ends of the tubes. From the chest-wall to the external opening of the auditory canal, and thence to the tympanic membrane, extends, for each ear, a column of air of uniform diameter. But the condition requires, further, that the columns of air should be easily displaced, so that, the auscultator retaining his position and the columns retaining their continuity and calibre, the collectors may be applied to different parts of the chest. The two main tubes consist each of two parts—a rigid metal part (A B) and a flexible part (B C)—the two being

accurately connected by a sliding joint. The two metal tubes are connected by a joint, D, (whose construction and uses relate to the second condition), and are adjusted to the ears together as a rigid whole. The mode of connection between the ivory ear-pieces of the metal tubes and the auditory canals allows movement of the metal tubes as a whole in the direction of the length of the patient's body. The flexible tubes provide for movement of their attached collectors in any direction we please; and by using a material of special and peculiar

manufacture, the movement is effected without disturbing the continuity or calibre of the contained columns of air. It is in this way that the whole instrument is virtually made flexible. The features of the stethoscope, as described thus far, are those that provide for accurate communication between any area of the chest and the tympanic membrane of each ear singly. By the terms of our second condition, it is required to bring both ears together into communication with one and the same area. The mode in which this has been brought about comes under the second head.

Secondly, as to the means adopted to secure transmission of sounds from any area to both ears of the auscultator simultaneously. The instrument consists of two chief tubes, connected together by a joint. We are concerned, under this head, with the mode of union, for it is on this that the binaural character of the stethoscope depends. The instrument has two collectors—a feature which relates to the third condition. It should, therefore, be binaural in respect of each collector; that is, sounds entering *either* collector should reach both ears. A cross-communication between the two tubes, somewhere in their length, would effect the purpose. But the communication must be effected without destroying the continuity of the columns of air, and, at the same time, adjustment of the ear-pieces to the ears must be taken into account. It has been found possible to provide for these contingencies by crossing the metal tubes, like the strokes of the letter X, and uniting them where they cross (near the distal ends) by a tubular joint (D). The construction of this joint is important. A very short metal tube is fixed at right angles to each crossed tube. One of these short tubes is of the same calibre exactly as the rest of the instrument; the other is fitted accurately to receive it. When the one short tube is inserted into the other, the two can revolve air-tight about their common axis; the two metal tubes can be opened and closed (like the blades of a pair of scissors), and therefore are easily adjusted to or removed from the ears; whilst always, the continuity of the cylindrical columns of air is complete. When adjusted to the ears, the metal tubes are retained in position by the action of an elastic band (E), placed at their extreme distal ends. Thus, sounds entering either collector pass up the corresponding tube to the joint, and thence on in two directions—straight on through the same tube for one ear, across by the tubular joint and through the other tube for the other ear. We have now, in fact, gained a double instrument; the two collectors represent two distinct binaural stethoscopes, and these are intended to be used separately. But, so far, their use must be coincident; or, whilst one is in use, extraneous sounds must be allowed to pass through the other to mingle with the sounds it is desired to hear. It is required that sounds should reach the ears from one area only at a time, when both collectors are placed over different areas; the sounds proceeding from one area should be stopped from reaching the ears during the time that sounds from any other area are being listened to.

Thirdly, as to the mode adopted to secure rapid and complete exchange of sounds engaging the ears from any area for sounds from any other area. To secure this, is to secure means for accurate comparison of sounds.

The flexible tubes are not immediately attached to their respective collectors; a short length of very thin India-rubber tubing (E) intervenes, a stout wire passing outside and parallel to the tube to give sufficient rigidity to this part of the instrument. On compressing this tube between the thumb and forefinger which hold the corresponding collector in position against the chest-wall, the canal of the tube is obliterated, the continuity of the enclosed column of air is destroyed, and all sound entering the collector is completely and instantly shut off from both ears. This intervening arrangement is called the "commutator". Alternate compression of the commutators brings each component stethoscope alternately, one only at a time, into use. The degree of pressure required is material. Compression of the flexible tubes themselves would effect their occlusion, but the necessary thickness of these tubes is such that the degree of pressure required to obliterate their canals would produce adventitious sounds—sounds due to the action of the tube itself, and to the muscular susurrus of the fingers. This difficulty is obviated by the thinness of the commutator-tube, whilst the defect introduced by excessive pliability is met by the device of the rigid wire. Thus the third condition is fulfilled, and it is fulfilled by the same instrument that fulfils the other two. It was not only required to fulfil this third condition; it was required that it should be compassed with the utmost exactness of combination with the other two conditions. For the very essence of diagnosis is comparison, and its issues, in diseases of the heart and lungs, are of the highest possible significance. Diagnosis presents, moreover, in diseases of these organs, a feature of peculiar interest; the judgment formed by the mind frequently turns upon evidence furnished solely by the stethoscope. Whether it be to catch the first faint whispers of incipient phthisis in altered rhythm of breath-sounds at the apex of one lung, or to fix peculiarities

of site and area in a cardiac *bruit*, the nature of the means by which we seek for evidence that may turn the scale is momentous in the extreme. It is strange that such issues have been left so long to hang upon the clumsy devices of our forefathers.

This description of the compound stethoscope, with regard to the prime conditions it fulfils, will not fail to suggest abundant illustrations of its advantages as an instrument for clinical use. I will conclude by a reference to one or two points, as I think, of much practical consequence. It is no small advantage that both ears are completely closed to extraneous sounds when the stethoscope is in use; the ears are engaged only by the sounds which it is desired to hear. Moreover, the attention is not diverted during the shifting of the collectors from point to point. Ease of position to the auscultator and patient are secured; it is possible to auscultate patients whose decubitus would preclude the use of the uniaural stethoscope, and the comfort of the patient who is in pain is eminently consulted. Apart from the fact that attention in hearing is liable to distraction when, at the same time, the attention is solicited in other directions through the eye, the sense of hearing is much aided and the evidence furnished to the ear is much corroborated by coincident inspection of the chest by the eye. I have frequently derived assistance, in determining the relations of a cardiac murmur to the sounds it has wholly or partially replaced, from having the cardiac impulse before the eyes. It is often essential to diagnosis that the point of maximum intensity of sounds should be accurately localised. To this end, means of making rapid exploration of the areas over which the sounds are heard, and means of marking the results of comparisons as they are successively made, are the desiderata. It is needless to point out how these are supplied by the two component stethoscopes of my instrument, either of which can be brought into use or rendered impervious instantly, and without disturbing the adjustment to the ears. Finally—and it is the student that this illustration chiefly concerns—the first recognition of a morbid sound depends on being able to compare it with its healthy correlative, and the more rapidly the one can be exchanged for the other in the ears the better will be the appreciation of the difference. Or, take the case of a sound which is morbid, not from its special character, but because it is heard in an abnormal position, a similar rapidity of exchange and comparison is required. In most patients, standard healthy sounds coexist in the same chest with sounds that are morbid both as to character and site. One collector being applied over the site of a healthy standard and the other over the site of a morbid sound, the sounds can be admitted to, or shut off from, the ears alternately, and thus compared under conditions which could hardly fail to produce accurate impressions. During an extended use of the instrument in the wards and out-patient rooms of a large hospital, its ready response to the endless and varied calls made upon it by the exigencies of clinical practice justify the expectation that it will stand the test of experience.

ON HYPEREXCITABILITY AND PARESIS.

By C. HANDFIELD JONES, M.B., F.R.C.P., F.R.S.,
Physician to St. Mary's Hospital, etc.

[Concluded from p. 372 of last number.]

THE next point on which we shall remark is the affinity between hyperexcitability and paresis. This has already been illustrated, to some extent, in the preceding remarks, but it deserves to be noticed more particularly.

1. Commencing with the faculty of sensation, we find, first, that the most marked hyperæsthesia is produced by conditions which also give rise to anæsthesia. Thus, in Dr. Waller's experiments on refrigeration of the ulnar nerve, the ultimate effect of the chilling was anæsthesia of the district supplied by the nerve; but this was preceded by hyperæsthesia. A case is recorded in the *Medico-Chirurgical Transactions*, vol. vii, p. 177, where, during the gradual recovery of the brachial plexus from injury produced by a fracture of the clavicle, the skin of the upper part of the arm possessed natural sensibility, another (probably the mid-region) was morbidly sensible, while that immediately beyond was quite insensible. Trousseau (*Clinique Médicale*, vol. ii, p. 312) states that cutaneous anæsthesia is often seen to succeed hyperæsthesia, especially in cases of herpes zoster. Secondly, inflammation of a nervous centre, as the spinal cord, giving rise to motor paralysis, will also give rise to hyperæsthesia, the two conditions existing together. In a case of alcoholic paralysis which I have recorded, complete motor palsy of the lower limbs coexisted with extreme hyperæsthesia and pain. Her powerless hands were numb, but not in nearly so much pain as the feet. Here the three phenomena were manifestly co-products of the same cause, and at the same time. Anæsthesia, however, is the more usual accompaniment

of palsy. Trousseau (*Clinique Médicale*, vol. i, p. 287) mentions, speaking of a case of complete paraplegia, that the anæsthesia, which had been considerable up to a certain date, was replaced the next day by hyperæsthesia.

2. *Hyperæsthesia is often associated with pain*, as in abdominal neuralgia, the hysterical breast, and irritable testis. In Dr. Fuller's case of obstruction of the arteries of the lower limbs with fibrinous deposit, the first symptom was acute pain, associated with exquisite tenderness of the whole limb, so great that the slightest touch caused intolerable suffering. Now, pain is regarded by so good an authority as Dr. Anstie as ranking on the same level as paralysis.

3. The remedies for hyperæsthesia are mainly of a restorative and recreative kind—not quite so absolutely, indeed, as those of neuralgia, but still so much so as to indicate not obscurely the nature of the process. Those who admit the truth of the adage, "Naturam morborum remedia ostendunt," will not think lightly of this argument.

Motor hyperexcitability exhibits a relation to paralysis in the following particulars. 1. The same conditions which usually produce paralysis of a motor centre, will also produce hyperexcitability. Thus, in a case of myelitis under my care, the left leg was simply paralysed, as well as the sphincters; but the right leg started and jumped, and was affected with twitching sensations. In another case, where there was very considerable paralysis of both motor and sensory power in the lower limbs, and the power of the sphincters was impaired, strong tremors were produced by passive movements of the legs, or by attempts to move them. As improvement took place, the tremor ceased. In a third case, where there had been complete paralysis of motion and sensation, in connexion with diseased vertebrae and abscess, the left thigh, at the time when I saw the patient, was affected with considerable tremor when he attempted to use the limb. In a fourth case, where motor power, which at first was quite lost, had been very much regained, there was great tremor of the lower limbs. In all these instances, the damaged nerve-tissue was hyperexcitable. A case of lead-poisoning was once under my care, where the symptoms were not the ordinary paralytic, but were decidedly indicative of hyperexcitability. The patient's arms were agitated by clonic convulsions when he attempted to use them. He could scarcely carry a glass to his lips without spilling the liquid, or hold it so as to drink. At one time, his arm used to be fixed to his side by tonic spasm for several hours every day. If he put himself out in any way, he shook violently, "like a leaf on a tree," and his gait became unsteady and jerky. He improved very much with strychnia, cod-liver oil, and faradisation. Here the motor centres were certainly affected by the poison; but the result was hyper- instead of non-excitability. The remedies which availed were those which serve us when paralysis exists. Surely all this plainly points to a close connection between the two states just mentioned. Regarding embolism as the cause of chorea, which it probably is in some instances, it will not be forgotten that the same cause gives rise to paralysis when it obstructs the blood-flow to the corpus striatum. Dr. Lockhart Clarke has recorded a case (*British and Foreign Medico-Chirurgical Review*, July 1864) in which there was partial paralysis of one arm; and so long as the arm was enveloped and kept warm in flannel, it remained perfectly still; but whenever it was exposed to the impression of cold air, it began to move in a spasmodic and jerking manner. Here the lesions and disintegrations found in the cord bore a very striking resemblance to those occurring in tetanus. 2. When hyperexcitability exists in one part, there is often also failure of nervous power in another. In a case where the sural muscles of the left leg contracted spasmodically, so that the patient walked on the point of his toes, and there was some permanent rigidity of both the flexor and extensor muscles of the ankle, the mental faculties were impaired; he was mopy, dull, listless, and more or less drowsy. These cerebral pareses had obliged him to quit his occupation. 3. In chorea, Trousseau states it as the general rule, that the intellectual faculties are more or less weakened as long as the motor disorder continues. He also affirms that anæsthesia or other derangements of the sensory faculty are present in the majority of instances. A medical friend related to me a case of tænia under his care, where there existed paralysis of one leg and spasmodic contraction of the opposite arm. Mr. Moodeen Scherriff has recorded some instances of paralysis not depending on organic lesion, in which there was rigidity of one limb and simple immobility of the other on the same side, the same cause having given rise to both conditions, and the same treatment removing them. Dr. Wilks mentions a case (*Guy's Hospital Reports*, 1866, p. 261) where, after a mental shock, a girl aged 15 passed into a semi-maniacal condition. Her face and hands were constantly affected by choreal movements, which at times became almost tetanic. After her menstrual period passed by, she became calmer and more like an ordinary choreic. She appeared to understand what was said to her, but was perfectly anæsthetic. Dr.