ON STETHOMETRY.

ON STETHOMETRY.

BEING AN ACCOUNT OF A NEW AND MORE EXACT METHOD OF MEASURING & EXAMINING THE CHEST, WITH SOME OF ITS RESULTS IN PHYSIOLOGY AND PRACTICAL MEDICINE.

Also an Appendix

ON THE CHEMICAL AND MICROSCOPICAL EXAMINATION OF RESPIRED AIR.

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TO

WILLIAM STOKES, M.D., F.R.S., HON. D.C.L., (OXON.)

ONE OF THE

FIRST TO INTRODUCE EXACT METHODS OF MEASUREMENT

INTO THE STUDY OF DISEASES OF THE CHEST,

This Volume is Dedicated,

WITH MUCH RESPECT AND AFFECTION,

BY HIS FORMER PUPIL,

THE AUTHOR.

PREFACE.

THIS treatise does not profess to give a complete account of the subject of chest measurement. It contains descriptions of several new instruments which were devised (1) to mark the situation of various thoracic phenomena, (2) to investigate more thoroughly than has hitherto been possible the complicated mechanism of respiration.

Some of the results are given that have been obtained by these means in physiology and practical medicine.

Of these instruments four were designed to solve certain special problems that arose in the course of the inquiry: these were the thoracic callipers, the goniometer for the ribs, and the two kinds of stethograph. These forms of apparatus are not likely perhaps to come into general use, but the remaining two, the chest-rule and the 3-plane stethometer, or some modification of them, are means of accurate measurement that will, I believe, be found useful in the every-day study of disease.

It is in the hope that further inquiry may be stimulated that this book has been sent to press.

There remains ample scope for further investigation, and this, in the words of Sir Thomas Browne, I propose unto acuter inquirers, "who nauseate crambe verities and questions over queried. Flat and flexible truths are beat out by every hammer, but Vulcan and his whole forge sweat to work out Achilles his armour. A large field is yet left unto sharper discerners . . . to erect generalities, disclose unobserved proprieties . . . affording delightful truths, confirmable by sense and ocular demonstration, which seems to me the surest path to trace the labyrinth of Truth."

I desire to express my grateful acknowledgments to the medical staff of the Manchester Royal Infirmary, for many opportunities which they have afforded me of pursuing this inquiry; to my friends Mr. Alfred Nield and the Rev. John Venn for assistance in the several mathematical problems involved; to Dr. W. Ogle, of Derby, for his help in kindly criticism and the revision of proofs, and to others who, from time to time have given me valuable assistance and encouragement in the prosecution of labours which, but for such help, might never have been completed in the necessarily brief leisure at the command of one engaged in active practice.

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Page 33, line 10, *for* "signs" *read* "sizes."

ON STETHOMETRY.

CHAPTER I.

INTRODUCTORY.

"Thou hast ordered all things in number, measure, and weight."—
Wisdom of Solomon xi. 20.

OUR knowledge of the mechanism of breathing must be regarded as still very imperfect. Men of high eminence do not even now agree upon such apparently simple problems as the action of a muscle or the mode of movement of a rib. And, whilst the healthy action of the chest is still a subject of controversy, it is not surprising that its disordered action, induced by disease, should be even more imperfectly understood. In stating this fact, it must not be supposed that there is any intention to undervalue the good work that has already been accomplished in this branch of medical research; but it can hardly be said that, as yet, more has been done than to map out the ground that will have to be occupied in the future.

The subject is, indeed, one of peculiar difficulty; and those who are best acquainted with it would probably be the first to acknowledge the need of further inquiry.

We are, moreover, indebted to those who have gone before us for pointing out the direction in which we may hope for the best results. The methods which must still be employed are necessarily in principle similar to those which have taught us what we already know.

It is only by means of an exact examination of the chest, steadily and patiently carried out in various ways, that we can arrive at a solution of the problems presented to us.

Doubtless a wider range of observation and a more minute inquiry into details, will be required; but "weight, measure, and rule" are now, as they have always been, the essential implements in the hands of the investigator.

Two well-marked lines of study lie before us: the first concerned with the examination of the healthy working of the chest; the second devoted mainly to the observation and explanation of its diseased conditions. And there are two chief methods by which each of these lines of study can be pursued with advantage.

1. The *mensuration* of various dimensions.

2. The *localization* of phenomena.

First, Mensuration is required to determine the natural proportions and healthy variations of the chest, to measure its movements, and to ascertain the relations in these respects of its several parts, and their intimate mechanism, and to gauge its force and its capacity; and all these inquiries must be repeated in states of disease.

Secondly, Localization is important, in order to fix the size, form, and relative position of organs in health and disease, and of any adventitious structures; to mark the variations that may take place in their situations in various positions of the body, and under various circumstances; to determine the changes in them that can only be produced by disease: and to localize the points at which any special phenomenon has been observed.

In this way also may be recorded, in a manner suited for future comparison, the advance or retrogression of fluid effusions, the waxing and waning of tumours, or other adventitious structures, and the increase or diminution of consolidation or of engorgement.

For all these purposes exact instruments of measurement are absolutely necessary. Without in any degree undervaluing the power of the "experienced eye" or of the "practised hand" for the detection, and even for the appreciation of the extent of most diseases, yet even when aided by the well-trained ear, they fail to meet all our requirements.

The utility—nay, the necessity—for artificial and numerical determinations will be sufficiently evident if we consider as briefly as may be the powers of the unaided senses, and note wherein they fall short of the exactitude which is needed in our researches.

First, the eye—"the guide, the ruler, the succourer of all the other parts,"[1]—is undoubtedly able to do many things that mechanical apparatus cannot do.

By sight we can mark those signs, invaluable to the physician, which tell of the general condition of the patient, and which constitute the physiognomy of disease; the aspect of the face and frame, the mode of breathing, even the muscles employed, the gestures and signs of distress.

The eye can also, with great accuracy, detect differences in shape, size, and situation of objects—that is, it can *localize* the signs it sees—but it cannot state their relations to surrounding parts, so as to permit of future reference.

It can also measure, but it cannot register its measurements, and is incapable of giving definite results.

Next, the *Hand*. "The instrument of instruments,"[2] is

[1] Roger Ascham.

[2] "ἡ χειρ οργανόν ἐστιν οργάνων."—ARISTOTLE.

able, by learned touch, to mark differences of size, shape, or motion; to appreciate resistance or elasticity; to distinguish fluctuations, vibrations, or thrills, heat or cold, moisture or dryness, softness or harshness, or flabbiness of texture; but, on the other hand, it is quite unable to measure accurately, or to register the extent of these several qualities otherwise than by comparison. It is, in short, most valuable to detect and to compare, but useless as an instrument for precise scientific measurement.[1]

The *Ear*, again, is still less likely to have its exclusive domain invaded by any instrument other than the simple conducting tube of various material and shape.

It can distinguish differences in the pitch, quality, and tone of the sounds of breathing, or in the character of the percussion note. It can discern the nature of the murmurs of respiration, and denotes them by a series of epithets, such as for variety emulate those applied by the bewildered poet to the water-shoot of Lodore—the snuffling, bleating, hissing, sonorous, snoring, cooing, whistling, blowing, and tubular sounds of disease, the appreciation of fine or coarse crepitation, the distinction between dry and moist sounds, the crackling, gurgling, bubbling, and splashing of fluid, the grazing, grating, rubbing, creaking, crackling, and rumbling, of pleuritic noises. In percussion, the quality of the half-deadened note, its degree of resonance, and its duration, can only be determined by the ear, and no instrument can be conceived that can take its place, or that can compare the two sides of the chest with the wonderful

[1] It is interesting to notice that the first attempts at linear measurement were made with portions of the human frame. Dr. Arbuthnot, in his quaint *History of Coins, Weights, and Measures*, remarks "that the Romans borrowed their measures from the Greeks, being about sixteen in number, and commonly taken from the members of a human body," thus the finger's breadth, *digitus latus*, δάκτυλος; the palm, *palmus*, δοχμὴ; the foot, *pes*, πους; the cubit or cubitus, πῆχυς, and so on.

accuracy attained by the practised ear. And yet with all this individualism of power, assistance is still required, even by the ear, to mark the exact situation where sounds are best heard, and to record these points in definite language for future reference, either in the progress of the same case or to compare the prophecy during life with post-mortem fulfilment.

Not one of the natural senses is thus able to dispense entirely with the use of instruments, and we may say with Bacon:—"Nec manus nuda, nec intellectus sibi permissus, multum valet; instrumentis et auxiliis res perficitur."—(*Nov. Org.*, Aph. II.)

There are indeed few who will doubt that accurate instruments of record or of measurement are needed in the physiological laboratory, but it is not unlikely that some will object to their intrusion into the domain of medicine.

But even for diagnosis, in difficult and doubtful cases, exact methods of research are often useful, and they are essential for the thorough investigation of disease. Diagnosis constitutes only a portion, and that a small one, of the work of both the practical physician and the student of disease. It is the opprobrium of medicine, as compared with other physical sciences, that it has neglected so long to obtain those distinct and definite data, without which true progress is hardly possible, and it cannot be allowed for a moment that the phenomena of disease should be studied with less accuracy than those of health.

The arguments that have been urged against the employment of instruments in the study of disease might be applied with at least equal force to their use in physiological inquiries. It is just as possible with the natural senses to mark differences of various kinds in healthy bodies as it is in disease.

Many of the observations which are made upon healthy bodies must be repeated in various forms of disease, both for the sake of learning what modifications these disorders introduce, and in order that the observations made in health may throw light upon the phenomena of disease. Even in the physiological laboratory it is often necessary to induce artificially some abnormal condition of parts such as may be found in certain morbid states of the body. And instruments of accurate measurement are not less requisite for purely pathological studies. Before a complete account of any morbid state can be given, its exact limits must be defined, its progress, and its variations must be noted, and, in order that comparisons may be made between the successive epochs of its own course, or with cases of a similar nature, it is requisite that these records should be expressed in definite language, and as much as possible that they should be cast into the numerical form.

In hospital demonstrations also, not only for the more complete study of disease, but in order to train students in habits of accuracy of investigation, or of noting, and to encourage them to compare physical signs observed during life, with post-mortem appearances; for all these purposes it is most important that exact methods of examination of cases should be adopted.

It is with the view of facilitating and advancing, in some measure, both physiological and pathological inquiries relating to the chest that the present work is undertaken, and in it I propose, first, to give a brief account of certain exact methods of examination of the chest, its form, capabilities, and mode of action. Second, to describe the results obtained both in healthy persons and in those affected by various diseases. Third, to endeavour from these details to deduce conclusions as to the working of the various parts of the chest, and the action of its muscles, and to trace the influence upon them of diseased conditions, and fourth, to indicate in what directions we may hope to obtain help in diagnosis, prognosis, and treatment from a more general adoption of exact methods of research.

In carrying out these objects I do not propose to give a systematic account of all the contrivances that have been used in chest measurement, nor yet to examine their results in detail; these will for the most part be better learnt in the writings of the observers themselves. It seems better for the real advancement of knowledge on this subject that, whilst briefly indicating what others have done, I should, in the main, limit myself to those experiments and observations which have come under my own immediate notice. A recapitulation or history of other men's labours is likely to be less useful than the evidence of an eye-witness, as Robert Boyle appositely says:—"'Tis a great convenience in this manner of writing, that the reader need not be tired with tedious repetitions of what others have said, and that the author being at liberty to break off when he pleases, is not obliged to endeavour to teach what he does not understand; and if such essays be, as they ought, but competently stocked with experiments, 'tis the reader's own fault if he does not improve by them. When an author acquaints me only with his reasoning, I am in some danger of erring with him; at least I may lose all the time and pains I may bestow upon him; but if a writer endeavours by enriching his discourse with new and real observations and experiments to credit his doctrine, let his private opinions be ever so erroneous, yet his experiments being true, I may make my own use of them and even plead them against his opinion, so that such a writer will certainly teach me useful truths and cannot easily lead me into error."

CHAPTER II.

ON SOME METHODS OF CHEST-MAPPING.

"That to come
Shall all be done by the rule."
ANTONY AND CLEOPATRA, Act ii., Scene 3.

THE localization upon the skin surface of the position of internal parts is to the physician of as much importance as an intimate knowledge of regional anatomy is to the surgeon.

Both by personal observation, and by a study of the works of such men as Walshe, Sibson, and Luschka, it is desirable that a student should obtain such a mental map of the viscera as may at any time be called forth for comparison with cases of disease. As the spectroscopist superimposes the perfect solar lines over the spectrum which he is examining, so the medical analyst may trace deviations from the normal standard of the relations of internal organs.

But it is often necessary to localize the parts by some device admitting of accurate comparison. For this purpose, something more is needed than (1) *the regional method* employed by Walshe and others. The knowledge of the normal position of organs within the several boundaries of the regions cannot tell us the exact extent of effusion or of consolidation, with their variations from time to time.

We cannot thus strictly localize the position of a crackle or of an amphoric resonance, nor can we, without danger of error, compare the post-mortem appearances with the signs noted during life.

Raciborski's attempt to improve upon this method, by dividing the body into thirty-two rectangular spaces, was not very successful; and Piorry's elaborate scheme of vertical, horizontal, and even obliquely-drawn lines, is far too complicated for general use.

II. THE METHOD OF NATURAL MARKINGS.

A somewhat more simple and perhaps more exact localization is secured by using the bony skeleton as a guide. If the ribs and costal cartilages are taken as very irregular parallels of latitude, and the sternum with vertical lines through the nipples as meridians, it is possible to refer the underlying organs to them with some approach to accuracy.

For various important objects, it is probable that this is the only readily applicable method. It is difficult to see what other means could be substituted for it when the observation is to apply a rule that shall fit various individuals.

Thus, to mark the normal positions of the heart and its great vessels and valves, the points where their sounds are best heard, the mutual relations of the heart and lungs, the size of these organs under differing conditions, the positions of the nipples in health and in disease, for all these questions no general measurement, by inches or other linear measure, is possible, owing to the varying size and shape of different individuals. Moreover, whilst there are great differences in the measurements of individuals, there is usually a remarkable agreement in most persons in the sites of the more fixed contents of the chest in relation to the several parts of the bony thoracic cage.

When the intention is to localize the parts in the same individual under different circumstances, however, as in the ordinary clinical noting of disease, there are serious objections to the plan.

1. The lines of reference are so irregular, that it is difficult to get from them a distinct idea of the space involved in the areas which they denote.

2. A cumbrous circumlocution is usually necessary to describe the locality of any moveable part at any one time—the number of words required to state some simple change of position of even a healthy organ under certain alterations of external circumstances is sometimes very great.

Let any one attempt to describe the variation in the situation of the heart's impulse in different positions of the body in terms of the chest-markings; he will find it necessary to take the bearings of these markings, and their distances from the impulse-site, and in the end the terms which he must use will not be available for comparison with other cases.

Take as an instance the case of a man aged forty-one, in whom, in the *upright* posture, the point where the heart's impulse was strongest was just under the lower edge of the fifth rib, $1\frac{3}{4}$ inches below the nipple, and $\frac{1}{2}$ an inch to the right of a vertical line through this point.

When he lay *on his back* it was felt just above the fifth rib, $\frac{3}{4}$ of an inch below the nipple, and the same distance to the right of this point.

Lying on the *left* side, it was just under the edge of the fifth rib, 2 inches below the nipple, and 2 inches to the left of its vertical line; and on the *right* ride, the pulsation was just perceptible in the narrow interspace between the fourth and fifth ribs, 1½ inches from the central line of the sternum, 2 inches from the nipple, and ½ an inch below its horizontal level. The difficulty of comparing together a number of cases in terms like these would be so great as to be almost impossible, especially when variations in the nipple-site occurred.

3. The points and lines of reference are themselves liable to alter their position, both in movements of the body or in the work of respiration and the processes of disease.

Dr. Sibson notes that in emphysema the sixth rib is sometimes so much raised as to be only about 1 inch below the nipple, whilst in phthisis, on the other hand, this same rib may be as much as 4 inches below this point on the affected side.

The *nipples* also vary somewhat in position in different persons even in health; thus Luschka (*Die Brustorgane*, p. 11), remarks that in most cases the left nipple lies close to the lower border of the fourth rib, but it may sometimes be found a rib's breadth lower.

The *clavicles* are placed at various angles with respect to the sternum, and how greatly the *scapulæ* alter their position is known to every observer.[1]

4. Again, there are not a few cases in which we should be glad not only of a means of greater brevity of noting,

[1] In his *Medical Anatomy* Dr. Sibson gives the following measurements of the movements of the scapulæ in one subject:—"When erect, and the arms pendent, the spines were 5½ inches apart, and were opposite the third dorsal spine; the angles were 6 inches apart, and were opposite the eighth dorsal spine. When the arms were drawn back the spines approached to 1½ inches and the angles to 3 inches. With the arms stretched upwards and forwards the spines were 9 inches asunder and the angles 13 inches; and with the arms crossed over the head the lower angles were 16½ inches apart. When the shoulders were shrugged as high as possible, the spines were level with the first dorsal spine.

but in which more minuteness of measurement is desirable than can be afforded by the bones of the thorax.

The ribs in an adult male are usually from 0.6 to 1.0 inches in width, and the interspaces vary very greatly in size, not only in different individuals, but in the same individual in the different zones of the chest and in its anterior and posterior regions.

III. THE TRACING FRAME.

Dr. Sibson's Tracing Frame is probably the most perfect of all the means which have hitherto been employed for chest-mapping.

It is hardly likely, however, that this method will come into general use. It requires much time and care in its application, and there are few medical men who would be able to employ it with the patience and skill put forth by its first foster-parent.

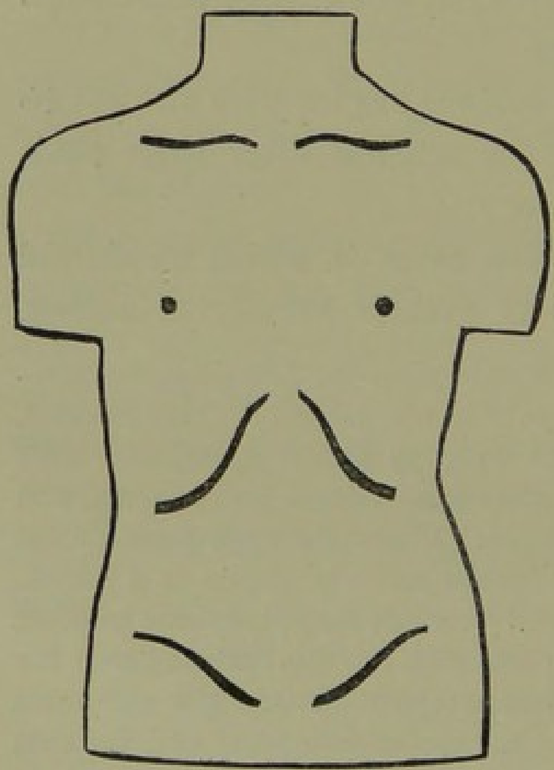


FIG. 1.—The Diagram-figure.

It is desirable on this account that some simpler plan should if possible be devised.

IV. THE DIAGRAM-FIGURE.

In 1870 Dr. Fairbank, following out the idea suggested by Dr. Bright, included in his clinical note-book a little brass plate, so cut that by outlining it with the pencil it would give the annexed figure, upon which might be marked the observer's estimate of the position of the various evidences of disease, or the limits of different morbid conditions.

V. THE CHEST-RULE.

I have adopted this simple contrivance; but in order to bring the size of the patient into relation with that of this diagram and to facilitate noting, and also to serve as a guide to the position of different structures, whether healthy or diseased, I have devised a little instrument which may be called a Chest-rule, since it is intended to mark out the chest into certain definite ordinate lines. It consists of

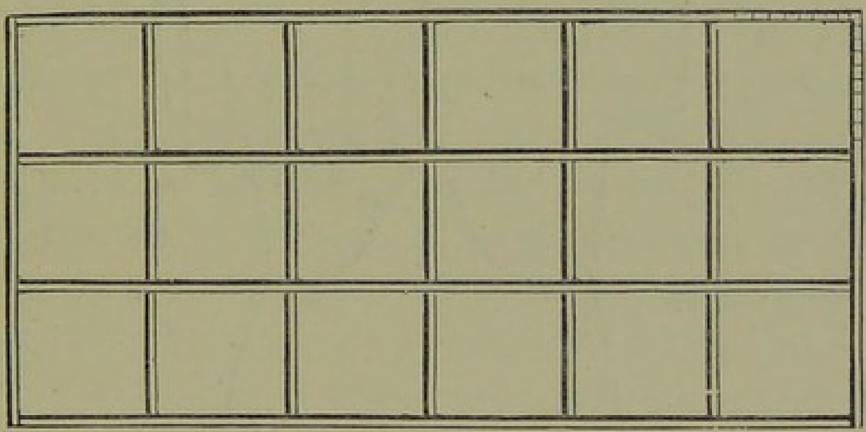


FIG. 2.—The Chest-rule.

thin, narrow spring steel, so arranged as to form a rectangular parallelogram, 6 inches long by 3 in width, and divided into eighteen squares of exactly 1 inch length of side.[1]

Owing to the lightness and flexibility of this rule it may easily be carried in a case-book, and may readily be applied

[1] This rule is manufactured by Messrs J. and W. Wood, King Street, Manchester.

to the chest, adapting itself to any inequalities of the surface. It permits both percussion and auscultation to be made while it remains in position, and thus allows accurate noting to be practised.

When it is required to use this Rule the median line of the sternum is taken as the line of departure in front, and behind, the spinal column is regarded as the base line, and the measurements start respectively from the top of the sternum and from the first dorsal spine. If the "diagram-figure" is used, marks may now be made upon it along the

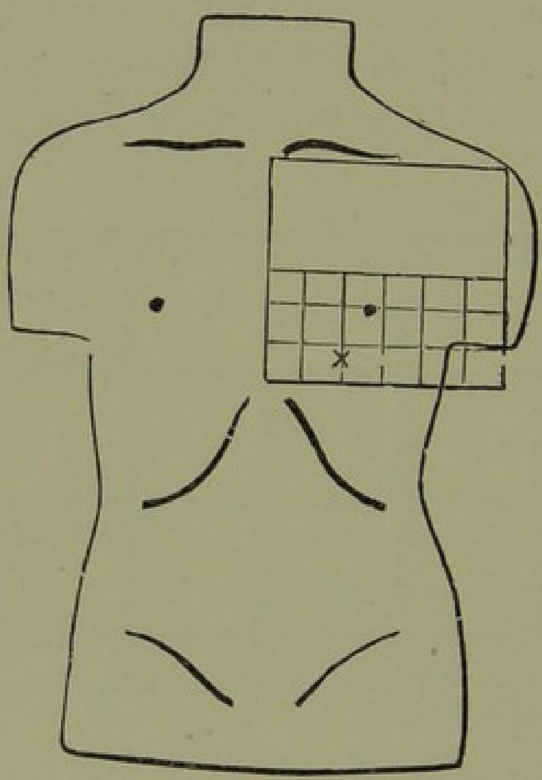


FIG. 3.—Showing the mode of using the Chest-rule.

central line of the body, showing its size in relation to the subject under observation. The spaces occupied by the Chest-rule on the patient's breast or back-bone being marked on the diagram, thus bringing it into relation with the size of the patient. Any point on the surface of the chest at which it is desired to note any phenomenon can now either be marked upon the figure in the square corresponding to the portion of the Chest-rule which lies over it, or it may be denoted by giving, in two ordinates:—1, the distance from the horizontal line through the top of the sternum, or through the first dorsal spine; and 2, the distance from the central line of the body. These ordinates may be marked as x and y, or by the simple device of making a stroke between the two figures; thus in the diagram fig. 3, the position of the right nipple may be given as 4x, 2.5y, or as 4 | $2\frac{1}{2}$; and the situation of the heart's impulse in the erect posture would be found by the signs 5.5x, 2y, or $5\frac{1}{2}$ | 2. When localities on each side of the sternum or spine have to be denoted, the addition of the letters R or L, or of the signs + or — will show which side is referred to, and when a surface or a space is meted out, a representation of it on the diagram as it lies under the Rule may be given with much more facility than by figures. If the diagram-figure is not at hand however, its extreme points of measurement may be noted. When a straight line has to be marked, its position may be found by giving the numerals denoting its origin and termination united by a stroke, thus, (5 | 2——4 | 6). If the line is not straight or nearly so, it will be simpler to mark it upon the diagram-figure than to give its several ordinates.

The space of a certain degree of dulness on percussion, extending from the clavicles downwards, may with advantage be marked, by giving the vertical ordinate of its inferior limit only, and the horizontal ordinates of its origin and termination; thus, in the annexed figure, the extent of dulness represented by the shading might be written down as 2 | ($\frac{1}{2}$—4), or as 2X ($\frac{1}{2}$—4) Y. It is usually better, however, to employ the diagram-figure, since it is easy upon it to denote the variations in the degree of dulness by the intensity of shading employed, and in this way superficial and deep dulness may be shown.

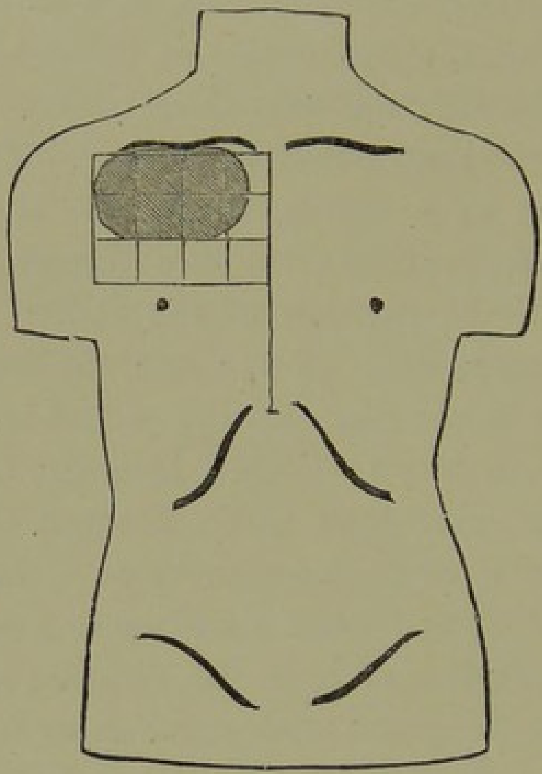


FIG. 4.

I have selected the following examples from amongst the many uses to which this instrument may be applied :—

I. ON THE POSITION OF THE HEART'S IMPULSE IN DIFFERENT POSTURES, IN HEALTH AND DISEASE.[1]

When it is remembered how often it is necessary in Clinical Medicine to observe the position of the heart's impulse, with a view to determine the presence or absence of cardiac disease, or to record its progress, the importance of ascertaining its normal position, and its healthy varia-

1 The substance of the following remarks was given in a communication to the "Journal of Anatomy and Physiology," Nov. 1875, vol. ix.

tions due to changes in posture, will be at once conceded—and it might fairly be anticipated that observations undertaken with these objects might well lead to interesting collateral results. It is therefore somewhat surprising to find how few have been the observations on the subject. It is true that anatomists have stated in general terms the usual impulse-site, but no variations are recorded.

In Quain and Sharpey's *Anatomy* it is stated that "the heart's apex strikes the walls of the chest in the space between the cartilages of the fifth and six ribs, a little below the left mamilla." Dr. Sibson gives the point "between the fourth and fifth or the fifth and sixth ribs," and Dr. Walshe, in more exact terms, states that it "beats in the fifth interspace and somewhat against the sixth rib, about mid-way between the vertical line of the nipple and the left border of the sternum" (*Dis. of Heart*, 4th ed., p. 18). Piorry on the other hand remarks that "in some individuals in health, the heart-beat is raised three, four, or five centimetres higher than in others," that "in some, it may be found three centimetres to the right of the sternum, in others three or four centimetres to the left of its ordinary state," and though he gives no proof of his statement, he believes it varies with age, sex, build, constitution, proportion of blood in the organism, and "a crowd of other circumstances." *Plessimétrisme*, p. 379. Still fewer records can be found of the degree of mobility of the impulse in different positions of the body. Dr. Quain (p. 1102) simply says that the heart "comes more extensively into contact with the anterior walls of the chest when the body is in the prone posture, or lying on the left side," — and Dr. Walshe that "changes of posture elevate, depress, throw it upwards or backwards,"—or again, "the heart falls downwards somewhat (if its substance be weighty the fall may equal an inch) in the erect attitude and comes more forward than in decumbency. Changing the posture in decumbency from the right to the left side will carry the heart an inch, or even more, to the right or left of the position it occupies when the individual lies on the back." P. 9.

But it will be observed that nothing is here said as to the extent to which the motion of the body affects the position of the impulse.

The effect of different diseases of the heart upon the impulse-site is indeed clearly pointed out by this acute observer, and even in that of some non-cardiac disorders; thus he notes the raising of the apex-beat in severe hæmorrhage, and the lowering of its level after a case of typhoid fever, but even Dr. Walshe gives no exact measurements on this point.

It is probable that one cause of absence of information has been the difficulty of localizing with sufficient definiteness any alterations in the site in question. It is not easy to describe in words the extent to which the impulse gravitates downwards or slantwise, or from side to side, this can only be done satisfactorily by means of ordinate measurements, vertically down the central line of the sternum, and horizontally at right angles to this line.

By means of the Chest-rule which I have devised, Mr. Patchett, late medical officer to the Manchester Workhouse, has kindly made for me a number of observations upon which I will now make some comments.

The measurements relate to 51 individuals, they have been made with great care, and are very accurate so far as they extend; they are perhaps as yet too few in number to found upon them any final conclusions, but they are an important contribution to the records on the subject. It is indeed probable that subsequent investigation will only confirm the chief results. Many of Quetelet's famous measurements of the average dimensions of the human frame were the result of still fewer observations, and yet they were found to be accurate by those who followed him. Even if the tables which follow are insufficient to afford trustworthy averages they at least give the extreme measurements as met with among the persons examined, and these will be found to present some very interesting points for remark.

In one sense only are the examples selected—that is, they are drawn from the class to be met with in a work-house hospital, and therefore represent neither the strongest nor the healthiest of their kind; otherwise as may be seen they were taken without discrimination of height or make. It may be stated however that cardiac cases were purposely excluded, since it was deemed desirable before passing to this class of cases, that the ordinary standard amongst other sick persons should be ascertained. Moreover, in order to obtain any practical result from such measurements, in cases of heart disease, it would be necessary to accompany them with careful notes of other physical signs and with ome history of the symptoms.

The method employed in taking the measurements, was to ascertain by careful touch the position on the chest-wall, where the strongest beat of the heart was to be felt, and at this point a mark with ink, or what is better, coloured collodion, was made. This search was first made in the recumbent posture on the back, next when the patient was sitting or standing up, then when he was lying on the left side, and finally when he lay on the right side. It will be found from the tables that the last-named observation was often doubtful and therefore omitted, and as might have been expected the omissions of this observation are most frequent in the larger and stronger made of the subjects. After each of these points had been ascertained and marked with the pigment, it was very easy afterwards to measure their ordinate distance, first along the vertical line down the centre of the sternum (x) and second along a line through the point at right angles to the vertical (y).

The tables on pages 22, 23 show the results obtained.

The length of the sternum has been taken as a guide in the arrangement of these cases, and though, as may be judged from the tables, this bone varies much in length in proportion to the other dimensions of the chest, yet it is probably as good a standard as could be chosen.

The position of the left nipple is also given, but this varies even more than the length of the sternum, varying in individuals with the same length of sternum, both in its vertical and horizontal ordinates. Thus in the group of cases with 8 inches length of sternum, the extreme vertical ordinates of the nipple are 4 and 6½ inches, and the horizontal ordinates vary from 3 inches to 4½ inches.

The relation of the heart's impulse-site to the nipple in the supine posture, varies from a position immediately under this point, to 1 inch or 1½ inch nearer to the median line of the body, but it is noteworthy that 6 out of the 8 cases in which it falls vertically under the nipple, were subject either to chronic bronchitis or phthisis, and it would therefore be important to know whether emphysema or any other lesion of the lung accounted for this, probably abnormal, situation.

The mobility of the impulse-site in different postures of the body varies considerably in these cases. The difference in its position is greater in the change of posture from side to side than in that from the lying to the upright position. In many cases (20 out of the total number) its level is the same in the upright and in the recumbent posture, and in the remainder it varies from ¼ inch to 1 inch. In 9 cases it is lowered ¼ inch, in 12, ½ inch, in 3, ¾ inch, and in 3, 1 inch. The size of the individual does not seem to make much difference in this regard, since there is as much alteration in the level of the impulse in the small as in the larger made men. One of the cases in which a fall of 1 inch occurs is in a man æt. 59, with a breast-bone 9 inches long, who suffered from chronic bronchitis. It seems possible that some unnoticed hypertrophy of the heart may have existed in this case, but in the other 2 there is no suspicion of this disorder. Of the 3 cases in which it dropped ¾ inch, one was a case of phthisis, another of chronic bronchitis, aged 74, and the third a man aged 33, suffering from a crushed leg.

It is interesting to observe that in most cases (*i.e.* in 60 per cent.) there was a small movement of the impulse to the left as the patient rose to the upright position, and in some instances this occurred even when there was no sinking in the level of the heart. The extent of this side-long movement varied from ¼ inch to 1 inch along the horizontal ordinate. In one case only (No. 20) was there a movement of the impulse to the extent of 1½ inches towards the right side: and as this man was the subject of phthisis, there might well have been some adhesions or loss of lung-substance to account for the exception.

The extent of the movement of the impulse-site from side to side is not, as I have before mentioned, always discoverable, since in some cases, when the patient lay upon the right side, the heart-beat was under the breast-bone.[1] In 12 out of the 51 cases the extent of the lateral movement was thus left uncertain; but in the remaining 39 it was traced, and was, in most instances

[1] In this statement it may be noticed that the term "apex-beat" has been avoided. It involves the theory that the heart's impulse is always occasioned by the impact of its apex against the chest-wall, but as Dr. Walshe has pointed out the chief vibration of the chest-wall is sometimes produced by its base, and in many of the cases recorded here, it was certainly not the apex that was felt beating under the finger.

CHEST-RULE MEASUREMENTS ON THE HEART'S IMPULSE-SITE (IN INCHES).

No.	Length of Sternum.	Position of Nipple.		Position of Heart's Impulse. (Males.) On Back.		Upright.		On Left Side.		On Right Side.		Age.	Duration of Decumbency.	Disease.
		X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.			
1	4¼	4	3	4½	2¼	4½	2½	4	4	4	1	11	4 weeks	Abscess
2	5	4	3	4¾	2½	5	3	5	5	5	1½	10	1 week	Scarlet Fever
3	5	4	3	4¾	2¼	5	2½	4¾	4	4¾	1	12	......	Ophthalmia
4	6	5	3	6	2	6	2½	6	3½	6	1½	14	......	Ophthalmia
5	6	5	3	6	2	6	2	6	4	6	0	31	2 weeks	Ch. Bronch.
6	6	4	3	5	3	5¼	3¼	5	4½	5	2	16	10 days	Phthisis
7	6	5	3	6	2	6	2¼	6	4	6	1	16	3 weeks	Phthisis
8	6½	4½	5	6	4	6¼	4	6¼	5	6	3	43	3 months	Ulcer of Leg
9	6½	4½	5	6	4	6¼	4	6¼	5	6	3	64	2 weeks	Pneumonia
10	6½	4½	5	6	4	6¼	4	6	5½	6	3	18	1 week	Catarrh
11	6¾	5	3¼	6¼	2¾	6¼	3	6¼	4½	6	1	22	1 month	Phthisis
12	6¾	......		5	3	......		5	4¼	5½	½	18	14 days	Fist. in Ano
13	7	4½	4½	6	4	6½	4	6¼	5	6	2½	24	1 week	Fist. in Ano
14	7	4½	3	6	2	6	2	6	4	6	1	25	1 week	Orchitis
15	7	5	3	6½	2	6½	2	6	3	Uncertain.		50	1 month	Bright's Disease
16	7	5	4	6	4	6½	4¼	6	5	6	2	20	......	Rheumatism
17	7½	5	3	6	2½	6	3	6	4½	6	0	35	2 days	Rheumatism
18	7½	5	3½	7	2	7½	2¼	7	5	7	0	30	2 days	Rheumatism
19	7½	5	4½	6½	3½	7	4	7	5½	6½	2	35	2 weeks	Rheumatism

20	8	4 . 4½	4¾ . 4½	5½ . 3	6 . 5	6 . 2	33	3 months	Phthisis 1½ years
21	8	4 . 4½	4¾ . 4½	5½ . 4¾	6 . 5	6 . 2	74	21 days	Ch. Bronch.
22	8	4½ . 4½	5 . 4½	5½ . 4½	5 . 6	5 . 2¼	26	3 months	Ulcer of Leg
23	8	5 . 3	6½ . 2	6½ . 2¼	6 . 4	......	20	14 days	Phthisis
24	8	5 . 3	7 . 2	7½ . 2¼	7 . 5	7 . 1	40	14 days	Ulcer of Leg
25	8	5 . 4	6 . 3	6½ . 3	6½ . 4	6 . 2	30	14 days	Bronchitis
26	8	5½ . 3	6 . 3	6 . 3	6 . 4½	......	48	10 days	Ch. Bronch.
27	8	6 . 3	7 . 2½	7 . 2¾	6½ . 4½	......	24	7 days	Ulcer of Leg
28	8	6 . 4	7 . 3	7 . 3	7 . 5	7 . 1	35	6 weeks	Hemiplegia
29	8	6 . 4	7 . 4	7¼ . 4½	7 . 5	7 . 2	40	14 days	Ch. Bronch.
30	8	6 . 4½	8 . 3½	8 . 3½	8 . 5	8 . 1	74	14 days	Ch. Bronch.
31	8	6½ . 3½	7½ . 2½	7½ . 2¾	7 . 5	7 . 1½	30	21 days	Phthisis
32	8¼	......	6¼ . 2¼	7 . 3¼	......	......	33	28 days	Crushed Leg
33	8½	......	6½ . 2¾	7 . 2¾	6 . 5	6¾ . 1	35	28 days	Ch. Album.
34	8¾	......	5½ . 3	5¾ . 3	4¾ . 4¾	5 . 1½	21	14 days	Ret. of Urine
35	9	......	6 . 3	7 . 3	......	......	45	1 month	Fract. Leg
36	9	......	6 . 4½	7 . 4½	6¼ . 6¼	6 . ½	39	3 months	Ch. Album.
37	9	6 . 3½	7½ . 2	7½ . 3	7¾ . 5	......	30	1 day	Rheumatism
38	9	6 . 4	8 . 3	8 . 3½	8 . 5	......	58	......	Ch. Bronch.
39	9	6 . 4	6 . 4	7 . 5	7 . 7	......	59	1 week	Ch. Bronch.
40	9	6 . 4	7½ . 3	7½ . 3	7 . 5	7 . 2	49	4 weeks	Ch. Bronch.
41	9	6 . 4	7 . 3	7⅓ . 3	7 . 5½	......	28	3 weeks	Ulcer
42	9	6 . 4	7 . 3	7 . 4	7 . 7	7 . 3	30	1 week	Bronchitis
43	9	6 . 4	7 . 4	7 . 5	7 . 7	7 . 2	30	3 weeks	Ch. Bronch.
44	9	6 . 4¼	7 . 4	7 . 4½	7 . 7	7 . 2½	35	9 days	Rheumatism
45	9½	6 . 4	7 . 3	7 . 4	7½ . 7½	7 . 2	70	14 days	Ulcer of Leg
46	9½	6½ . 4	7½ . 3	8 . 4	7 . 6	......	33	7 days	Rheumatism
47	10	6½ . 4	8 . 3	8 . 3½	8 . 5	8 . 2	35	Not in bed.	Ch. Bronch.
48	10	6½ . 4½	8 . 3½	8 . 4	8 . 6	8 . 1½	35	7 days	Syphilis
49	10	7 . 4½	8½ . 3½	9 . 4	8½ . 6	......	60	21 days	Ulcer of Leg
50	10	7 . 5	8 . 3	8½ . 3	8 . 5½	8 . 1	40	21 days	Ch. Bronch.
51	10	7 . 5	8¾ . 4	9 . 4½	8¾ . 6	8¾ . 1½	43	2 days	Rheumatism

found to be much larger than could have been anticipated from the remarks which have just been quoted.

The mean extent of the movement in the whole number of cases was about $3\frac{3}{4}$ inches, the maximum was $5\frac{3}{4}$ inches, and the minimum two.

As might have been anticipated, the degree of movement increased, in the main, with the length of the sternum; in other words, with the size of the chest: thus, the mean of the 18 cases, with less than 8 inches of sternum, was 2·8 inches, that of the eleven having this bone 8 or 9 inches long was about 3·6 inches; the remaining ten possessing a lateral movement of over 4 inches.

The case (No. 36) having the maximum motion of $5\frac{3}{4}$ inches belonged to the last group. It was one of chronic albuminuria, and the patient had been confined to bed for three months; the length of his sternum was 9 inches: here again there may have been some cardiac hypertrophy. Of the four cases with the minimum movement of 2 inches, three came within the first group, and one had a breast-bone 8 inches long; this last was a case of bronchitis in a man thirty years of age.

In most instances (27 cases) when the body was turned upon the left side, the heart's impulse remained at the same level that it had in the supine posture; but it is interesting to note that, in a fair proportion (21 cases), the heart-beat was as low as in the erect position; in 4 cases it sank even lower than this, and in 22 it was found at a slightly higher level.

It would be impossible to draw from these cases of disease any trustworthy conclusions as to the usual extent of the motion of the impulse-site in health; and their number is still far too small for us to gather much information as to the variations introduced by different disorders.

It is, however, already evident that such variations do occur, and we may reasonably expect that further investigations will enable us to trace some definite relations between the disease and the mobility of the heart. It is at least highly probable that conditions affecting the expansion of the lungs, or permitting the relaxation of the parts composing the ligaments of the heart, would manifest themselves in observations such as those now before us.

It is also important to notice what emphasis these measurements give to the caution that in all observations upon the heart's impulse in cardiac disease, care should always be taken to place the patient in the same posture at each observation, otherwise most serious errors might easily be made.

2. THE USE OF THE CHEST-RULE IN THE CLINICAL NOTING OF CASES.

The following case illustrates the use of the Chest-rule in phthisis—the physical signs alone are extracted.

October 2nd, 1872. B. M., æt. 25. Female; height, 5 ft. 3 in.; length of sternum, 6 inches.

Right side.—Slightly diminished resonance above the clavicle, but clear, almost tympanitic percussion note to about 4 | 2 (A, Fig. 5). Under this part amphoric breathing and pectoriloquy, bubbling rhonchus; below 4 | puerile breathing. Similar signs posteriorly.

Left side.—Above the clavicle and to 4 | (1–4·5) (B) (Fig. 5), almost universally dull on percussion, except at 3 | 2 (C, Fig. 5), where there was resonance on deep percussion, and large gurgling rhonchus on coughing, and occasional fine crackle on ordinary breathing, with bronchial breathing and bronchophony. The heart-sounds were conveyed, its impulse much extended, at 5 | 2 (D, Fig. 5);

tubular breathing and cavernous sounds were heard, and, on deep respiration, gurgling and almost bubbling rhonchus were heard at this point.

On Oct. 15th she complained of severe pleuritic pains above the left mamma, and loud creaking was audible about 4 | 2–4.

On Oct. 28th, after much cough and copious expectoration of purulent matter, the resonance on the left side

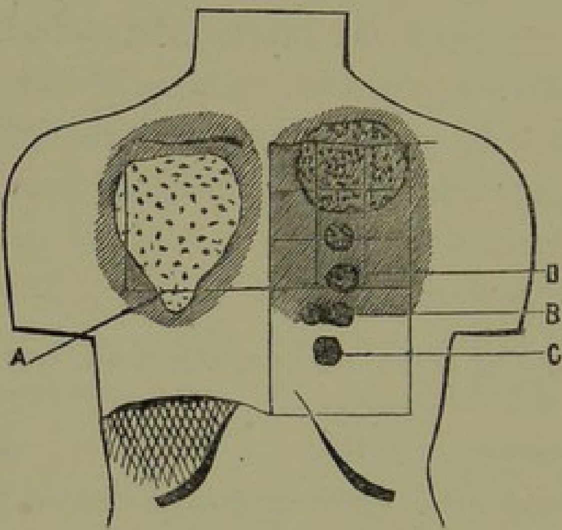


FIG. 5.

over 4 × 4 was clearer, slightly amphoric in quality, and large gurgling was heard from 2 × 2 to 5 | 2.

On Dec. 7th, on the left side, a peculiar squeaking sound was heard at 4 | 1, with both inspiration and expiration as of a viscous fluid forced into and out of a small cavity, gurgling and medium-sized crackle and clicking sounds were heard around this spot. To the left of 4 | 3, and below this point, the respiratory murmur was comparatively clear.

After her death, which took place on December 19th, the chest rule was used at the post-mortem examination, and the following diagram (Fig. 6) was constructed without any reference to the preceding figure.

Post mortem, 36 hours after death:—

Lower borders of the ribs, 2nd at 3 | ; 3rd at 4 | ; 4th at 4·75 | ; 5th at 6 | .

Body not excessively emaciated, lower half of sternum much drawn in; upper level of the heart at 1 | , of the liver at 6 | .

Right side.—Recent pleuritic adhesions at 4 | 2–3. (A) Fig. 6. The upper lobe reached to 3 | , and contained one

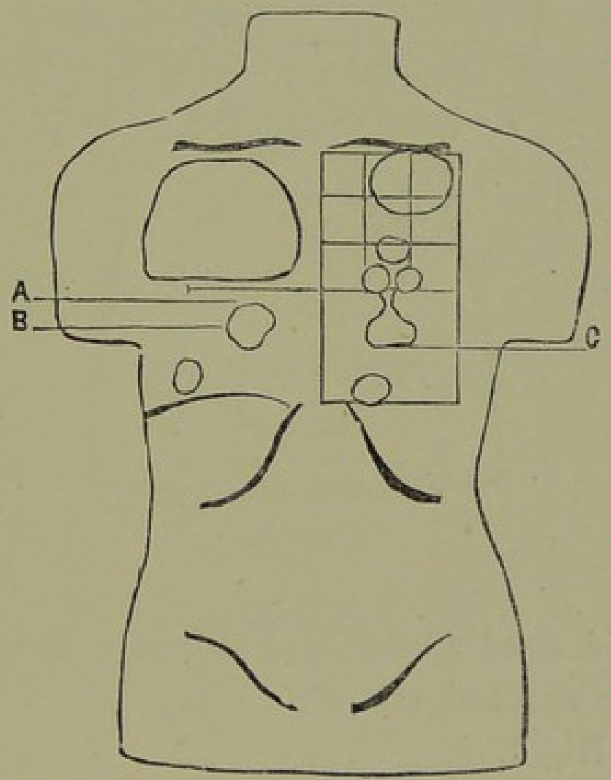


Fig. 6.

large partially empty vomica; at 5 | 2 (B, Fig. 6), was a smaller cavity covered by condensed lung-substance; and at 6 | 3 another the size of a small marble.

Left side.—Universal pleuritic adhesions, the most recent at 4 | 2; a cavity occupying the chief part of the apex to 2 | ; from this point a chain of small vomicæ, covered by a thin layer of condensed lung-tissue, and partially filled with pus, extending to 5 | 2 (C, Fig. 6).

The following two cases are pleurisy, with effusion noted by means of the chest-rule, and show the precision and brevity introduced by its use.

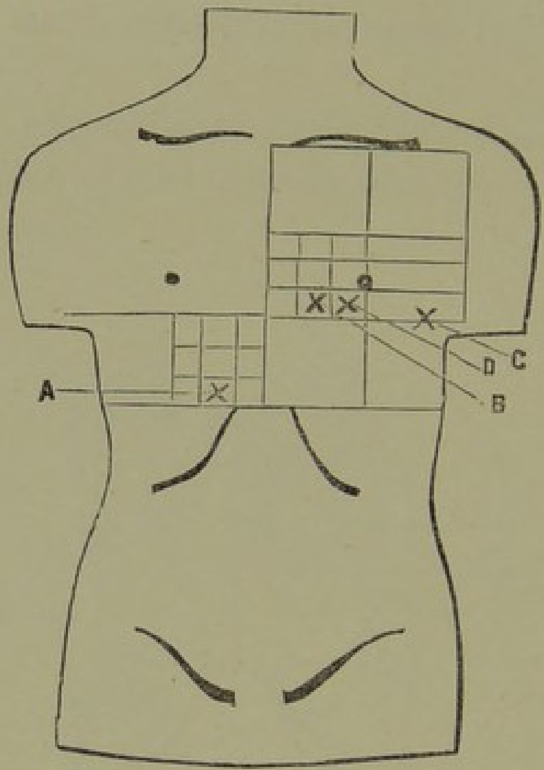


FIG. 7.

J. G., male, aged nineteen, of strumous family. Pleurisy on each side successively.

Jan. 1.—Rigor.

„ 15, when first seen: Friction sound on left side; cough; heart's position, natural; no dulness on percussion.

„ 20. Slight dulness and œgophony at left base to 8 |.

Up to Jan. 29, effusion rose until it reached 6 x; heart's impact – (9 x, 2 y), (A, Fig. 7).

Feb. 2.—Absorption commencing.

4.—Rapid absorption going on; dulness at 7 x, heart + (6 x, 2 y), (B, Fig. 7); expansion still imperfect.

Feb. 22.—Effusion gone; contraction of side.
 ,, 24.—Convalescent.
Mar. 2.—Went from home; took cold.
 ,, 8.—Returned, with effusion on right side.
 ,, 10.—Effusion level at 6 x.
 ,, 14.—Effusion level at 3·5 x; heart at 6 x, 5 y (C, Fig. 7).
 ,, 17.—Effusion diminishing at 4 x; heart at 6 x, 4 y.
 ,, 23.—Effusion at 6 x; heart at 6 x, 3 y (D, Fig. 7).
April 2.—Effusion at 7·5 x; heart as before.
 ,, 6.—Convalescent; contraction on both sides.

The changes in a case of pleurisy may be still more briefly noted, as follows:—

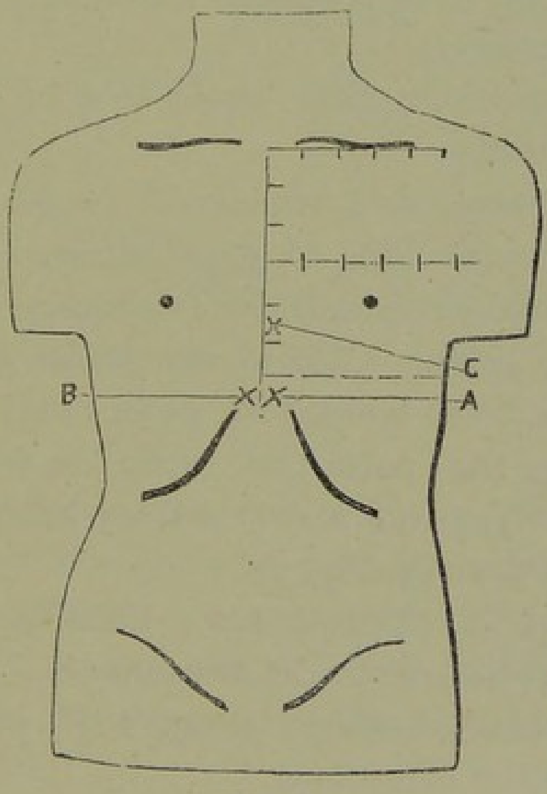


FIG. 8.

R. C., aged twenty-eight, nursemaid; no history of phthisis; five weeks ailing; occasional pain in left side; loss of appetite; debility.

A week ago, severe pain in side; two days afterwards, slight cough; no fever.

April 6.—Effusion on left side to 10 | behind (*i.e.*, from first dorsal spine); temp. 101·5°.

„ 9.—Effusion to 7 | ; heart's impulse at epigastrium.

„ 10.—Effusion to 6 | ; temp. 101·5°; pulse, 140; heart's impulse at 7 | 1 (A, Fig. 8).

„ 12.—Universal dulness; heart's impulse at 7 | – 1 (B, Fig. 8).

Remained in this state until April 20th, when effusion began to subside at the following rate:—22nd, to 1 | behind; 24th, 3 | ; 26th, 4 | ; heart's impulse, at 6 | 1; 28th, 5·5 (C, Fig. 8); 30th, 6·5 | 2. On May 6th the effusion had disappeared; but there remained immobility of the chest, and slight contraction.

The chest rule is equally serviceable in the noting of cases of pericarditis.

C. D., aged twenty-five, housemaid, lymphatic temperament, had rheumatic fever six years before.

Acute rheumatism commenced December 25th, and attacked several joints. Cardiac symptoms first appeared December 28th, when temp. 105°, pulse 120.

Dec. 29.—Temp. 104°, pulse 120. Effusion from 1·5 x, (1·5 × 3) y to 8 x, (– 1 – 3) y; heart's impact at 1·5 x, (A, Fig. 9).

„ 30.—Temp. 103·5°, pulse 120. Effusion to 1, x; heart as before; slight delirium.

„ 31.—Effusion subsiding; temp. 101°, pulse 100; no head symptoms.

Jan. 2.—Temp. 99°, pulse 76. Effusion 3 x, (1 – 2·5) y to 7 x; heart's impact normal (B, Fig. 9).

„ 6.—Convalescent.[1]

[1] It seems highly probable that the frequent use of the chest-rule would reveal interesting variations in the usual shape of pericardial dulness in these cases.

These illustrations could easily be multiplied if necessary; but they will suffice to show both the great utility of the instrument and the method of its employment. I will therefore merely mention that I have used it also for fixing the sites of heart-murmurs and the points at which

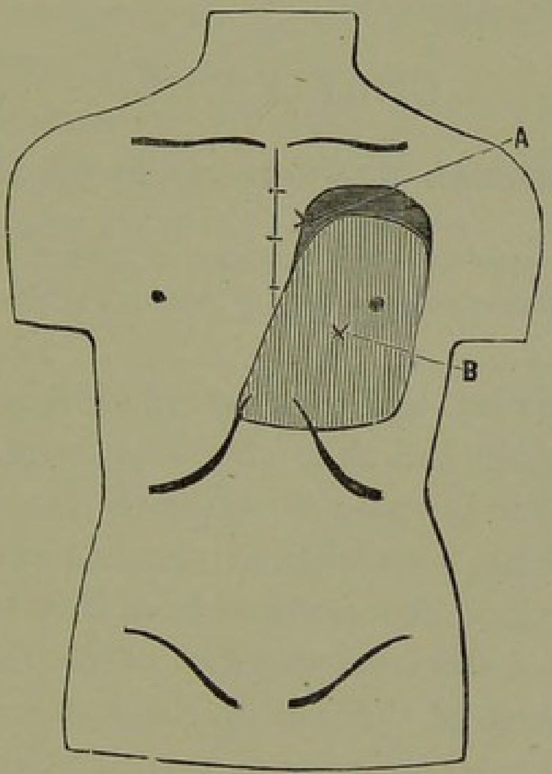


FIG. 9.

they are most audible; the position of aneurismal bruits; and the limits of various kinds of intra-thoracic tumour. It is probable that other uses might be found for it in practice, since there are many cases in which accurate chest mapping is desired, and can only be attained by careful linear measurements.

CHAPTER III.

ON THE GENERAL MEASUREMENTS OF THE CHEST.

"Numerical precision is the very soul of Science."—HERSCHEL, *Preliminary Discourse on the Study of Natural Philosophy*, p. 122.

WHEN we pass on to more extended measurements of the chest, we again find that numerous methods have been employed for the purpose of marking its peculiarities in health and disease, both when at rest and in movement.

In the first place, observations have been made on what might be termed the vital statistics of the thorax—on the simple dimensions of the healthy chest at rest—and these have, for the most part, been determined either by various kinds of unyielding tapes, or by callipers. In this way numerous interesting facts have been brought to light, and without entering into details it may be sufficient to group them under the following heads:—

1. The great variations which have been observed in the healthy chest, in different individuals, both in its general shape and in its several dimensions.

2. The observations made by Woillez showing that the circumference of the chest is greatest in trades requiring active exertion of the whole body, not in those in which the upper extremities are chiefly employed.

3. The measurements which demonstrate the greater size of the right half of the chest of most persons, left-

handed men being excepted—this observation being found to hold good with respect to the diameters as well as the circumference of the chest. (Walshe.)

4. Certain relations which have been discovered between some of the dimensions of the thorax—as between the girth of the chest and the width of the shoulders, or between the distance from nipple to nipple and the antero-posterior diameter. (Brent.)

5. The alterations which take place with advancing years, in the shape of the chest and in the relative signs of its several zones. (Wintrich.)

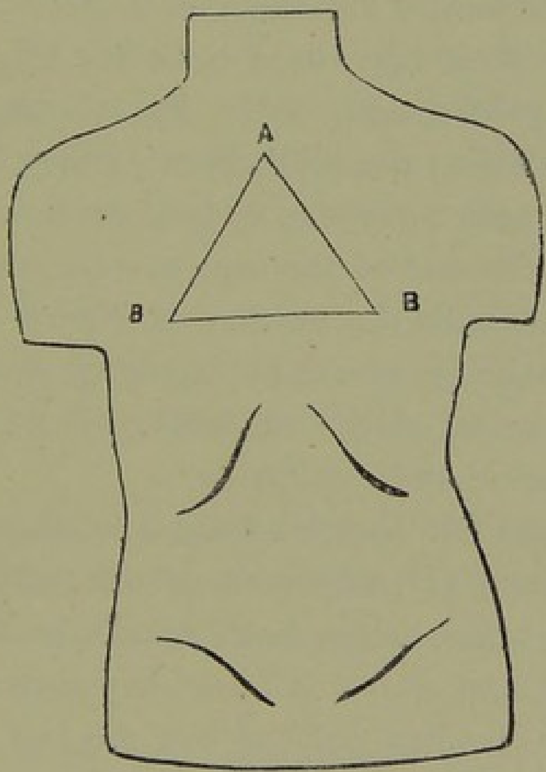


FIG. 10.

6. The remarkable observations of Quetelet, on the numerical laws which govern the proportions of the several portions of the body, and, with especial regard to our own subject, his remarks upon the measurement of the mode of increase of the chest, and the relations between the sides of the triangle (*a b b′*, Fig. 10) at particular periods of growth and in different nations. (*Anthropométrie*, pp. 223–227.)

In disease also important observations have been made with the tape and callipers, and with Woillez's cyrtomètre; but on this head I must content myself with referring to Dr. Walshe's admirable treatises on Diseases of the Heart and of the Lungs, where the subject is very fully discussed.

MOVEMENT MEASUREMENTS.

Even more important results have been gained by observations upon the movements of the different parts of the thorax, both in health and disease.

Thus, tapes have been used both for local and general movement measurement, either by the simple device of marking upon them the differences on the two sides of the chest, before and after expansion, or by Dr. Wintrich's adaptation to the end of the tape of a piece of indiarubber, which stretches with the motion of the chest; the extent of the motion being noted, by marking the relative positions of the ends of the unyielding parts of the bands during inspiration and expiration.

By this means Dr. Wintrich has been able to demonstrate the large extent of movement of the thoracic wall even without respiration, when both mouth and nostrils were tightly closed, and efforts at breathing were made.[1]

Dr. Walshe also has pointed out the fact that in forced inspiration, the circumference is more enlarged on the right than on the left side, and he has shown the influence of posture upon the extent of the respiratory movement, and the fact that the abdomen is not expanded in forced breathing.

By Dr. Quain's and Dr. Leared's additions of dials, the observation of the degree of movement is facilitated, and

[1] This observation I have myself verified.

Dr. Marey has recently applied to the circumferential band drums by which the variations in breathing may be inscribed upon a rotating cylinder.

Dr. Burdon Sanderson's stetho-cardiograph is essentially a pair of callipers provided with similar drums, and it gives the alterations in the diameter of the chest in both tranquil and difficult breathing.

These and other graphical methods have already proved very useful in recording the exact rhythm of the respiratory movements, and their variations in extent and regularity under various conditions. Thus Traube and Rosenthal have watched the effects of the division of the vagus and other nerves upon respiration; Riegel and Fick have noted the influence of disease; and Bert has given tracings of the breathing of the various classes of the animal kingdom.

A record of interesting observations in disease is made by Dr. Walshe in the works already cited, and to these I must again refer the reader for fuller information on the subject.

The following is a good example of the use both of the tapes and of Dr. Sanderson's stethograph in determining a problem which still seems to be *sub judice*.

THE ORDER OF THE MOVEMENT OF THE RIBS.

In watching the action of the chest in deep breathing, it has appeared to me that the earliest portion of the expansive act is accomplished by an increase in the ordinary action of the diaphragm, then the chest seems gradually to swell outwards, the expansion commencing in its lower portions, and ascending from below upwards. The ribs are gradually raised by their special muscles, and the lower ribs are probably at the same time straightened at the anterior angle between them and their costal cartilages; at last, for the final effort of inspiration, the head and shoulders are fixed, the spinal column is curved backwards, and all the muscles capable of producing upward movement of the bony cage are exerted to their utmost powers.

In expiration after this effort the operation is reversed, except that the first to give way seems to be the diaphragm. The abdomen in spare subjects collapses, and then the ribs descend more gradually, beginning first with the upper ribs, and when a forced expiratory effort is required the abdominal muscles are strongly contracted; the ribs, and even the scapulæ, are pressed downwards, and the spine is pushed forward, so as to contract the cavity as much as possible. This seems to be the most frequent order of events so far as I have observed them, but it is important to remark that the action is undoubtedly greatly under the control of the will; and thus variations in the order of movement may be brought about by various causes—habit, disturbing emotions, suggestions from others, or antecedent ideas of what ought to take place. This fact may, perhaps, account for the different descriptions which have been given of the process by different observers. It is indeed remarkable what a variety of opinions have been held on this subject. Thus Haller[1] considered that the first rib is the fixed point towards which all the others move in succession, the third following the second and so on. Sabatier stated that the ribs differed in the direction of their movement according to their position, the superior ribs moving upwards, the lower ribs downwards, the middle ribs outwards.

Magendie, on the other hand, thought that all the ribs moved at once, and Dr. Sibson seems to share this opinion,

[1] *De respiratione experimenta anat.* Göttingen, 1747.

whilst Hutchinson and Humphry both take the same view as Haller; thus, Hutchinson says, "The clavicles, shoulders, scapulæ and superior ribs are raised, the sternum advances, the infra-clavicular region swells remarkably upwards and outwards (particularly in females) like a rolling wave, the supra-clavicular region is raised, the whole apex of the thorax is rendered more obtuse, particularly the antero-posterior diameter. The lower ribs at their cartilaginous extremities spread outwards, increasing both the lateral and antero-posterior diameter of the base of the thorax, the cartilaginous (Gothic) arch formed by the junction of the sixth, seventh, eighth, ninth, and tenth ribs below the sternum, becomes more obtuse by their lateral motion, the abdominal space under this arch down to the umbilicus sinks inwards."

"There is an indescribable undulating roll produced by the consecutive action of the respective ribs, which always commences with a superior rib; in costal breathing a lower rib *never* moves first."

Humphry repeats the statement, "In the normal expansion of the thorax," he says,[1] "the upper ribs are raised first, the others following in quick succession." Dr. Walshe[2] again says that "even in the male the expansile action, if abrupt, commences superiorly."

I do not profess to place my limited experience in opposition to opinions expressed by such able observers, but in working with the stethometer my impression has been that the most usual form of breathing, at any rate in males, is the direct opposite of that mentioned by Mr. Hutchinson. I have taken some pains therefore to try to learn which account of the order of movement is most usually

[1] *Human Skeleton*, p. 349.

[2] *On Diseases of the Lungs*, 4th ed. p. 17.

correct, and have adopted two methods of testing the matter.

1st. I have fastened tapes of paper around the chest at different heights, whilst the ribs were stationary in the position of somewhat forced expiration, abdominal breathing only being permitted during the process of fastening; slow but deep inspiration was then allowed, and in every instance which I have so far examined, the order in which the tapes were torn was from below upwards.

2nd. I have had several opportunities of using Dr. Burdon Sanderson's stetho-cardiograph, and have applied the button simultaneously to the second and fifth or sixth ribs in both males and females. Figure 11 gives the tracing obtained in a case to which Dr. Sanderson himself kindly applied it, a young man, in good health and of average size.

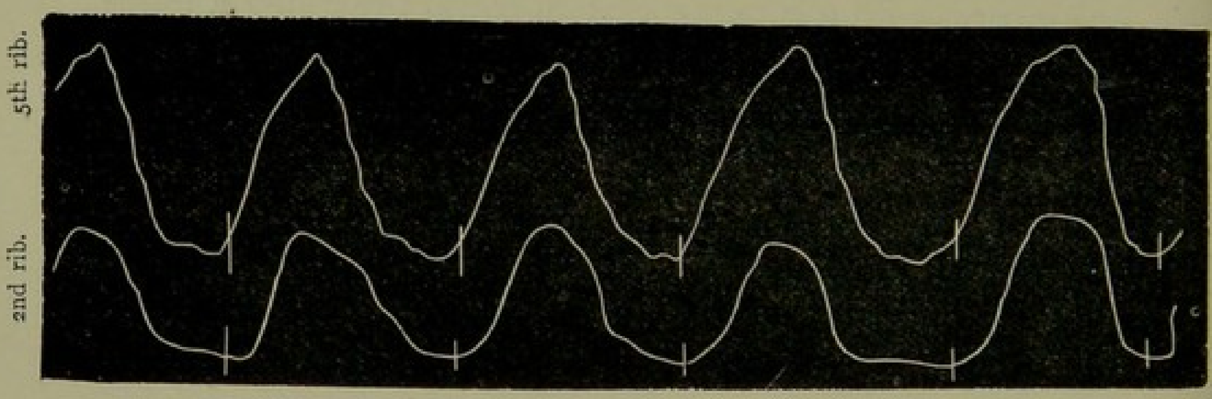


FIG. 11.—Simultaneous tracings of the movements of the fifth and second ribs in an adult male, made by the stetho-cardiograph. The vertical strokes show the points at which the two pens were working simultaneously.

The diameters taken were (*a*) from the fourth vertebra to the second rib, one inch to the right of the sternum; and (*b*) from the eighth vertebra to the fifth rib, half an inch to the right of the sternum. The strokes at the base of the undulations show the corresponding points, in time, of the curves. A comparison of the tracings shows that in every act of breathing, whatever the extent of the inspiration, the lower rib is the first to rise and the last to descend.

The movements of the second rib are, moreover, less extensive than those of the fifth, as might have been anticipated from the greater length of the latter bone; but they are also less acute, and more equable in their rise and fall, showing that the work done by the upper ribs is performed more gradually, and that they remain at the point of extreme expansion rather longer than the lower ribs.

This is, I think, what might have been anticipated in the inferior costal type of breathing, since it would need a longer time for the expansion of the upper portions of the lung, if the action had previously commenced in the lower part of the elastic organ—in other words, the inspired air would be partly taken up in expanding the lower part of the lung, and would need a longer time to overcome the elasticity of the upper lobes.

In females, displaying as they do the true "superior costal" type of breathing, we might have expected to find that the upper ribs would have a very decided precedence in the order of movement, but this does not seem to have been very decidedly the case in the examples which I have been able to examine by this method.

Several tracings of female respiratory curves were made with the kind assistance of Mr. Hawksley of Blenheim Street, and of these Figures 12 and 13 may be taken as examples. The curves show the simultaneous movements of the second and sixth ribs, in two healthy young women during forced breathing, in another instance both ordinary and extraordinary acts of breathing were registered. In each case the stays were removed during the experiments.

The positions of the buttons of the stethograph were approximately the same as in the previously given tracing of male respiration.

The peculiar predominance of the action of the upper ribs in female breathing is at once perceived in these

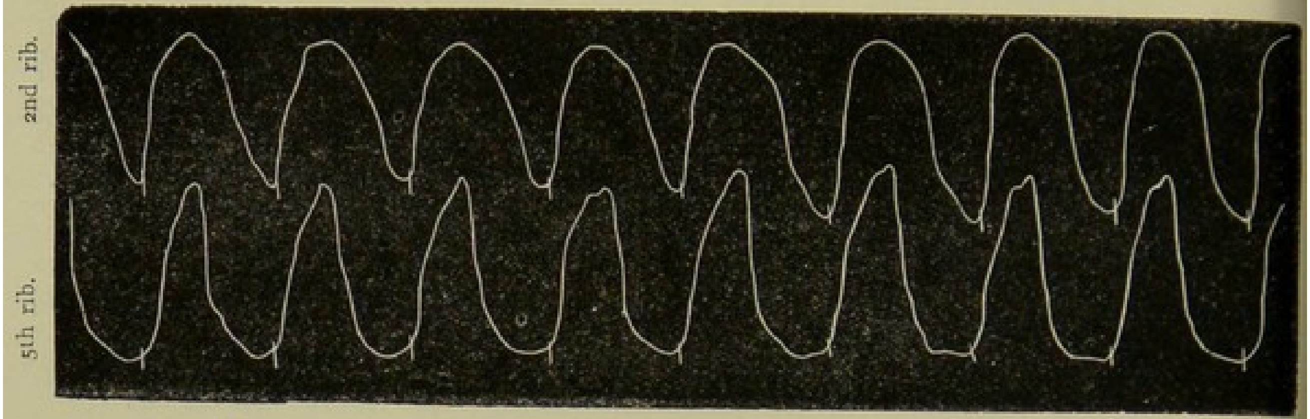


FIG. 12.—Simultaneous tracings of the movement of the second and fifth ribs in an adult female during forced respiration.

diagrams, but it may be observed that in all the curves there is much less difference in the times at which the ribs

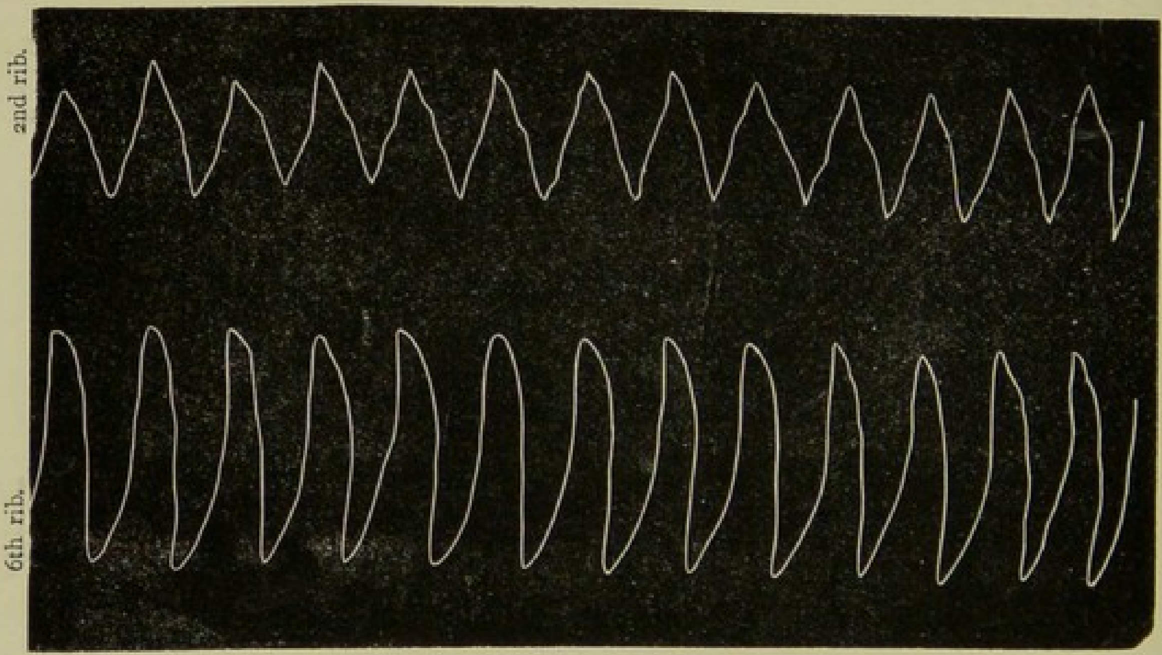


FIG. 13.—Tracings of the movements of the second and sixth ribs in an adult female, forced respiration.

come into action than in the male chest. As it has been well pointed out by Bérard,[1] in this type of breathing, the

[1] *Cours de Physiologie*, Paris, p. 258.

whole of the chest often seems to be raised at once, so that "one sees the clavicles, the sternum, and the first ribs raised, and this action communicated, though in less degree, to the upper part of the inferior portions of the chest." A close examination of the undulations, however, does show a slight difference in the times of rise and fall. A difference which, unlike that observed in male breathing, is sometimes in favour of the upper ribs, sometimes of the lower. In tranquil breathing there was apparent in every act of respiration a small precedence in the moving of the second rib. In forced respiration the two cases differ on this head, in one (Figure 13) the sixth rib is the first to move and is the longest time in action; and the second rib, although it still has the largest extent of motion, yet lags somewhat behind the other. In the other (Figure 12) the case is reversed, and the second rib retains to a very small extent its precedence. It may also be noticed that for the most part the female respiratory curves are more abrupt in their rise and fall, and hence more pointed than those in the male subject.[1]

Figure 12 somewhat resembles in its character the tracing of male breathing, especially in the more prolonged sustaining of the inspiratory effort by the upper ribs; but even in this tracing there is more abruptness in the general action of both sets of ribs.

It would not be just to assume that these few examples are sufficient to decide this question, but they may serve to show the value of this method of inquiry. It may be observed also that the subject is not without practical importance. There is still some controversy as to whether

[1] Riegel in his work: *Die Athembewegungen*, Wurzburg, 1873, gives similar tracings (*Tafel* iv. No. 3) of the upper and lower ends of the sternum in a young woman, Oct. 18, and the precedence of the manubrium is in these curves very distinct.

pulmonary phthisis appears most readily, or lasts longer in the more or the less used portions of the lungs, and when definite results have been obtained as to the relative movements of the ribs they may probably be advantageously compared with other statistics relating to this disease.

ANALYSIS OF THE CHEST MOVEMENTS.

However useful the various means just mentioned for measuring the chest movements may be for many purposes, they fail to give an exact representation of the motion of the several parts of the chest, and do not record the lineal extent of movement in any one direction; they only give either the gross circumferential enlargement of the chest, or else merely mark the rhythm, and rate, and relative degree of the respiratory movements.

Dr. Sibson's well-known "chest measurer" has been for many years the only means of ascertaining the exact degree of movement of points on the chest-wall, and has thus been of great service both to the physiologist and to the student of disease.

But even this instrument fails to deal with all the many problems that relate to this subject. It cannot analyse the several motions of which the total expansion is compounded—it can only give at any one time the resultant of these movements, and thus any questions depending upon the relation of these several movements to one another cannot be solved by its use.

These questions, as will appear in the course of this work, are more in number than might at first be supposed.

No complete examination of the mechanism of breathing is, in fact, possible by the means hitherto mentioned.

The thorax enjoys such singular powers of altering its capacity, that it would seem at first sight able to expand almost as completely as a sac inflated with air, and although a closer examination shows that this expansion is conditioned by the mechanism of the bony framework, yet the arrangement of the parts is so complicated that it is extremely difficult to assign to each portion its share in the resulting movement.

It is not indeed difficult to mark the degree of movement permitted to the several parts of the chest by their respective articulations; the problem lies in the influence exerted by each portion of the machinery upon the rest. Thus the vertebral column in the dorsal region is free to alter its curvature from an arc of lesser to one of greater curvature.

The ribs move upon hinges, the axes of which pass horizontally through their vertebral joints; and these articulations also permit a revolution about an antero-posterior axis from the sternum to the vertebral column, and at the same time allow the ends of the ribs to approach or recede to a certain extent from the sternum.

The costal cartilages also are sufficiently elastic in most persons to yield to the motions of the ribs, and their sternal joints give still further freedom to these movements, although they are sufficiently firm to make the sternum obey the forward or upward thrust of the ribs.

All these possibilities of movement have then to be taken into account in the consideration of our subject; and it may well happen that differences of opinion will arise, as they have formerly arisen, upon the various questions which it involves. I do not pretend to set at rest these debatable points, but only offer a contribution towards that result.

In any attempt to measure accurately the motions of the various parts of the thoracic wall, there are two chief conditions which must be observed.

The first depends upon the mode in which the ribs are articulated, their obliquity, and their rotation upon two axes; and hence, as may readily be perceived, the motions of any point on the chest-wall, on either side of the sternum, may, in forced breathing, take place in three planes at right angles to one another. A satisfactory stethometer must therefore be able to measure the extent of movement in each of these planes, viz., in the forward, upward, and outward directions.

The second condition is due to the fact that there are often perceptible differences between two acts of breathing —at one time the forward, at another the upward, or again the outward movement being most prominent. The stethometer must therefore measure the several motions of the ribs during one and the same act of breathing.

The *simultaneous* measurement of all the three dimensions of the chest movement is therefore essential both for an accurate knowledge of the movements themselves, and in order that the mechanism of the action may be thoroughly understood.

I venture, after some years of use, to affirm that these conditions are sufficiently complied with in the instrument sketched in the accompanying diagrams, to which I have given the name of the three-plane stethometer.

THE THREE-PLANE STETHOMETER.

The stethometer consists of a light steel rod (L, Fig. 16), having at one end a small button (B) attached to it by a ball-and-socket joint (J); the other end of the rod is attached to some simple machinery, which records the motions of the rod, giving duly the movements of the button-end of it forwards, upwards, and outwards.

The forward movement is marked by the sliding for-

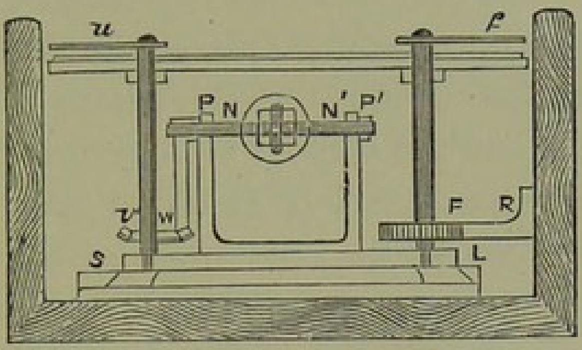


FIG. 14.—Sectional end elevation.

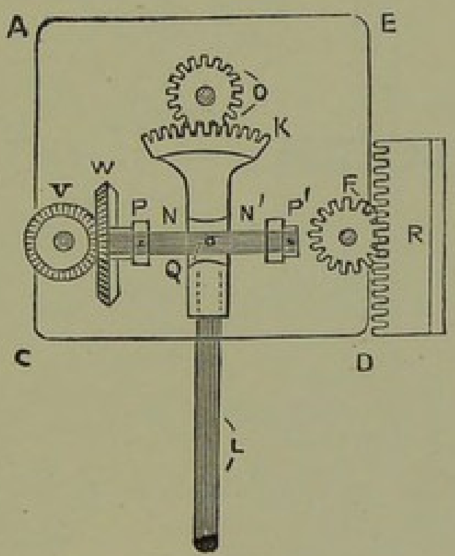


FIG. 15.—Sectional plan.

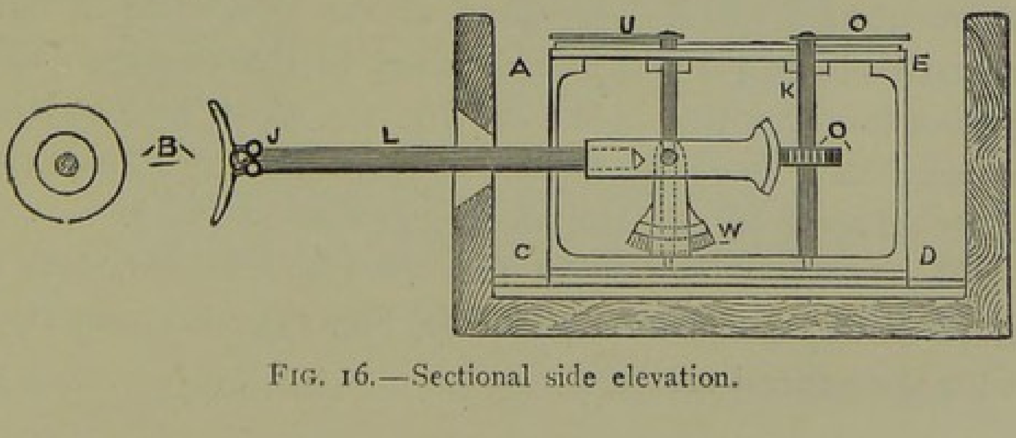


FIG. 16.—Sectional side elevation.

wards of a carriage (A C D E, Fig. 15), carrying a pinion (F), which is turned by a rack (R) placed in the course of the slide (S L, Fig. 14), and in its turn this pinion moves an index (*f*) upon a dial, and the amount of movement is registered by two small loose fingers (*s* and *s*′, Fig. 17), which are pushed to each side by the oscillations of the index. The dial is divided into 100 parts, of which each division represents ·01 of an inch.

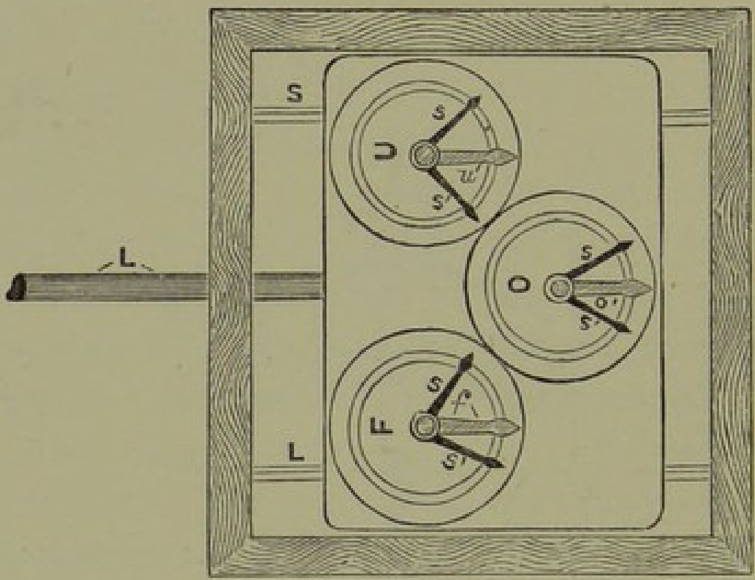


FIG. 17.—Plan. U, upwards; F, forwards; O, outwards.

The upward and downward motion of the button-end of the rod is transmitted through the lever (L) to a shaft (N N′, Fig. 15) placed at right angles to it, which turns upon pivots (P P′) at each end, and upon this again is fastened a segment of a wheel (W), racked at the side, so as to turn a small pinion (V) which is attached to the carriage; this pinion turns another index (*u*, Fig. 17), which registers the upward motion upon the dial in the same way as index *f*. Every degree of this dial represents ·02 of an inch.

The *outward* motion of the chest is recorded upon a third dial by means of a pinion (O, Fig. 15), also connected with the general carriage.

This pinion is set in motion by the rackwork (K) attached to the end of the rod (L) beyond the pivot (Q). In order to allow of the upward and downward movements of the end of the rod, this rackwork is made in a peculiar fashion, consisting of vertical divisions of a portion of a sphere, so arranged that only the outward and inward movements of the rod are recorded by the pinion, not those in the upward or downward direction. Every degree on this dial represents ·02 of an inch. By this arrangement of parts each motion is indicated without interference with the others.

MODE OF APPLICATION.

When the instrument is used it is placed in a box and fixed by means of a split ring and screw to a pillar at the

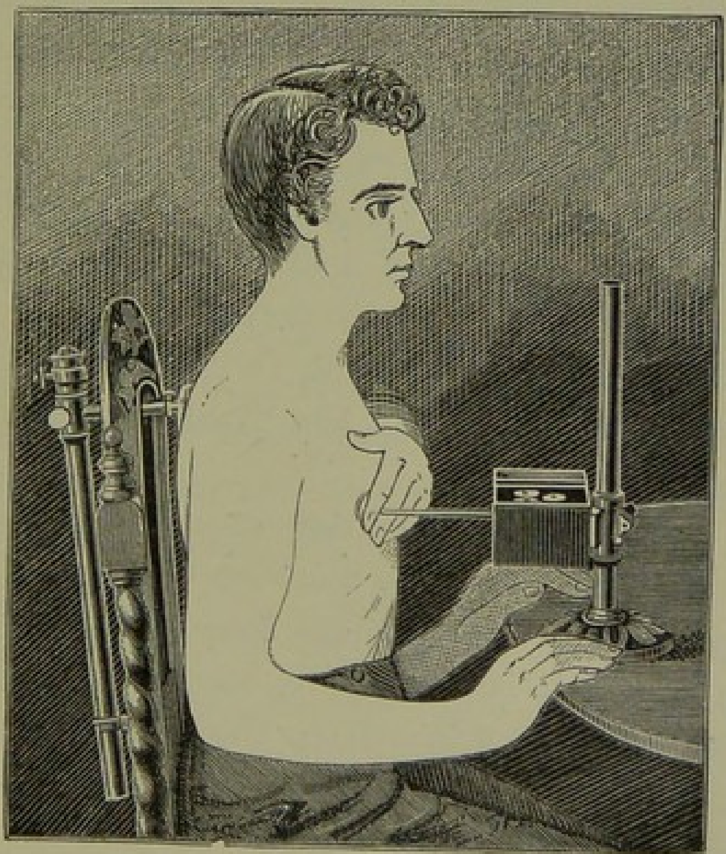


FIG. 18.—Mode of Application.

required height, and this pillar is furnished with a clamp, by which it is fastened perpendicularly to any convenient table.

The patient, with the chest exposed and devoid of any ligature, &c., is seated upon a straight-backed chair, which fixes the head and shoulders, and, if possible, his head is also allowed to rest against a support. In this manner the probability of any side movement and any bending of the spine not due to respiration is reduced to a minimum. The button-end of the rod is then brought against any point of the chest, in such a manner that the direction of the rod is perpendicular to the plane of the shoulders, and also perpendicular to the front of the box containing the apparatus.

The distance of the patient from the apparatus also is so arranged that in ordinary breathing the carriage containing the machinery rests about half way upon the slides; in other words, that the index *f* is about its mid position upon the dial. The registering fingers are then applied to each side of the indices, and when it is required to know the extent of forced breathing, the patient is directed to take a deep inspiration and then to make as complete an expiration as possible. The rod is then held so as to prevent further motion, and the extent of the movements in the three directions read off upon the dials.

When it is desired to take the extreme extent of several respirations, this is done by allowing the patient to go on breathing forcibly several times before the instrument is stopped; and if it is needful to ascertain the extent of movement in ordinary breathing, the patient is permitted to take several quiet respirations before the registering fingers are placed in position.

SOURCES OF ERROR.

The only appreciable error in the indications, arising from the construction of the instrument, is to be found in the influence of the radial movements upon the forward motion. This is, however, very easily calculated, and depends upon the length of the lever. Mathematically stated, the distance through which the button moves forwards is registered as less than it really is, by the versed sine of the angle formed by the rod in its angular motion.

The longer the rod or arm, therefore, the less the error from this source. In my instrument it amounts to ·021 or an inch for every 100 degrees of upward or outward motion.

There are several sources of fallacy to be regarded in applying the instrument, and corresponding precautions to be taken. In the first place, the mode of breathing, especially when it is forced, may be unnatural and irregular from nervousness, officiousness, or anxiety; the ribs may be even kept entirely fixed, and the breathing abdominal.

It is necessary, therefore, to urge the patient to breathe easily and naturally, and, when a deep inspiration is needed, to ask him to breathe quietly and deeply; and sometimes a little time has to be given, and the attention has to be drawn away from the instrument.

It is hardly necessary to state that those observations in which the breathing has not been natural were rejected as worthless.

It is also desirable that the muscles of the arms should not be allowed to take part in the process of breathing, as they generally introduce some irregularity in the movements. In all cases, therefore, the patient is directed to rest the tips only of the fingers upon the edge of the table; this arrangement also steadies the body of the patient.

Obesity is a complete bar to the use of the apparatus. If there is much fat upon the ribs, it is almost impossible to keep the button of the lever pressed equally upon them. In every case care has to be taken not to move the skin over the bone.

This circumstance is of less consequence, however, since most of the patients who require these observations to be made are already reduced in flesh by disease, and are spare and even thin.

For physiological observations the subjects were purposely selected from amongst thin persons.

POINTS OF OBSERVATION.

It was necessary to fix upon certain points on the chest upon which to apply the button, and most of the observations have been made on the anterior region of the chest. I have also considered it important that the end of the rod should rest on bone; the points selected have therefore, for the most part, been the top, middle, and lower end of the sternum, the middle of each clavicle, and the middle of each third rib. In males, observations were made on the fifth rib, close to the nipples. A few special observations have also been taken with regard to other points to be mentioned further on.

GRAPHICAL REPRESENTATIONS OF THE RESPIRATORY MOVEMENTS.

The degree of variation in the different motions may be shown graphically by means of lines drawn to scale as in the following diagrams (Fig. 19, &c.), but since one of the planes of movement is perpendicular to the other two, the course of one of the three movements must be imagined. The lateral or outward push is, therefore, represented by

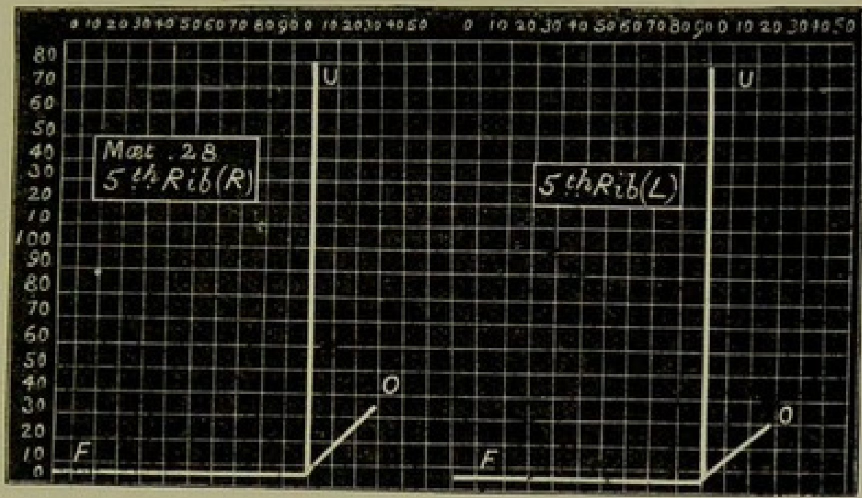


FIG. 19.—Showing the movements of the fifth ribs in a healthy young man, æt. 28.

the device of tracing it at an angle of 45° to the other two.

GENERAL MOVEMENTS OF BREATHING.

The following observations were the subject of a communication to the Medico-Chirurgical Society of London, and are now for the most part extracted from the Transactions of that Society for the year 1873.

In ordinary breathing the extent of movement of the ribs is very small, especially in the upper part of the chest, and it is very irregular in extent, even in the same person.

In both men and women a large part of the respiratory act in ordinary breathing is performed by the diaphragm, a fact remarked by Haller, who says:[1] "In naturali inspiratione solum movetur diaphragma, costis ad sensum

[1] *De Musculis Diaphragmatis*, p. 27. Berne, 1733.

TABLE. I.

Extent and Direction of the Movement of different points on the Chest in 100ths of an inch.

Extent and direction of Movement.	Top of sternum.	Middle of sternum.	Ensiform cartilage.	Centre of clavicle (right).	Centre of clavicle (left).	3rd rib (right).	3rd rib (left).	5th rib (right).	5th rib (left).	Remarks.
1. Forwards	90	96	80	90	78	80	85	102	102	Male, æt. 35, healthy.
Upwards	111	120	99	108	105	129	135	135	135	
Outwards	—	—	—	—	—	27	27	30	30	
2. Forwards	71	90	127	—	—	119	94	144	122	Male, æt. 40, tall, healthy.
Upwards	75	90	114	—	—	115	135	150	135	
Outwards	—	—	—	—	—	35	40	45	45	
3. Forwards	107	114	85	60	54	92	75	95	85	Male, æt. 30, tall, healthy.
Upwards	120	120	105	75	75	75	75	75	105	
Outwards	—	—	—	—	—	30	36	40	36	
4. Forwards	—	98	—	56	59	124	127	112	102	Male, æt. 28, healthy, strong.
Upwards	—	111	—	99	90	150	165	180	180	
Outwards	—	—	—	—	—	24	30	36	30	
5. Forwards	85	85	—	59	59	—	—	—	—	Male, æt. 45, middle height.
Upwards	135	150	—	135	135	—	—	—	—	
Outwards	—	—	—	—	—	—	—	—	—	
6. Forwards	—	75	25	25	25	35	30	—	—	Male, æt. 40, tall, rather stout.
Upwards	—	60	50	60	60	50	60	—	—	
Outwards	—	—	—	—	—	10	10	—	—	

TABLE I.—*continued.*

Extent and Direction of the Movement of different points on the Chest in 100ths of an inch.

Extent and direction of Movement.	Top of sternum.	Middle of sternum.	Ensiform cartilage.	Centre of clavicle (right).	Centre of clavicle (left).	3rd rib (right).	3rd rib (left).	5th rib (right).	5th rib (left).	Remarks.
7. Forwards	55	50	50	40	45	50	65	85	90	Male, æt. 23, slight, healthy, left-handed.
Upwards	110	110	120	100	110	110	120	160	160	
Outwards	—	—	—	—	—	15	15	25	30	
8. Forwards	85	93	95	80	85	135	115	115	110	Male, æt. 32, tall, healthy, muscular.
Upwards	100	120	115	130	130	160	150	110	120	
Outwards	—	—	—	—	—	30	25	30	30	
9. Forwards	25	55	100	55	50	85	78	100	100	Male, æt. 42, 6 ft., healthy, active.
Upwards	50	110	100	100	90	130	115	130	110	
Outwards	—	—	—	—	—	15	12	20	15	
10. Forwards	25	35	40	25	25	50	50	50	50	Male, æt. 21, slight, healthy, middle height.
Upwards	20	35	40	30	30	35	35	50	40	
Outwards	—	—	—	—	—	10	10	12	14	
11. Forwards	30	25	43	25	23	—	—	68	50	Male, æt. 32, 6 ft., healthy, strong.
Upwards	65	60	65	60	60	—	—	84	90	
Outwards	—	—	—	—	—	—	—	20	25	
12. Forwards	15	30	45	25	20	70	60	55	65	Male, æt. 22, 5 ft. 6 in., healthy, athletic.
Upwards	30	85	100	40	35	120	100	100	100	
Outwards	—	—	—	—	—	15	14	20	20	
13. Forwards	68	85	—	50	50	105	105	—	—	Male, æt. 45, 5 ft. 8 in., healthy, slight.
Upwards	65	100	—	60	54	95	100	—	—	
Outwards	—	—	—	—	—	10	15	—	—	

immotis, nisi quod imæ una vel altera septi motium sequantur." [1]

Little information, therefore, as to the action of the chest, can be obtained by means of any stethometer except in deep or forced respiration.[2]

THE MOVEMENTS OF THE CHEST IN FORCED BREATHING.

The actual extent of these movements varies in different individuals and in different regions of the chest; probably no two persons breathe with the same kind or extent of motion. It becomes necessary, therefore, to examine the details of each individual case, and then to attempt to extract from them some general conclusions which represent what is usually found to exist. A fair representative selection of examples must thus first be given in order to estimate the results obtained.

The foregoing table records the motions of different parts of the chest in healthy adult males, who were purposely selected as men of average capacity in breathing. No examples of extraordinary power are given, as they would be less suitable to the objects of the inquiry.

[1] Quod in dormientibus, sanis, tranquillis, planum est. Comp. Winslow, 1165; Galenus, *De loc. adf.*, l. 4, c. 6; also Hier. Fabricius ab Aquapendente, de Respirationis instrumentis.

[2] Sibson's *Medical Anatomy*, p. 63. "In the majority of males the thoracic movement during tranquil inspiration is about one-twentieth, the abdominal movement one-third of an inch. This indicates that the diaphragm descends about half an inch. In the robust the thoracic movement is even less. In two remarkably well-built men, Sewell the American runner, and in the third-best English runner, it was only one thirtieth of an inch. In many weak persons, on the other hand, it is as much as one tenth of an inch."

REGIONAL MOVEMENTS.

The Sternum.—It might be supposed that, in consequence of the mode of its attachment to the ribs and clavicles, the sternum would only be able to move in the upward and forward directions, and that it could not deviate from the middle line of the body; but owing to the different size of the two halves of the thorax, and to the varying strength of the muscles on each side, it is usual, even in healthy persons, to find a slight difference in the degree of motion of the right and left ribs, either in the forward and upward or outward directions; this

TABLE II.

Movements of the Sternum.

Movements of the Sternum.	Forward.	Upward.	Outward.
(1). Male, æt 21. Tubercle; contracted pleuritic adhesions on left side ...	85	45	12 (L.)
(2). Female, æt. 48. Spinal curvature to right side	35	60	8 (L.)
(3). Female, æt. 33. Crushed ribs on the right side. Upper sternum ...	25	20	12 (R.)
(4). Same case. Lower sternum	55	100	15 (R.)

fact must needs cause some slight lateral movement of the sternum, especially at its lower end, which would be drawn towards that side which has the least power of expansion.

It would, however, require great care in fixing the body in order to note the very small deviations which would arise from this source in most individuals, and the readiness with which this outward reading of the instrument is affected by movements of the body renders it untrustworthy for very small readings. It is on this account that the record of this motion is sometimes omitted from the tables, even in the measurement of the third or fifth ribs.

In disease or malformation of the thorax, either congenital or accidental, the lateral movement of the sternum may, however, become very perceptible. The preceding table gives the movements of the sternum in three cases.

As a general rule, the sternum moves forward and sometimes upward more freely than the clavicles, and the motions of the lower portions of the bone are greater than those of its upper end. There is thus an alteration of its plane towards a less vertical position, but this tilting forward of the lower sternum is not as great as might have been concluded from the greater length of the lower ribs, their greater mobility, and the obliquity of the costal cartilages. If the problem were a purely mathematical one, there ought to be some definite relation between these conditions and the extent of motion of the sternum; but it cannot be traced in the record of measurements given in the tables. The explanation of this fact is probably to be found in the yielding nature of the levers employed, and in the action of the great inspiratory muscle, the diaphragm. The action of this muscle on the six lower ribs will probably prevent the forward and upward motion of the sternum and, perhaps, also of the ensiform cartilage, in children. To some extent it would appear from the tables that the more elastic the thorax, the more is this influence of the diaphragm felt.

Many of the remarkable vivisections made by Traube would seem to bear out this explanation of the lesser degree of motion of the lower end of the sternum.

For example, at p. 150 (*Gesammelte Beiträge*) he says, "The only influence which, according to our experience, the diaphragm exerts upon the lower part of the thorax, consists in the drawing inward of the foremost (bony) ends of the seventh and eighth or from the seventh to the ninth rib." This opinion is fully borne out by his experiments, notably the tenth, eleventh, and seventeenth.[1]

The clavicles show, as might have been predicted, more upward than forward movement, and they are especially affected by the final effort of breathing, when the extraordinary muscles attached to them are brought into action.

There is little or no outward motion of any point on these bones, or on the first and second ribs in the anterior region of the chest, but on the third rib this motion is already distinct, and it increases in amount as we descend to the lower ribs, where the costal cartilages become more and more oblique.

The ribs at their anterior ends generally move more decidedly upward than the sternum, owing, perhaps, to their power of outward rotation, which permits them to rise more freely. Their forward push is also very considerable, especially in the lower ribs, the fifth and seventh, and in some cases even the second and third ribs, enjoy more forward movement than the sternum.

In most healthy male subjects the fifth and seventh ribs enjoy much more general mobility than the third, but this is by no means universally true, and possibly in obese persons this might not be even the usual case, since in them the so-called superior costal type of breathing may prevail. I have not, however, been able to apply my instrument in these cases.

There is certainly no regular increment of movement in the ribs as we descend from the upper to the lower. Owing to the gradual increase in the length of the ribs from the

[1] See also Mr. Le Gros Clark's "Remarks on the Mechanism of Respiration," *Proc. of Roy. Soc.*, vol. xx. p. 122.

first to the eighth or ninth, we might have expected that this circumstance would have given them a wider sweep at their anterior ends, but I can fully corroborate Dr. Sibson's statement that in some cases the second or third ribs have more power of forward movement than the fifth or even the eighth. There is also in the tables abundant evidence of the independent action of the different ribs. Mr. Hutchinson has well pointed out this power of independent movement in the case of certain chest diseases, and in most of the cases of the table it will be found that the third and fifth ribs are by no means in exact accord in the proportion which the several dimensions of the movements bear to one another.

The outward movement of points upon the five or six upper ribs appears to increase as they recede from the sternum until a limit is reached about midway between that bone and the vertebral column, beyond this point, measuring from behind, this motion naturally again gradually diminishes.

VARIATIONS IN HEALTHY BREATHING.

1. *Influence of Sex.*—The following table gives a few of the results which have been obtained by means of the three-plane stethometer in young and healthy women.

It has been noticed by most observers that in women both the ordinary and extraordinary breathing is chiefly costal; and since this fact has not been successfully traced to the fashion of dress, it may possibly be arranged to facilitate gestation.[1]

[1] This opinion was held by Boerhaave and Haller, but, as Dr. Walshe points out, if this were true, ascitic females ought to escape dyspnœa, and the difference between male and female breathing is much less during sleep, and male and female animals breathe almost exactly alike.—*Diseases of the Lungs*, Ed. 4, p. 16.

TABLE III.

Dimensions of the Movements of Respiration in 100ths of an inch. Adult Females.

Extent and direction of Movement.	Top of sternum.	Middle of sternum.	Ensiform cartilage.	Centre of clavicle (right).	Centre of clavicle (left).	3rd rib (right).	3rd rib (left).	Remarks.
1. Forwards	51	—	—	51	51	61	59	J. H., female, æt. 27, healthy (stays on).
Upwards	45	—	—	51	60	60	63	
2. Forwards	117	—	—	85	102	—	—	E. R., female, æt. 27, healthy (wearing stays).
Upwards	114	—	—	99	99	—	—	
3. Forwards	76	102	96	60	85	119	105	L. E., female, æt. 29, healthy, (no stays).
Upwards	75	90	90	90	90	105	105	
Outwards	—	—	—	—	—	30	30	
4. Forwards	51	85	93	51	60	60	76	M. F., female, æt. 22, healthy (no stays).
Upwards	54	51	45	60	75	96	96	
Outwards	—	—	—	—	—	30	33	
5. Forwards	31	51	—	42	46	68	76	M. D., female, æt. 33, healthy (no stays).
Upwards	105	94	—	60	75	99	105	
Outwards	—	—	—	—	—	—	—	
6. Forwards	37	40	—	42	38	51	51	B. M., female, æt. 36, healthy (no stays).
Upwards	70	75	—	75	75	90	105	
Outwards	—	—	—	—	—	21	18	
7. Forwards	30	35	—	50	55	75	90	M. R., female, æt. 34, healthy (no stays).
Upwards	50	60	—	70	75	110	120	

It does not appear to have been remarked, however, that the superior costal type of breathing does not give proportionately any increased power of raising the ribs in forced inspiration.

In the cases which I have examined it was rare to find any female who could raise the clavicles and third ribs more than one inch, and if the proportions between the motions are altered at all it is rather to the advantage of the forward thrust, which in several instances attained to or exceeded one inch.

Fig. 20 gives a representation of the movements of the third rib in a healthy male and female.

The peculiarities of motion of the different bones are also for the most part similar in females and males.

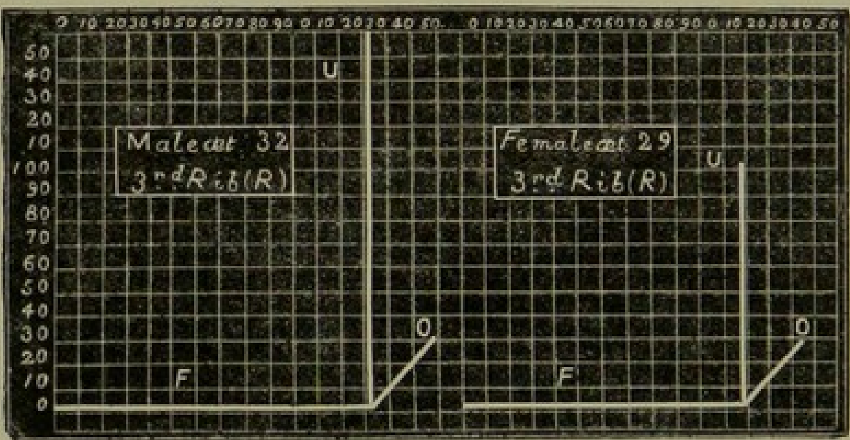


FIG. 20.—Dimensions of movements in males and females.

The forward movement of the middle of the sternum slightly exceeds in most cases that of the manubrium, and again we find the total movement of the ensiform cartilage somewhat lessened. The clavicles move at about the same rate as the sternum, in most cases rather less, in some rather more than that bone, and they move considerably less than the third rib, which as in men moves more than either sternum or clavicles.

TABLE IV.

Dimensions of the Movements of Respiration in 100ths of an inch, in Young Children and Old People.

Direction of Movement.	Top of sternum.	Middle of sternum.	Ensiform cartilage.	Clavicle (right).	Clavicle (left).	3rd rib (right).	3rd rib (left).	5th rib (right).	5th rib (left).	Remarks.
1. Forwards ...	98	98	—	64	64	110	102	110	102	Male, æt. 11, healthy, tall.
Upwards ...	111	96	—	117	120	75	100	100	100	
Outwards ...	—	—	—	—	—	20	20	30	25	
2. Forwards ...	—	—	—	30	29	—	—	—	—	Female, æt. 6, healthy, small.
Upwards ...	—	—	—	36	36	—	—	—	—	
3. Forwards ...	45	—	—	55	55	95	85	—	—	Male, æt 9, healthy, strong.
Upwards ...	50	—	—	110	110	120	120	—	—	
Outwards ...	—	—	—	—	—	30	30	—	—	
4. Forwards ...	17	25	30	45	40	35	30	30	35	Male, æt. 80, gardener, healthy.
Upwards ...	45	50	54	50	50	45	55	50	55	
Outwards ...	—	—	—	—	—	10	10	10	10	
5. Forwards ...	30	20	10	20	—	25	35	25	25	Male, æt. 59, merchant, healthy.
Upwards ...	100	75	60	100	—	100	100	70	75	
Outwards ...	—	—	—	—	—	15	15	20	20	
6. Forwards ...	10	25	25	15	15	30	35	30	30	Male, æt. 66, healthy, spare.
Upwards ...	50	30	30	45	35	50	70	55	60	
Outwards ...	—	—	—	—	—	—	—	—	—	
7. Forwards ...	45	35	—	30	30	50	45	—	—	Male, æt. 70, healthy.
Upwards ...	70	70	—	50	35	90	100	—	—	
Outwards ...	—	—	—	—	—	20	20	—	—	
8. Forwards ...	10	15	30	7	7	20	30	35	30	Male, æt. 82, healthy.
Upwards ...	30	30	40	24	25	40	40	70	60	

The fifth ribs were not examined. It is somewhat remarkable that, in most of the women examined, the motions on the left side exceeded those of the right.

2. *Age.*—The preceding table contains the measurements of the respiratory movements in children and old persons of both sexes.

It is interesting to observe the large relative movement of the chest-walls in children as compared with that of adults, and to notice the diminution in the power of chest motion as age advances.

This fact arises partly, no doubt, from the greater mobility of the bones, and elasticity of both bones and cartilages in youth; partly, perhaps, from the shape of the thorax in children, the deep lateral grooves on each side of the spine being absent; there is thus less difference between the chord lengths of the ribs of children and those of adults than might be anticipated, and the chest in children being shorter from above downwards, all the movements forward and upward are necessarily exaggerated in order to produce a corresponding alteration in the capacity of the chest. It is possible also that muscular energy in children may be comparatively greater in proportion to the amount of resistance during the respiratory act.

I have not observed that the proportions between the three dimensions of the movements are very different in children and adults, especially female adults, except that the forward push is somewhat increased. In old age, however, there is both a general diminution in all the dimensions of the movement, and in some cases the forward motion is lessened to the lowest degree compatible with any angular rise of the ribs.

The following figure affords a means of comparing the movements of the third ribs in a child of eleven and a man of fifty-nine ; the difference in the degree of forward movement is very striking :—

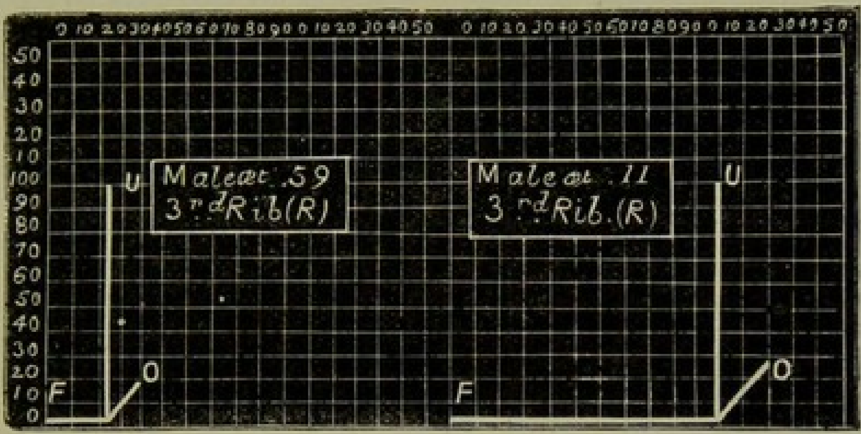


FIG. 21.—Showing dimensions of movements in youth and age.

3. *Position.*—The influence of position on the freedom of breathing is worthy of note. Interesting observations on this point have been made by Drs. Sibson and Hutchinson. I have myself, as yet, only made observations upon the influence of the position of the arms upon the breathing of persons in a sitting posture, especially as to the relative motions, upward and forward, of the sternum.

The following tables show the variations in these movements in three individuals :—

TABLE V.

Movements of the centre of the Sternum in different positions of the Arms.

	Case I.		Case II.		Case III.	
	F.	U.	F.	U.	F.	U.
a. Hands supported on a level with the shoulders, or on the table	102	105	107	114	90	100
b. Hands resting on the sternum	93	99	92	84	90	90
c. Hands locked behind the head	90	70	43	70	75	60

TABLE VI.

Showing the Movements of the lower end of the Sternum in different positions of the Arms.

	Case I.		Case II.		Case III.	
	F.	U.	F.	U.	F.	U.
a. Hands supported on a level with the shoulders, or on the table	76	115	115	150	100	120
b. Hands resting on the chest	73	84	105	129	95	115
c. Hands locked behind the head	65	66	98	129	—	—

The movements most affected were those forward, but both the upward and forward motions were impeded by any position of the arms except that on a table or on a level with the shoulders. This observation shows, therefore, that the well-known position of the asthmatic patient, during a paroxysm of dyspnœa, is the one which really gives the greatest amount of power of moving the chest-walls.

4. *Muscular power.*—In a very large proportion of the male cases examined it was found that the movements on the right side of the chest exceeded those on the left—a fact which may be placed in relation to the observations of different observers, notably Drs. Sibson, Walshe, and Wintrich, that in right-handed men the circumference of the right side may naturally exceed that of the left by from one-half to three centimetres. But it appears probable that both the increased power of movement, and the increased size on the right side, are due to the greater force of the muscles on this side. The power of movement certainly is remarkably affected by the muscular force of the subjects, and it is reasonable to believe that

the increased size of the right side of the chest may be partly at least, due to the same cause. The cases, in which the greatest amount of movement of the ribs and sternum was observed, were almost always men of considerable muscular development, although, even in these men, those who were most lithe and active, and who therefore had the greatest freedom in their joints, could exceed in some of their chest measurements the more sturdy and more muscularly strong.

VARIATIONS IN THE RESPIRATORY MOVEMENTS IN DISEASE.

Some of the peculiarities in the mode of movement of the chest-wall in disease will have to be considered shortly in reference to the questions of diagnosis and prognosis. It will nevertheless be convenient in this place to speak of some of the modifications produced by different affections of the lung; and in order to avoid the encumbrance of long tables of measurement, I shall now give very few illustrations of each observation, but shall refer to the tables which follow at pp. 151, 154, 157, 158, *et seq.*

A survey of all the cases on the register shows, as might have been expected, that the movements of respiration in disease are, on the whole, much less extensive than those in health. It is difficult at first glance to see how disease can ever produce exaggeration of motion, except by bringing about an enlargement of the sound side to compensate for the loss of breathing on the other. The extent of motion of the bony walls also in the ordinary breathing of some diseased subjects may, by habit, be increased, the voluntary muscles being more brought into action; but, even in this case, the limits of extreme expiration and inspiration will probably be less than in health.

INCREASED MOVEMENT.

Increased movement may, however, in rare cases, be

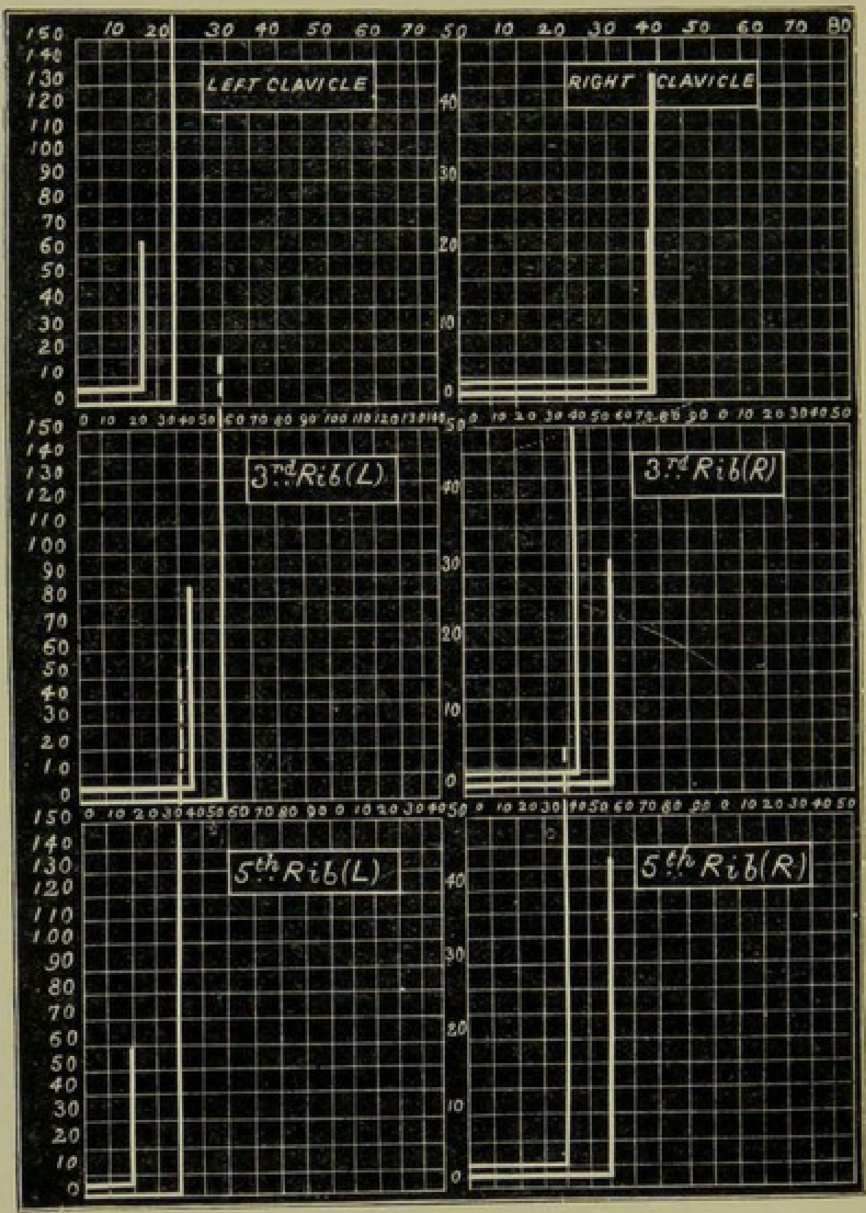


FIG. 22.—By an oversight, the latest measurements in the case of the right 3rd and 5th ribs are placed above instead of below the earlier record.

brought about by disease, especially in the extent of the upward motion.[1]

1 Dr. Walshe says, the chest movements may "exceed the healthy standard where a muscular effort is made to overcome some obstruction seated low in the chest."

Fig. 22 affords a good instance of this fact. From this patient two series of measurements were taken, the first soon after the pleuritic effusion on the left side had taken place; the second about two months afterwards, another attack of pleurisy with effusion on the right side having intervened.

It is very interesting to note the great increase in the upward readings in the last series of observations, due, no doubt, to an increased use of the respiratory muscles, which seem to have become stronger by use; at the same time it may be remarked that in the lower regions of the chest the forward motion is reduced to the smallest dimension compatible with the degree of upward motion recorded.[1]

A reference to the register of cases contained in Tables XVI. and XVII. on pp. 156 and 158, will show that this observation of a diminished forward movement with an increased upward rise is common to most of the instances of pleurisy,—both in males and females,—and in many cases the severity of the attack is declared by the degree to which the forward motion is impaired, whilst the upward movement is unaffected or increased.

This exaggeration of upward movement seems to extend in some severe cases even to the bones on the sound half of the thorax.

Take the following movements as an example of this—

[1] If the initial angle of the rib be taken to have been about 65°, and the chord-length of the rib about 6·5 in., both average dimensions in a man nearly 6 ft. in height, then it will be found, on calculation, that the forward push must have been at least 0·5 in., to permit of an upward rise of 1·70 in.

Case.	Direction of motion.	Mid-sternum	3rd ribs.		5th ribs.	
			Right.	Left.	Right.	Left.
Male, æt. 34. Two years ago had pleurisy in left side. Effusion rapidly absorbed.	Forw.	25	50	25	45	30
	Upw.	100	120	100	120	110

A comparison of these measurements with those given in Table I, page 52, will show at once the altered proportions between the forward and upward movements.

This fact, now noted in pleurisy, seems to be only a part of a more general law common to several diseases.

There seems to be a tendency in different parts of the chest-wall to compensate for loss of movement in some parts, or in some directions, by an exaggerated movement in those parts that are free to move.

Thus in phthisis numerous instances of this compensatory increase of motion are to be found, and in this disease it is sometimes the forward thrust that is exaggerated, sometimes the upward rise.

The following cases may be regarded as instances of this increase, in most cases over the diseased portions of lung—(an asterisk is placed over the measurements which are supposed to be in excess).

Other instances of a similar character will be found amongst the female cases of chronic phthisis, Table XX. p. 177, cases 1, 4, 6, and 9. The same peculiarity is also to be noted in non-phthisical cases, in which the action of individual ribs is interfered with, *e.g.* the cases recorded on pp. 145 and 146.

TABLE VII.

Showing Compensatory Movements of the Ribs.

Cases.	Direction.	Sternum.			Clavicles.		3rd ribs.		5th ribs	
		Upp.	Mid.	Low.	Rt.	Lft.	Rt.	Lft.	Rt.	Lft.
Male, æt. 60. Softening tubercle on right side; left healthy ...	F.	42	—	—	34	54	*93	85	—	—
	U.	69	—	—	69	57	69	105	—	—
Male, æt. 21. *Right* upper lobe consolidated; *left*, large contracted vomica at apex	F.	56	85	—	85	54	*110	68	*110	68
	U.	39	45	—	41	39	75	39	75	39
Male, æt. 21. Softening deposit under right clavicle ...	F.	50	55	55	55	55	48	55	*60	45
	U.	80	80	80	90	90	60	90	60	50
Male, æt. 28. *Left*, incipient deposit under clavicle ...	F.	50	70	70	75	50	110	95	85	*100
	U.	90	85	105	100	80	120	110	125	100
	O.	—	—	—	—	—	28	25	38	20
Male, æt. 62. Thirty years ago, softening tubercle at apex of left lung	F.	55	90	45	20	68	75	*75	75	75
	U.	90	116	110	100	100	100	*130	100	*120

In one rare case of idiopathic pneumo-thorax, on the right side,[1] which I had an opportunity of examining, twelve years after the patient's recovery, it was somewhat remarkable to find that the movements on the affected side were greater than on the other. The difference may perhaps be ascribed to the greater muscular power, usual amongst men, on the right side of the body, and the case may simply show the complete recovery of healthy power on that side. The following were the measurements obtained :—

[1] This case was published in full by Dr. Thorburn, in the *British Medical Journal* for June 2, 1860.

Direction of Movement.	Sternum.		Clavicles.		3rd rib.		5th rib.	
	Upper.	Mid.	Right.	Left.	Right.	Left.	Right.	Left.
Forward ...	45	80	75	75	125	95	145	125
Upward ...	75	125	120	125	145	135	155	130
Outward ...	—	—	—	—	28	38	30	38

DIMINISHED MOVEMENT.

It is amongst emphysematous and asthmatic patients that the most distinct examples of extreme diminution of motion are to be found, and in these cases all the three dimensions of the movement seem to be equally lessened. (See Table XVI., p. 151.)

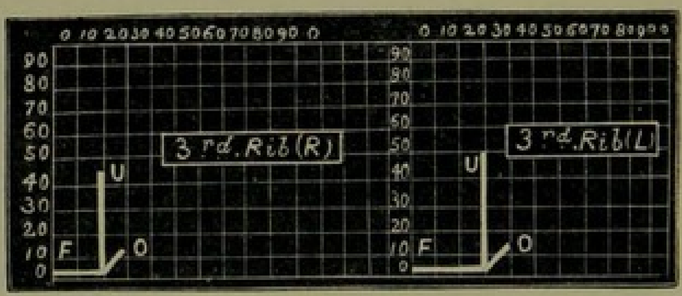


FIG. 23.

Fig. 23 represents the movements of the third rib in a case of advanced emphysema.

The rigidity of the thorax in these disorders seems to offer an almost equal impediment to all the movements of the ends of the ribs.

In chronic bronchitis there is also usually to be found considerable diminution of motion.

The following case is an extreme instance of this impairment of motion in an advanced case of chronic bronchitis. It will be found that the chest-movements in this case were even smaller than in the emphysematous example just given:—

Case.	Direction.	Sternum.		Clavicles.		3rd ribs.	
		Upper.	Mid.	Right.	Left.	Right.	Left.
Male, æt. 60. Had bronchitis 30 years. Now very feeble ...	F.	15	10	5	10	15	15
	U.	20	20	30	20	40	40

From this observation it would appear that even in this disease there must be in most cases a loss of elasticity, and in many, probably, some emphysema as well. It might otherwise have been anticipated that the respiratory muscles in these patients might at times have increased in power, and thus might have given greater extent to forced breathing.

There can be no doubt, however, that in all these cases there is an exaggerated costal motion in ordinary, unforced respiration.

In *phthisis* one of the earliest symptoms of the onset of the disease is a general lowering of the muscular power of the chest. The following case was probably an extreme example; but in some advanced instances the costal movement is entirely lost:—

Case.	Direction.	Sternum.	Clavicles.		3rd ribs.	
			Right.	Left.	Right.	Left.
Male, æt. 22. Phthisis of six months' duration. Right upper lobe consolidated and softening. Left, healthy .	F.	12	5	10	15	35
	U.	28	10	15	30	40

In the following instance, in which I was fortunately possessed of a record of chest-motion before the onset of the disease, the diminution of movement immediately after its invasion is very strikingly shown:—

Case.	Direction of movement.	3rd ribs.	
		Right.	Left.
Male, æt. 21. Healthy, though of phthisical family	F. U.	90 60	90 60
Same case, one year after. Had shown signs of tuberculosis for four months	F. U.	48 60	55 90

In the four Tables at pp. 175 to 178, a number of instances of phthisis are given upon which further observations might be made, but I prefer to postpone these until we come to speak of stethometry as an aid to prognosis.

CHAPTER IV.

ON THE CAUSES OF THE RESPIRATORY MOVEMENTS.

"A rib
Crooked by Nature, bent, as now appears."—MILTON.

THE subject of this chapter is necessarily divided into two branches:—1, the mechanical conditions of the respiratory movements, imposed by the form of the bony framework and the mode in which it is articulated; and 2, the forces which are capable of producing the movements of its different parts.

In proceeding to this inquiry, the indications afforded by the 3-plane stethometer are peculiarly valuable, since by its use, and by the manner of its use, several important sources of error are avoided.

1. In the first place, since all the measurements in the three directions are made during one act of breathing, their relations to one another are not liable to errors due to variations occurring during two or more efforts at forced respiration. The proportions between the several motions may be regarded as the result of one and the same movement of the underlying bone, and the consequence of the action of the same set of muscles. We can therefore, without any hesitation, rest our conclusions upon the basis of the figures obtained by the instrument.

2. Dr. Sibson, in his admirable treatise on the *Mechanism of Respiration*,[1] noticed two important facts bearing on this subject: 1st, that the spinal column itself curves backwards during inspiration; and 2nd, that the posterior angles of the ribs, during their change of obliquity in inspiration, rise, and at the same time are drawn backwards, so as to enlarge the deep groove on each side of the spinal column; and when they do this, that they often protrude beyond the spine, thus causing a *backward* thrust of greater or less extent, according to the individual experimented upon.

I have ascertained that this account of the motions of the back, though differing from that given by Mr. Hutchinson, is in some cases perfectly correct; and hence, if the whole back be supported in experimenting with the 3-plane stethometer, the before-mentioned *backward* thrust will appear in the indications of the *forward* motion, and will give too large a reading. In most of the experiments recorded in Table I. this source of error has been guarded against by simply supporting the spinal column by a fixed pad applied opposite the vertebral articulation of the rib to be examined; and in the examples which I shall use for the purpose of this discussion this precaution has invariably been taken.[2]

3. Again: it is well known that the ribs during inspiration undergo a certain degree of twisting movement by rotation upon an axis supposed to pass through their sternal and vertebral articulations. The lower edges,

1 Communicated to the Royal Society in the year 1846. *Phil. Trans.* vol. 136, part iv. pp. 504—512, 531.

2 I may state that I have only found an increased arching of the dorsal portion of the spine, in inspiration, in a small proportion of the cases examined; and with regard to the alleged bulging of the posterior angles of the ribs, in several instances, as the ribs have risen from greater to less obliquity their posterior angles have become less, instead of more, prominent.

especially those of the inferior ribs, are thus tilted forward, and might in this way exaggerate the reading of the forward push of the ribs. To some extent it is impossible to avoid this source of error; but it is lessened to the utmost by the mode in which the button of the stethometer is applied to the rib. Its centre should be placed on the middle line of the bone; and it will remain there because of the ball-and-socket joint. The error is thus at most very trifling, and does not exist for the upper ribs.

TABLE VIII.

Extent of Forward Motion observed in Healthy Subjects in Forced Breathing, by Dr. Sibson (selected from his work).

Case.	Age.	Sternum.		2nd rib.		4th and 5th ribs.		6th rib.		8th rib.		10th rib.	
		Upp.	Low.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
1.—Adult Males.													
4	23	120	75	130	125	120	120	120	120	—	—	—	—
8	28	100	120	115	115	120	120	130	130	130	130	80	80
9	37	130	110	110	100	95	90	80	80	95	90	95	80
12	26	180	190	225	—	—	—	—	—	—	—	—	—
13	26	100	100	150	—	—	—	—	—	—	—	—	—
16	22	90	60	100	100	100	100	50	40	—	—	—	—
2.—Boys.													
18	16	50	110	90	70	60	90	—	—	100	75	60	45
22	15	60	70	100	80	—	—	100	95	90	75	80	70
25	11	110	50	130	150	90	85	40	35	60	60	35	25
26	10	70	50	100	100	100	100	—	—	50	50	—	—
3.—Old Men.													
39	61	90	90	75	70	80	80	60	60	60	60	22	22
40	68	100	80	50	50	75	75	50	50	30	25	—	—
41	65	80	90	50	40	50	45	73	35	30	30	—	—
42	71	50	50	55	55	35	20	20	20	10	50	2	2

4. Although an examination of the construction of the stethometer employed will show that there is no reason to doubt the accuracy of its records, yet it may increase the confidence of many to know that its results, with respect to the forward motion of the chest-wall, accord very

closely with those obtained by Dr. Sibson. The preceding Table gives a few of his results, and they correspond closely with those which I have obtained, except that I never observed any forward thrust of the second rib at all comparable to that of Case 12.

I proceed now to the deductions to be drawn from the measurements respecting the mechanical conditions of the motions of the different parts of the chest; but in the first instance will confine my observations to the movements of the anterior ends of the third and fifth ribs. It has been commonly assumed in anatomical works that all the motions of the front part of the chest, on either side of the sternum, are to be accounted for by the movements of the ribs considered as rigid levers: the *upward* rise and the *forward* thrust, by their angular movement from an oblique to a more horizontal position, and the *outward* or lateral motion, by a rotation of the ribs upon their antero-posterior axis.

I am not aware that any attempt has been made to test the correctness of this view; and it would not easily be brought to the proof so long as accurate measurements of the several motions were still wanting. By means of stethometric tables the theory may be readily tested, although to this end it will be found that some additional data are required.

It will, I think, be granted that, if the upward and forward movements are simply due to the angular rise of the ribs, they must be determined—1st, by the angle through which the rib rises; and 2nd, by the length of the radius by which the arc of the curve is described.

I.—OF THE ANGULAR MOVEMENTS OF THE RIBS.

It would appear that the angles made by the plane of each rib-circuit with the vertical have not yet been measured in reference to this subject.

The only approach to a numerical statement that I have been able to find is that of Dr. Quain, who, in his work on Anatomy, says: "The first rib is almost a right-angle; the others slope gradually more and more to the ninth."

I have, however, endeavoured to estimate these angles as represented in the plates of different anatomical works, such as those of Cloquet, Luschka, Maclise, Quain, Sibson, and Wilson.

From these plates it would appear that the angles in question vary for the third rib between 50° and 70°, and for the fifth rib between 46° and 65°.

In Dr. Sibson's *Medical Anatomy*, a view is given of the relative positions of the ribs during forced inspiration and expiration; but even in the latter case, the smallest angle of the third rib appears to be 54°, and of the fifth rib 46°.

I have also measured the angles made by the third and fifth ribs with the vertical, in most of the better preserved skeletons contained in the museum of the Manchester Royal School of Medicine; and although it was obvious that most of them had been articulated in a position of greater obliquity than would have been caused by an extreme degree of expiratory effort,[1] yet in no case was the angle made with the vertical by the third rib less than 60°, nor by the fifth rib less than 55°.

It is not difficult, however, to measure the angles made

[1] Perhaps in consequence of the shrinking of the costal cartilages.

by the ribs with the vertical in the living subject. The simple instrument figured below is sufficient for the purpose, and may be made to give diametric measurements as well.

It consists of an upright support (*a*), bearing a semicircular dial (*b*) at the back; and attached to it, at the centre of the dial, is a pair of callipers hinged at (*c*), and carrying a needle, so that any change in the obliquity of the plane of the callipers is at once indicated upon the dial. Then, by placing the buttons (*e* and *f*) respectively opposite the

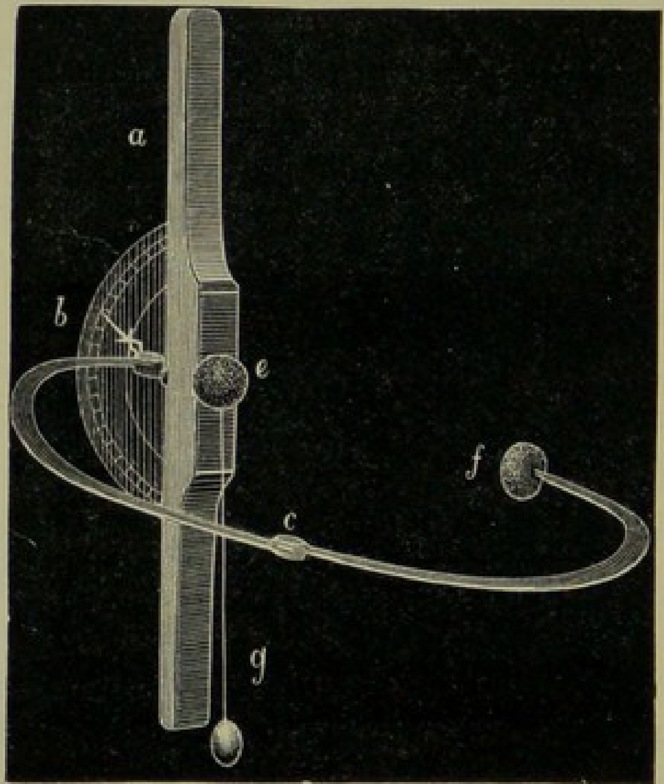


FIG. 24.—GONIOMETER FOR THE RIBS.

spinal and costo-cartilaginous articulations of a rib, and holding the support (*a*) in a vertical position, ascertained by a plumb-line (*g*), the angle made by the rib with the vertical may be registered in the two positions of inspiration and expiration, and use may safely be made of the results in the proposed inquiry.

A large number of observations have been made with this instrument; and it may be stated generally, that although much variation has been found in the degree of obliquity of the ribs in different individuals, yet in none has the angle of the third rib in expiration been less than 51°, nor has the fifth rib formed a less angle than 50°, and in most cases the angles were much greater.

Each case must, however, be observed separately; and before any calculation can be made as to the sufficiency of the usual explanation of the rib movements, it is necessary that the chord-length of the rib, whose angle has been ascertained, should also be as carefully measured as it is possible in the living subject. A few examples of the angles made by the third and fifth ribs are given at p. 81.

THE CHORD-LENGTHS OF THE RIBS.

The curvature of the lever used in respiration, composed as it is of two segments of circles of different diameters, may make it difficult to see with what radius the motions of the ends of the ribs are described; but very little consideration will show that this radius must be the straight line joining the head of the bone with its anterior extremity, in other words, the "chord-length of the rib."

If a bow be bent and used as a means wherewith to describe curves with one end fixed, it will be seen at once that the radius in this case is simply the string of the bow—the chord of its arc. In the case of the rib, whatever may be the motions of its anterior end, if the bone be regarded as a rigid lever, these motions must be regulated by its chord-length regarded as the radius of its circular, or, more strictly speaking, of its spheroidal course.

In the spare living subject a very fair approximation to the chord-length may be made by using callipers stretching from the spinal column, opposite to the articulation of the rib to be examined, to its anterior extremity. There must of course be an allowance of from one inch to one and three-quarter inches for the thickness of the bones and muscles intervening between the rib and the posterior limb of the callipers.

Fortunately, in the investigation before us it will be found that an error of a quarter, or even of half an inch, in this dimension will not materially affect the result ; so that we may now consider the possibilities of movement which would be conferred upon the end of the rib, in the three directions—upwards, outwards, and forwards—on the ordinary hypothesis that these motions are due to the radial and lateral sweep of the bone considered as a rigid body.

It will be found, not only that we shall have tested the accuracy of this view of the respiratory movements, but we shall have gained an insight into the working of the machinery that we could hardly obtain in any less elaborate manner.

The following Tables contain a few selected examples which may serve as data for our calculations :—

TABLE IX.

Measurements relating to the Third Rib (in Males).

Case.	Angles made by the rib with the vertical.		Gross diameter in plane of rib.	Estimated chord-length.	Stethometric dimensions.		Remarks.
	Inspiratory.	Expiratory.			Forwards.	Upwards.	
1	73°	65°	6·	5·	0·65	0·75	Æt. 11. Tall, healthy, thin.
2	75°	65°	7·50	6·	0·65	1·20	Æt. 23. Spare, medium height.
3	62°	51°	8·15	6·65	1·20	1·10	Æt. 25. Spare, 5 ft. 11 in. in height, deep-chested.
4	78°	63°	8·5	6·75	1·35	1·60	Æt. 32. Strong, healthy. 6 ft. high.
5	85°	73°	7·75	6·25	0·85	1·35	Æt. 37. Healthy. Height 5 ft. 8 in.

TABLE X.

Measurements relating to the Fifth Rib.

Case.	Angles made by the rib with the vertical		Gross diameter in plane of rib.	Estimated chord-length.	Stethometric dimensions.	
	Inspiratory.	Expiratory.			Forwards.	Upwards.
1	71°	62°	6·5	5·5	·65	·75
2	72°	60°	8·	6·5	·85	1·60
3	—	—	—	—	—	—
4	73°	61°	9·5	7·65	1·15	1·20
5	84°	71°	8·5	7·	1·00	1·50

A very simple calculation is all that is necessary, in order to learn the distances, forwards and upwards, through which the end of a rigid lever of given length will move in describing the arcs of circles such as are noted in these tables.

If O A $= r =$ the length of the lever, and the angle A O D described in its revolution about the point O, from the horizontal line O D = θ, and the angle D O C = ψ, then A B, the amount of forward thrust of the point of the lever = r (cos ψ − cos θ) and B C its upward rise = r (sin θ–sin ψ.)

Applying these formulæ to the data which we have supplied in Tables IX. and X. we are enabled to compare the actual movements of the ends of the ribs, as observed by the Stethometer, with the motions they should

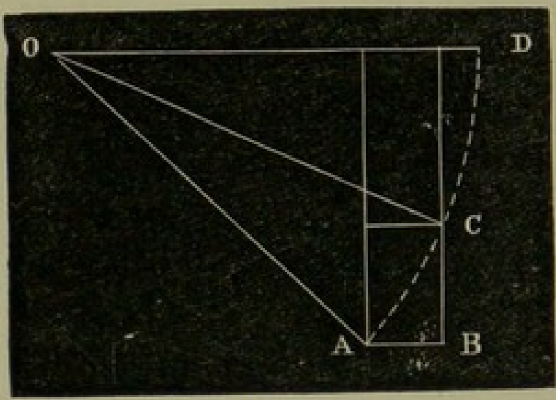


FIG. 25.

have had if the ribs moved like the unyielding bars of a machine articulated like the thorax. The following Table XI. exhibits the results, and we are therefore now in a position to study the movements of the ribs in each plane of direction, and to estimate the explanations to be given of them.

TABLE XI.

Comparison between the Calculated and Observed Motions of the ends of the Ribs on the data supplied in Tables IX. and X.

	Forward Motions of the ends of 3rd and 5th ribs, from		Differ-ence.	Upward Motions of the ends of 3rd and 5th ribs, from		Differ-ence.
	Stetho-metry.	Calcula-tion.		Stetho-metry.	Calcula-tion.	
Third rib ...	0·65	0·25	— ·40	0·75	0·80	+ ·05
	0·65	0·25	— ·40	1·20	1·10	— ·10
	1·20	0·65	— ·55	1·10	1·07	— ·03
	1·35	0·61	— ·74	1·60	1·60	...
	0·85	0·25	— ·60	1·35	1·30	— ·05
Fifth rib ...	0·65	0·33	— ·32	0·75	0·75	...
	0·85	0·35	— ·50	1·60	1·50	— ·10
	1·15	0·53	— ·72	1·20	1·40	— ·20
	1·00	0·35	— ·65	1·50	1·50	...

1. ON THE CONDITIONS OF THE UPWARD MOVEMENT.

When the third and fifth ribs are separated from all their muscular attachments, their vertebral and sternal articulations remaining intact, it may easily be shown that a simple radial movement of the ribs is sufficient to produce a greater degree of upward movement than any of the upward dimensions recorded in the Table. Thus a third rib with a chord-length of $5\frac{1}{2}$ inches will easily rise to the extent of 2 inches, and a fifth rib, of $6\frac{1}{2}$ inches of chord-length will rise upwards of $2\frac{1}{2}$ inches.

There is therefore, in the mechanical conditions of rib-articulation, nothing that would prevent the whole of the upward rise from being due to the radial sweep of their chord-lengths.

The close correspondence between the observed and the calculated rise, also makes it probable that this is the complete explanation of the movement. (Table XI., last column).

There is, however, a possible influence that might affect the extent of this movement in the straightening or increased curvature of the spine.

It has been observed that the vertebral column in its thoracic region becomes more curved during inspiration, and this would have the effect of lessening the height of the body, and so of diminishing the upward readings of

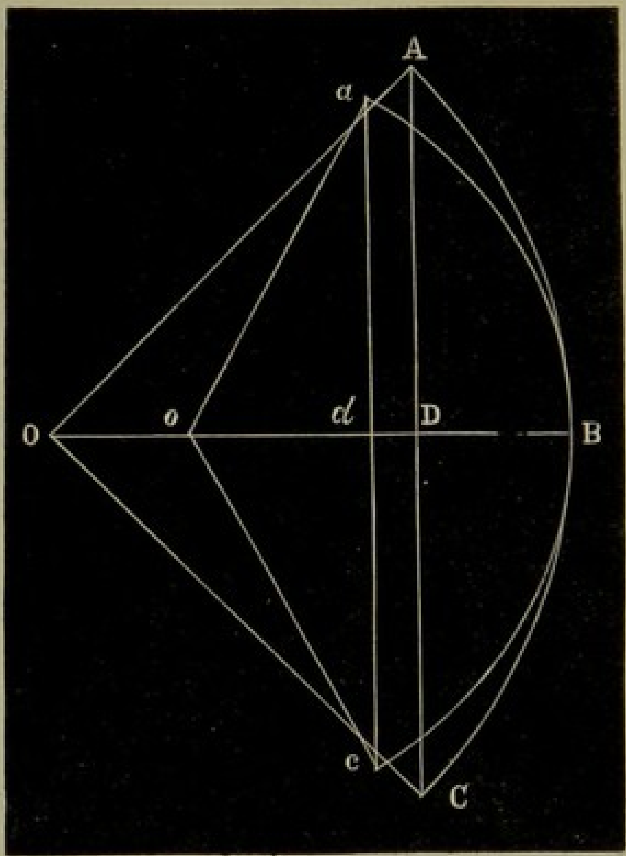


FIG. 26.

the stethometer; but it may be easily proved that the extent of this disturbing influence must under all circumstances be almost inappreciable.

The accompanying diagram (Fig. 26) will illustrate the kind of problem that would arise in this case:—

If A B C is the usual degree of curvature of the spine, and *a* B *c* its increased curvature in inspiration, then the difference in length between A C and *a c* will be the loss of height of the spinal column due to this curvature.

If, then, we take the case in which the dorsal region of the spine forms an arc of about 42° of a circle of 12 inches radius,[1] then the greatest amount of backward push that I have measured during inspiration has been 0·25 in.

A geometrical calculation from these data shows that in this case, the extreme alteration in the distance of the first dorsal vertebra from the twelfth is less than 0·15 in. It is probable also that in most cases there is an equally small effect arising from any alteration in the lumbar curvature of the spine; therefore we may assume—what indeed the table itself displays—that the stethometer applied to the front part of the chest chiefly registers the simple radial movement of the chord-length of the ribs.

2. CONDITIONS OF THE OUTWARD MOVEMENT.

The measurements of the outward motion of the ends of the ribs are also mainly to be accounted for by the action of the ribs, considered as simple rigid bars, from their rotation upon the antero-posterior, or sterno-vertebral, axis. I am not aware that any record has been published of the angles usually made in healthy subjects by the costal cartilages with the sternum. It probably varies somewhat; but in most anatomical drawings I find that these angles for the third ribs are generally about 95°, and for the fifth ribs about 55° and 60°.

From my own measurements in living subjects it is probable that these dimensions are fairly correct; and if this assumption be made, and if we take the costal cartilage of the fifth rib as measuring about three inches in length, and

[1] A supposition in accordance with Dr. Humphry's observations on the human skeleton.

use it as a radius, then we shall find that, in order to get an outward movement of 0·36 inches, as in case 3, Table I., page 52, with an initial angle of 55° the rib must move through an angle of about 15°. This amount of movement of the costal cartilages is clearly much within the possible extent of their motion; and we need not, therefore, seek for any other source of this indication of the measuring instrument.

It may be remarked that this explanation holds good, whether the outward motion of the end of the rib is caused by the raising of the costal cartilages by their own peculiar (inter-cartilaginei) muscles, or by a drawing apart of the ribs themselves, owing to the action of other muscles.

It is probable that both these sources of this movement are at work.

The outward movement of the rib is not affected by the degree of forward push; but, as I have before pointed out, it is peculiarly liable to error in the anterior regions of the chest, from the influence of any slight twist of the body or movement of the arms. We cannot, therefore, regard the numbers obtained in the measurements as anything more than approximative, and cannot submit them to close calculation.

3. ON THE CONDITIONS OF THE FORWARD MOVEMENT.

It is at once evident from the figures contained in the fourth column of Table XI., that the usually received hypothesis, which has proved sufficient to explain the *upward* movement, entirely fails to account for a large part of the extent of the *forward* thrust of the ribs.

The striking differences, between the observed and the calculated dimensions of this movement, are far too great and too constant to be caused by an error of observation; but if any doubt on this point should linger in the mind of any reader, let him attempt to account for the forward thrust of the second rib as observed by Dr. Sibson to the extent of more than two inches, and he will find that, even supposing its chord-length to have been seven inches, it would have been necessary for it to have started from an expiratory angle of 47°, in order to produce such an astonishing degree of forward push.

Other circumstances might also make him hesitate to accept the simple mathematical explanation of the movement. Thus, there is no constant relation between the amounts of forward and upward motion: the same rib with the same extent of upward rise will differ at different times in the extent of its forward thrust; and it is even possible, by an effort of the will, to produce at one time a greater degree of forward, at another of upward, motion. Such variations would be impossible if the forward push were simply the result of the angular rise of the rib.

The following instances are interesting examples in proof of what I have stated:—

1. A. B., a strong healthy man, aged thirty-two, with a well-developed chest, when directed to raise his ribs, was able to give an upward movement to the button of the stethometer of 0·6 inch, with a forward thrust of only 0·1 of an inch; and again, by restraining the upward motion, he could produce a forward push of 0·75 inch, with an upward rise of only 0·25 inch.

2. C. D., aged thirty-seven, thin, healthy, was able to raise the button of the stethometer, 0·6 inch, with a forward push of 0·3 inch, and also could produce a forward thrust of 0·5 inch, with an upward movement of only 0·2 inch.

It is evident, therefore, that something more is needed than the altered obliquity of the ribs to account for their forward thrust; and from the manner in which the measurements have been made, it will be seen that only alterations in the radius of the arc described by the rib would explain the discrepancies which we have pointed out between fact and theory. In other words, that the ribs must be capable of altering their curve, and that they can be bent to some degree either outwards or inwards. I have satisfied myself by experiment that this is quite possible.

In the dead subject, by carefully fixing the ribs, and applying weights in the direction of their chord-lengths, I have ascertained that the pressure of a few, five or seven, pounds suffices to diminish the measurement by 0·25 to 0·75 inch. In living persons, by making them hold their breath in the position of full inspiration, and fixing the back, the stethometer shows that, in spite of the resistance of the inflated lung and other structures, pressure with the fingers on the button of the instrument produces a very appreciable movement of the index of the F, dial—a movement varying in different persons from 0·3 to 0·7 inches. Pathology also shows clearly enough that the ribs are capable of being bent. The sinking in of the thoracic wall over the site of a dried-up vomica, or when pleuritic fluid has been absorbed, the barrel-like distension of the chest in emphysema, the indrawing of the lower rib in dyspnœa, are proofs sufficient of the flexibility of these bones.

The following cases, given by Mr. Le Gros Clarke, in an interesting paper on the Mechanism of Respiration, will illustrate further the influence of diseased conditions upon the ribs :—

1st.—"A patient at St. Thomas's Hospital, in whom there was fracture with displacement of the sixth cervical vertebra, by which the chord was compressed. He survived the injury less than three days, and there was complete paralysis of motion and loss of sensation below a line level with the nipples; the movement of the arms was also impaired. 'The walls of the chest, across and below the nipples, were retracted at each inspiration.' I quote the words of the Hospital registrar, but I repeatedly proved this, and demonstrated the fact to others, by placing around the chest just over the nipples a tape, which became relaxed at each inspiration to the extent of at least half an inch."

2nd.—"F. F., æt. 58, a bricklayer, was admitted into St. Thomas's Hospital in February 1871, having fallen from a considerable height and struck some projecting object in his descent; he remained incapable of movement, though perfectly sensible. The lower limbs were paralysed, and the movements of the upper extremities were impaired. . . . . In breathing, the whole chest was very perceptibly drawn in during inspiration, and the abdomen became more prominent than is normal. The chest was slightly raised as a whole, and the sterno-mastoids were seen to act strongly. The lower ribs were *not drawn downwards, but appeared to be pulled directly inwards*, or inwards and slightly upwards. . . . Subsequently the chest appeared to act unilaterally, as if from unequal action of the two sides of the diaphragm, the ribs on the left side being drawn inwards during inspiration, whilst the right half of the thorax was thrust outwards passively. He survived the accident about sixty hours; and the cord was found crushed between the fifth and sixth cervical vertebræ, which were fractured." [1]

Some of Traube's experiments upon difficult breathing in rabbits, (notably the VIth. and XIth.)[2] also show very clearly the possibility of an inbending of the ribs during respiration.

But we need not be left to inference to decide this question. It is not difficult to demonstrate on most spare

[1] *Proc. R. S.* vol. xx. No. 131, p. 125.

[2] *Gesammlte Beiträge zur Pathologie und Physiologie erster-band*, pp. 147, 152. See also p. 150.

persons the fact that there is an alteration in the diameter of the rib-circuit during forced respiration.

By the use of a suitable apparatus the degree of rib-bending may be measured with considerable accuracy. The instrument which I have employed for this purpose is figured below.

It consists of an ordinary pair of callipers, with the following modifications:—1, a screw at the central joint by which the blades can be firmly fixed in any required

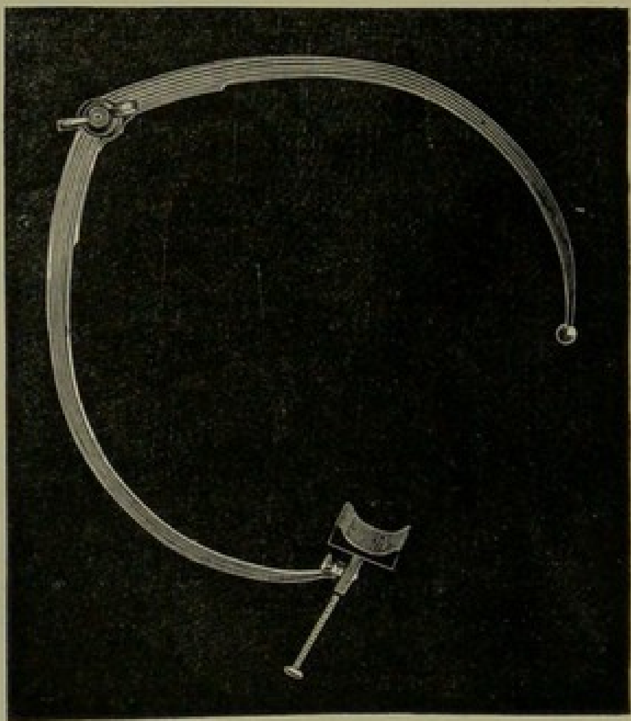


FIG. 27.—Thoracic Callipers.

position; 2, an ivory button on one of the points; 3, a pad, hollowed to receive the rib, and to fit into the inter-costal spaces on either side of it; and 4, this pad is attached by a ball and socket joint to a small rod, which slides in a tube on the other point of the callipers, and which is so graduated that the extent to which it moves in the socket may be read off in tenths of an inch. A little side-screw (5) serves to fix this rod in the socket when necessary.

In using this instrument the ivory button (2) on one arm of the callipers is applied to the spine, opposite to the vertebral articulation of the rib to be examined.

The central screw (1) is loosened, and the pad (3) is placed with its central point as nearly as possible over the end of the rib selected, at its junction with its costal cartilage. Care is taken to fit its projecting ridges well into the adjoining spaces. It is obvious that this can only be done in spare subjects, so that these persons only can be examined.

The patient is now directed to inspire fully, and the callipers are so bent as to push the rod home, and bring the pad close up to the socket; the central joint is then tightly fixed in that position. A forced effort at expiration is now made by the subject, and during this act the rib is followed in its downward course by the pad, which is allowed to do this by letting the rod move freely in the socket. It is usually found that this movement takes place to a considerable extent, and that the pad is separated from the end of the callipers by a space varying with the individual and with the rib examined. The rod is now fixed by means of the little side screw, and the amount to which the rod has had to be pushed through the socket is read off. It is evident that the callipers give the gross measurement of the chest, in the direction of the chord-length of the rib examined, and if there is any difference between the two measurements in the situations of deep inspiration, and forced expiration, this must be due to an alteration in the chord-length of the rib; in other words, that the rib must have bent, otherwise its chord-length would be invariable. The sources of error in this simple experiment are few, and not difficult to guard against.

1. The pad may slip over the rib, and not follow its descent in expiration, and when there is much fat under the

skin it is difficult to avoid this accident. By selecting thin subjects and with care, however, this error is easily avoided.

2. Too much pressure may be used, either in the position of inspiration or expiration, and thus the rib might be bent inwards by external force; in the first case too small, and in the latter too great, a reading of the instrument would be obtained.

A fair number of measurements have now been carefully made with this apparatus, both by myself and by other medical men, and the results fully confirm those which were arrived at by deductive reasoning from the stethometric observations.

The readings of the instrument are tolerably constant in the same individual; and had the construction of the instrument been more perfect I believe they would be even less variable. They are, however, amply sufficient to demonstrate, and to measure approximately, the degree of bending of the ribs; and the slight variations which occur in the measurements of the same ribs are probably in part due to the varying amount of force employed by the respiratory muscles. The same fact may be noticed in the use of the more perfect instrument, the three-plane stethometer. As might have been anticipated, there was great variation in the amount of bending of the ribs in different individuals. In children it was large in proportion to the small diameter of the chest, and their muscular power.

In women the motion of the rod in the socket was relatively somewhat less, but it was still considerable, varying from 0·2 to 0·4 in.: for the third ribs. In adult males, with elastic chest walls and vigorous muscular power, the movement was much greater, and, in the larger part of the cases examined, the degree of motion increased in passing from the upper to the lower ribs, and in one or two instances the reading for the seventh ribs reached the large amount of 0.9 in.

In other subjects the third rib showed a greater flexibility than the fifth or sixth, and the amount of 0·6 and 0·7 in. was noted in two individuals, as the difference between the inspiratory and expiratory chord-lengths of the third ribs.

In two instances I have endeavoured to ascertain, whether the amount of bending of the ribs measured by this instrument, would correspond with the excess of forward movement recorded by the three-plane stethometer.

1. In one man, aged 39, middle height, of average strength, slightly built, but healthy, the total forward motion of the right third rib recorded by the stethometer was 0·85 in.

The angle with the vertical line from which the rib rose was 65°: and its position after full inspiration was 77°. The estimated chord-length of the rib was 6·5 in. From these data it may be readily found (see page 81) that the forward push due to the upward rise of the rib was about 0.44 in.

The difference in the inspiratory and expiratory chord-length of the rib, as observed with the instrument, was found to be 0·425 in., which gives a total of 0·865 in., an amount not very different from that registered by the stethometer.

2. In the other case, a strongly healthy man, 5 ft. 9 in. in height, the forward movement of the third right rib, indicated by the three-plane stethometer, was 1·24 in., and the rib rose from an angle of 55° to 70°. These angles with an estimated chord-length of 6·75 in., give 0·81 in. as the forward motion due simply to the angular movement of the rib, and by the callipers applied over the same points the inbending noted was 0·475 in., and this, with the above mentioned calculation, gives a total of 1·285 in., which is again somewhat slightly in excess of the observed amount,

but not more than might be accounted for, by the difficulty of the experiment.

This variation in the degree of flexure of the ribs may then be regarded as the source of the discrepancies which have been noted between the actual and the calculated extent of the forward movement.

But there still remains a question of some importance to be decided. Does the difference in the expiratory and inspiratory diameters arise from an inbending of the rib in the former case, or from a straightening in the latter?

I. STRAIGHTENING OF THE RIBS.

It is difficult to conceive the existence of any power of straightening, and consequently of increasing the chord-lengths of the ribs which would act from within the chest.

The old doctrine of the Montpellier physicians, of the power of self-inflation of the lungs, has long been exploded, and the action of the diaphragm is usually antagonistic to any outward thrust of the ribs. In opposition to Beau and Maissiat, Traube and Bert agree in stating, as the result of many interesting experiments, that Haller's opinion on the action of the diaphragm is for the most part correct, and that when the ribs are laid bare and the intercostal muscles divided, it is powerless to raise the six upper ribs, and, when the abdomen also is opened, it cannot raise the lower ribs, on the contrary its tendency is to draw inwards all these levers. Mons. Bert, however, goes further than this, and shows that at any rate in dogs, when the abdomen is left intact, the action of the diaphragm is reflected from the abdominal organs, and raises the lower ribs, whilst it depresses the upper.[1]

[1] *Leçons sur la Physiologie comparée de la Respiration.* Paris, 1870, pp. 350—353.

This observation of M. Bert may easily be verified during the abdominal breathing of obese persons. I may state also that I have observed this contrast in the action of the upper and lower ribs during tranquil, and necessarily diaphragmatic, breathing in a woman affected by general paralysis, produced by progressive locomotor ataxy. The fact, however, of the diaphragmatic raising of the lower ribs does not affect our observations upon the upper five ribs; if, therefore, there is any straightening of the true thoracic ribs, it must arise from some other source.

Traube has made the interesting observation that when the chest is opened in the living body there is an increase of volume experienced by the altered position of its ribs. This arises, he believes, from the release of the walls of the chest from their connection with the lungs, which by their vital elasticity draw inward all the pliant parts of the thorax.

It does not occur in the dead subject, and is therefore due to the "tonus" of the rib-raising muscles which, after the concentrically acting power of the lung tissues has been neutralized, places the ribs in a more horizontal position, and thus brings about expansion of the chest. It is possible that there may also be in the ribs themselves some power of straightening themselves to a slight degree, when they are released by the action of the various muscles of inspiration from the weights and impediments which ordinarily rest upon them.[1]

This may be one mode in which an addition may be made to the forward movement of the ends of the ribs.

The question may also be asked, whether in paroxysms of dyspnœa the muscles of the shoulder have any power of drawing forward the parietes of the chest, but so far as

[1] *Op. cit.* pp. 141, 142.

these experiments are concerned, we need not enter upon this question, since in all of them the arms were purposely prevented from assisting in the respiratory effort.

ON THE EXPIRATORY SHORTENING OF THE CHORD-LENGTH OF THE RIBS.

The other mode in which the excessive forward motions, indicated by the stethometer, are to be accounted for is by an inbending of the rib during the preliminary expiratory effort.

A careful examination of the order of movement of the indices of this instrument will show, I think, that this is the most usual source of the excess in question. During an act of forced breathing the index of the *forward* dial generally moves first, a forward push of from 0·25 to 0·30 in. being often noticed before any decided action of the other indices takes place, and by an effort of the will the forward may easily be made to precede the upward movement by 0·50 in.

This fact would probably be sufficient to prove that there must be some preliminary indrawing of the chest wall in the expiratory act.

But this hypothesis is also in conformity with other facts. The extraordinary degree of motion of which the ribs of young children are capable, and the fact that the forward movement tends to diminish with age, would both be explained by the inbending of the ribs, since this action would be most readily performed whilst the ribs retain their elasticity.

The theory further throws light upon the extraordinary fact, first noticed by Dr. Sibson, but not explained by him, that the second and third ribs, notwithstanding their comparatively small obliquity and their shorter chord-lengths, yet have a very large extent of forward movement, in some cases greater even than the lower ribs, the sixth and seventh for example.

The truth is that these upper ribs are thinner and more flexible than the lower, and they are placed with their edges less obliquely with regard to one another, so that they are more readily bent than those below them.

The phenomena of coughing and sneezing are also best explained by the expiratory inbending of the rib, but since the nature of these involuntary actions will be best understood after an investigation by another method, the consideration of them will be postponed to the next chapter.

Perhaps the most important application of this hypothesis of the nature of the respiratory movements, is the explanation which it affords of the measurements obtained in various diseases of the chest. We have seen that in chronic bronchitis, asthma, and emphysema there is little alteration in the proportion of the several movements to one another; the motions of the chest in these disorders are pretty equally impaired in all directions, but in tubercular consolidation of the upper lobes of the lungs, and in some cases of pleuritic adhesion, in cases, in fact, in which there is an impediment to any bending of the ribs, in such disorders the ratios between the dimensions of the movements are very greatly altered, the forward push is much reduced, whilst the upward rise is either left unaltered or is exaggerated, so as in some degree to compensate for the loss in other ways. In the more severe forms of these diseases the forward thrust is so far reduced that it takes place only to the small extent necessary to permit the radial rise of the rib. In these cases it seems most in accordance with the facts to conclude that the pliability of the ribs has been interfered with, that in the case of the pleuritic adhesions, the ribs have been already so bent inwards by the bands of lymph that no further preliminary inbending is possible, and that in the case of tubercular deposit, either the intercostal muscular fibres are weakened, or the loss of elasticity of the lung presents so much resistance to their action that the bending cannot take place. A proof of the truth of this remark might be found in the fact, that after softening of the lung has taken place, and large vomicæ are formed, the rib is often in great measure released from its bonds, and the forward push is again permitted to almost as large an extent as before.

We shall have to refer to this point again in speaking of stethometry as an aid to prognosis.

I have endeavoured to discover at what point of the ribs the greatest amount of bending takes place, by comparing the extent of the forward motion, at different distances along the rib from the vertebral column, and, in the few cases examined for this purpose, I have found that the excess of forward motion—that, namely, which is not due to the radial movement of the rib—increases rapidly in extent towards the anterior end of the bone.

It was comparatively slight near the middle portion of the rib, and became rapidly greater in the anterior region of the chest. This is precisely what would happen if the ribs were pliable at all; since they are slighter and thinner, and so more easily bent, at their anterior ends, the purchase of the muscles effecting this action would also be greater at this point. Here then, we have an additional proof of the correctness of the view taken.

CHAPTER V.

ON THE STETHOGRAPH AND ITS RESULTS.

"Litera Scripta manet."

FROM the observations contained in the last two chapters it will have been sufficiently evident that the course described by the end of a rib in respiratory action is very far from being regular. But its actual track has still not been fully made out.

It becomes desirable therefore that further investigation on this point should be made, and the best mode of obtaining the required course will undoubtedly be to procure exact graphical tracings of the rib-movements, we may then not only study their peculiarities in different cases, but we may also at the same time throw further light upon some of the questions discussed in the last chapter.

As may readily be supposed, the chief difficulty in the way of obtaining accurate tracings of the movements of the ribs is to be found in the fact of their "three-plane" character, and hence it is impossible to inscribe them upon a flat surface, such as a piece of writing paper or a sheet of glass.

But inasmuch as by the three-plane stethometer it has been shown (pp. 52, 53) that the degree of outward or lateral motion possessed by the ends of the upper ribs is very small, we may, without much harm, exclude this dimension from observation—at least in experiments upon the front part of the chest.

It is the more allowable to do this because, as we have seen, the measurement of this lateral thrust is of much less real importance than that of the other two, which carry with them interesting practical indications.

It is not difficult to exclude the outward movements, since all that is necessary is to rest the apparatus, of whatever kind, upon a swivel joint which permits of free rotation with any lateral movements of the chest-wall, and, in experiments upon the ends of the ribs, this motion is so small that it produces no perceptible effect upon the movements in the upward and forward directions, and any error that it introduces may safely be neglected.

The stethograph which was at first employed consisted simply of a lever suspended at its central point, by a joint which permitted of free movement up and down but in no other direction, and which firmly fixed the lever to a sliding plate, working backwards and forwards in a frame, and this frame, along with a writing plate in the same plane, in its turn, rested upon the swivel joint that was intended to exclude the interference of the lateral motion. The accompanying sketch shows the character of the instrument (Fig. 28). With this apparatus, when one end of the lever was placed upon the chest, its opposite extremity could be made to write upon the paper or glass placed in the writing frame, and all the movements of the chest end of the lever, with the exception of that directly outward, could thus be recorded.

There is, however, in this instrument a certain source of error in its delineation of the forward movement, which it was desirable to eliminate owing to the angular movement of the rod; the forward push in the highest and lowest positions of the button of the lever is represented as somewhat smaller than it really is. Practically the error was not great, but the indications of the instrument could not be regarded as exact.

I am indebted to Mr. Gibbon, late assistant in the physiological laboratory at Owens College, for pointing out a mode in which the apparatus could be improved, and entirely freed from all suspicion of error of this kind. By replacing the lever of the instrument by a series of jointed rods, such as are employed in the pentagraph, the backward and forward motions of the pen are not produced by the sliding

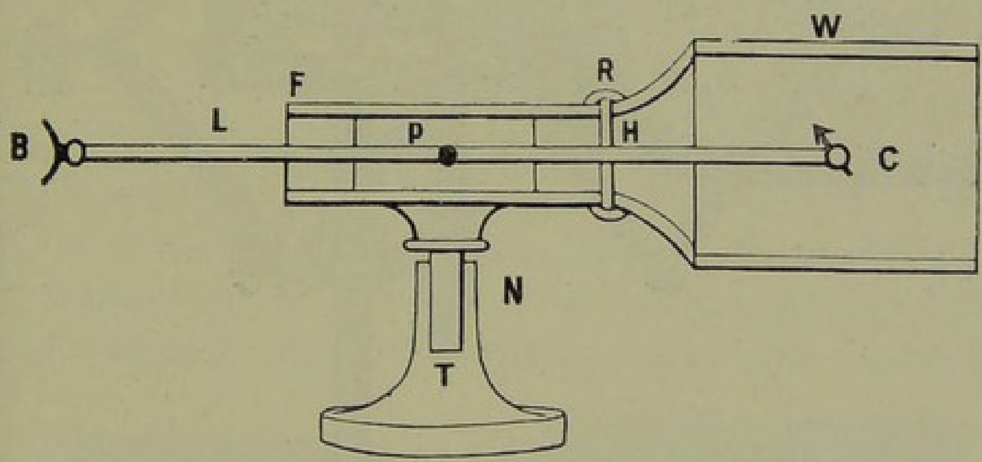


FIG. 28.

of the lever, but by the shortening or elongation of the parallelograms inclosed by the rods.

Figure 29 shows the instrument with this modification. [1]

A small glass pen is fixed to the end of this jointed system of levers at C, and when in use a writing frame (W) is attached to the instrument by a hinge (H) and a spring (R) to keep it pressed against the pen.

The whole mechanism rotates upon a pivot (N) in the stand (T) so as to set it free from disturbance caused by any outward movement of the rib.

A little consideration will show that by these arrange-

[1] The letters having been omitted from Fig. 29, those in the text refer to the parts of that figure corresponding to Fig. 28.

ments an exact imitation of the horizontal and vertical movements of the button end of the instrument will be traced, only in reverse, upon the paper placed in the writing frame.

In using this apparatus it is fixed to the table by a clamp, or by a sufficiently heavy weight attached to its foot, and the back of the subject to be examined is firmly

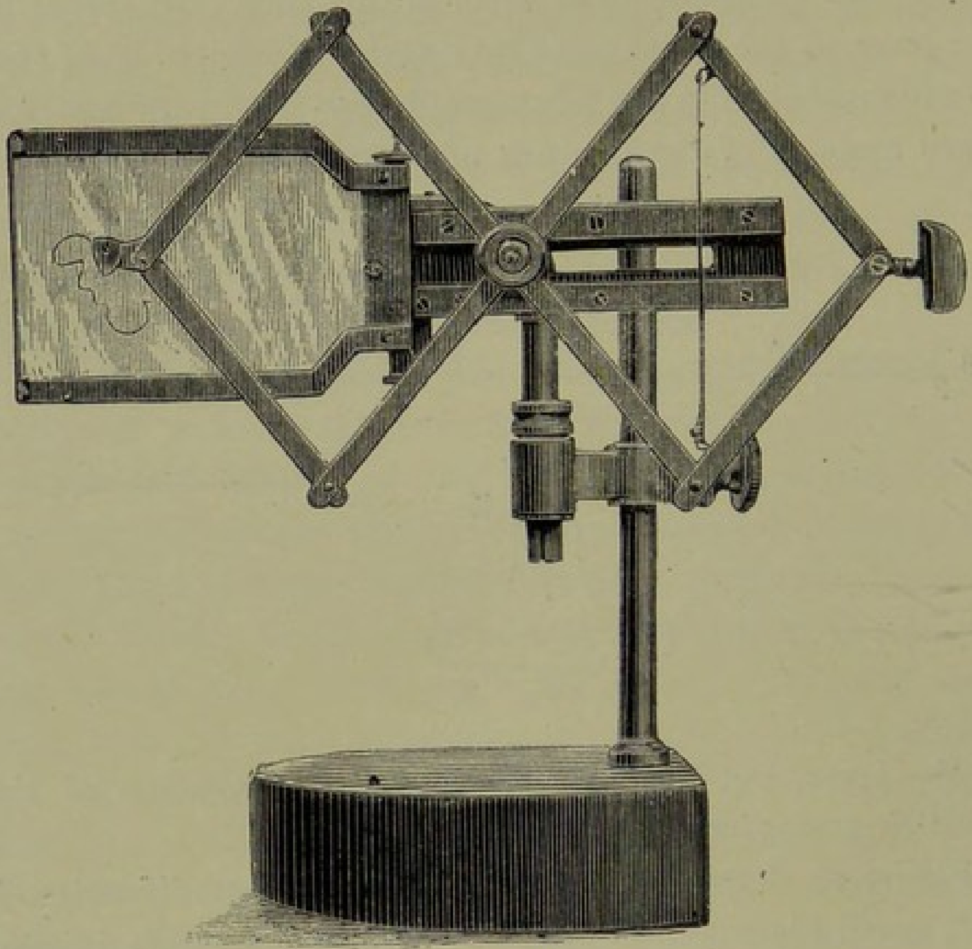


FIG. 29.

supported by a pad, placed opposite the costo vertebral articulation of the rib whose movements are to be traced.

It will be observed that the medium for receiving the writing is fixed, so far as its relation to the pen is concerned, that it is not a rotating cylinder as in Dr. Sanderson's stetho cardiograph, nor a travelling carrier as in Dr. Marey's sphygmograph. These devices are needed when a record of the relative force and frequency of the motions is required; but, on the other hand, the introduction of this extraneous movement prevents the accurate delineation of the actual track pursued, in the forward and upward directions, by any point on the chest-wall.

By means of the instrument[1] now described this tracing may be obtained without difficulty.

The following curves are selected in illustration of the results which have been obtained with the stethograph. To afford a simple basis for comparison they are in the first instance limited to the movements of the ends of the third pair of ribs.

MOVEMENTS IN HEALTH.

In observations made with the three-plane stethometer it had been remarked (see page 95), that the forward motion of the rib is the most equable throughout the whole act of respiration, and that, in men, the upward movement takes places chiefly at the latter portion of the respiratory

FIG. 30.—Movements of the left third rib in a healthy male, æt. 37.

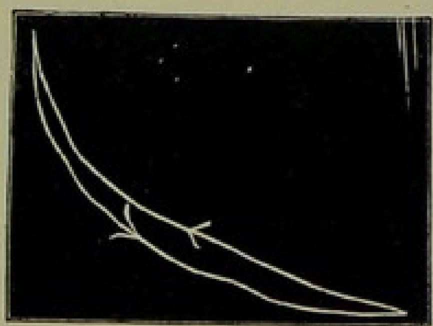


FIG. 31.—Same case, right third rib.

act, but that in women and children, this movement keeps pace with the forward push. Figs. 30 and 31, from a healthy adult male, Figs. 32 and 33, from a woman, and Figs. 46 and 47 from a youth, entirely bear out this remark. In the tracing No. 31, taken from the right third rib of an adult male, it will be found that the ordinates of the curve in the

[1] This stethograph and the three-plane stethometer are now made by Mr. Hawksley, of 300, Oxford Street.

first half of the course are 0.9 in. forward to 0.3 in. of upward motion, and in the latter half they are 0.4 in. forward to 0.75 in. upward. In the female and the youth the curves are much more equable in the two directions of motion.

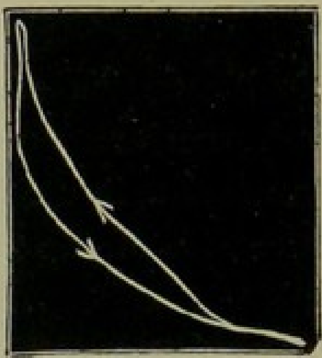


FIG. 32.

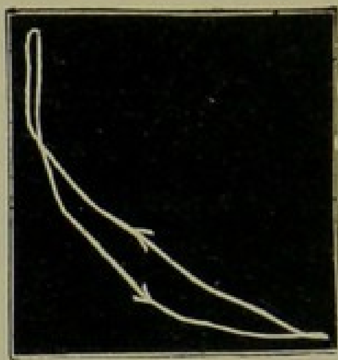


FIG. 33.

Movements of the third rib in a healthy female, æt. 29.

It may also be noticed in these healthy curves that the lines of the tracing inclose an irregular but yet a perceptible space; in other words, that the anterior end of the rib takes a different course in its ascent from that of its expiratory descent.

In some cases the uppermost line is that of inspiration, and when it reaches its highest point it descends somewhat more abruptly than it rose, being afterwards drawn inwards more horizontally. In other instances, however, this track is reversed, and the descent of the rib is more gradual than its ascent (see Figs. 34, 35); and in some, the two tracks will interlace with one another, once or twice, or they may occasionally, but very rarely in healthy breathing, follow the same line.

These variations are doubtless produced by the varying degree to which the will interferes with the action; the expiratory act in many persons is at first automatic and mainly due to the elasticity of the parts, but when the forced effort of expiration is made, the voluntary muscles of respiration are called upon to act at various periods of the effort, and are used to a greater or less extent according to the will of the subject.

In curves 34 and 35, in which the undermost curve is that of inspiration, it may be supposed that in commencing to in-

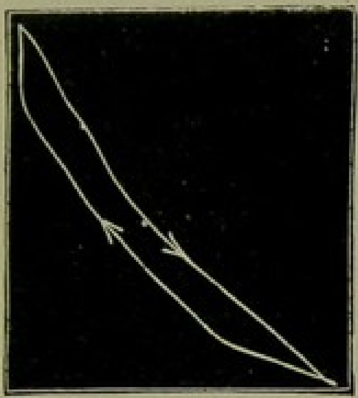


FIG. 34.

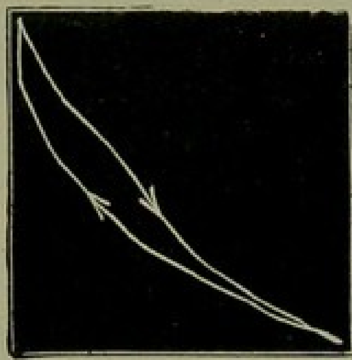


FIG. 35.

Movements of the third ribs in a healthy male, æt. 40.

spire the inbending of the rib is first released, and then its upward stroke takes place. In the subsequent descent of the rib, the expiratory muscles draw it backwards again more gradually, and in many cases the slight resistance of the air

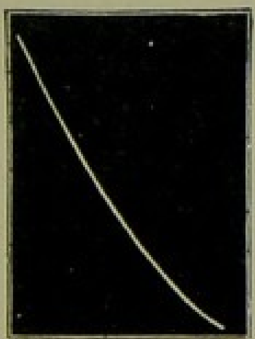


FIG. 36.

FIG. 37.

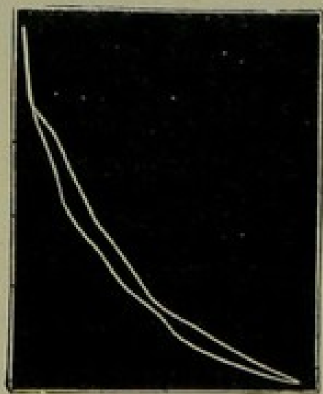


FIG. 38.

Hypothetical respiratory movements of the ribs.

as it rushes through the air-tubes may prevent the rapid collapse of the ribs.

That this view is probably correct is shown by the fact that, when a sudden expiratory effort is made, the rib in its descent is nearly always bulged forwards at first, and thus forms the foremost line of the tracing.

The actual shape of this respiratory curve is very different from what it would be on the usually received hypothesis, that the ribs are simply rigid bars moving upon the support of their costo-vertebral joints. It is not difficult to construct the curve which ought to be described by the end of the rib on this hypothesis. The average chord-length of the third rib is known, and the expiratory and inspiratory angles made by the plane of the ribs with the vertical can easily be ascertained. Fig. 36 gives the curve produced with a radius of 6 in. and an initial angle of 60°, conditions resembling those of the chest from which Figs. 30 and 31 were taken.

Again, another more direct means of ascertaining the curve formed by the end of the rib in its rise and fall may be taken, and Fig. 37 represents the actual motion of the fifth rib in a dead male subject, in whom the fourth and fifth intercostal spaces had been divided and the costo-sternal attachments released so as to permit of free movement at its vertebral articulations. The rib was then simply raised and depressed whilst the button of the stethograph rested upon it. In Fig. 38 some inward pressure was made upon it during its descent and gradually removed during its ascent.

Now the curve constructed by the simple rise and fall of the rib considered as a rigid body must necessarily possess the following attributes :—

1. It must approximate to a segment of a circle.

2. It will be the same in its ascent and descent.

3. Its shape for the same rib will always be nearly the same.

4. Its curvature will depend (*a*) upon the angle formed by the plane of the rib circuit with the vertical, and (*b*) upon the length of the radius, the chord-length of the rib employed.

It is hardly needful to point out that the first and second of these characteristics are not found in the actual curves described by healthy ribs, and in order to test the third and fourth, an attempt was made to ascertain what influence could be exerted upon the movements by the constraining power of the will. In Fig. 39 the result is given in one case, of an effort to raise the rib with but little forward motion; and secondly, to push its end forward without raising it.

Although the tracing is irregular from the constraints put upon the ordinary motion, it is evident that in the uppermost curve we have a closer approximation to the simple radial movement, and in the lower one the effort has succeeded in producing 1·20 in. of forward push with only 0·6 in. of rise.

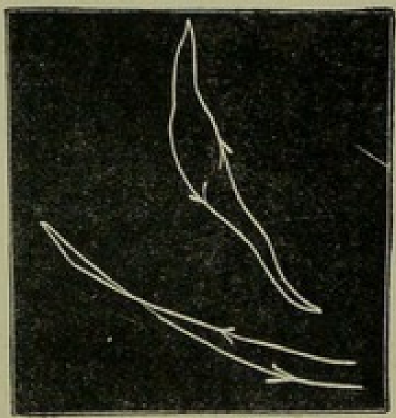


FIG. 39.—Constrained movements of the third ribs.

These peculiarities of the motions of the rib in health, can only be accounted for by an alteration in the chord-length of the rib, due to the action of some constrictor power possessed by certain of the respiratory muscles.

TRACINGS OF REGIONAL MOVEMENTS.

In order to show the variations in the movements of different parts of the thorax, the following tracings were taken from a man æt. 40, of fairly average build and strength:—

FIG. 40.—Movements of the clavicles in a healthy male, æt. 39.

THE CLAVICLES.

The clavicles at their centres describe very regular curves both in their ascent and descent (Fig. 40). The course taken in expiration being in reverse very similar to that of inspiration. The degree of forward motion is a little greater than could be due simply to their ascent and descent, owing doubtless to the advance of the upper end of the sternum, and as might be expected, variations in the degree of movement of the sternum occasionally introduce irregularities into the motion of the clavicles.

THE STERNUM.

The curves described by the sternum in its three regions, as might be anticipated from what we have seen of the varying action of the third ribs, varies somewhat in inspiration and expiration.

In the instance before us (Fig. 41.) it may be noted that there is a slight but steady increase in the obliquity

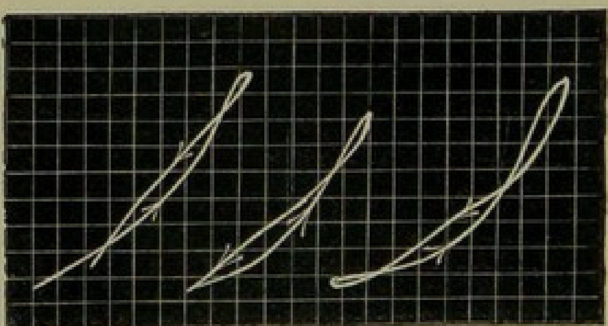


FIG. 41.—Movements of the sternum in a healthy male, æt. 39.

of the curve, showing that in inspiration the lower end of the bone is tilted forward more than the upper. This is probably the usual course, but by no means universal, as may be seen without tracings, by reference to the figures given in columns 2, 3 and 4, of Table I., p. 52.

THE RIBS.

That the increase in the forward motion of the lower part of the sternum is not to be explained by the usual theory of the longer radius of the lower ribs is sufficiently proved by its variation just referred to, but the remarkable course taken by the ends of the lower ribs shows still more clearly the true nature of the action.

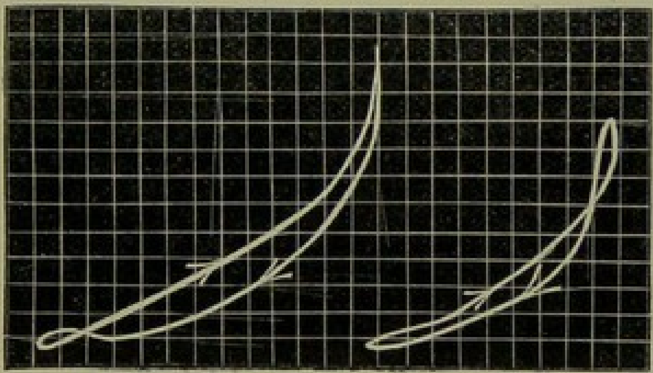


FIG. 42.—Healthy adult male, movements of the third ribs.

There is apparent in these rib tracings a steady increase in the degree of forward motion from the second to the eighth, but the extent of upward rise does not increase after

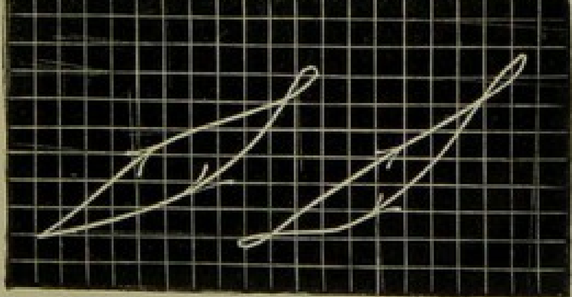


FIG. 43.—Same case, fifth ribs.

the fifth ribs, and both the seventh and eighth ribs display a very large forward push with a very small degree of rise.

The spaces inclosed by the inspiratory and expiratory curves seem, in this instance, to have on the whole increased

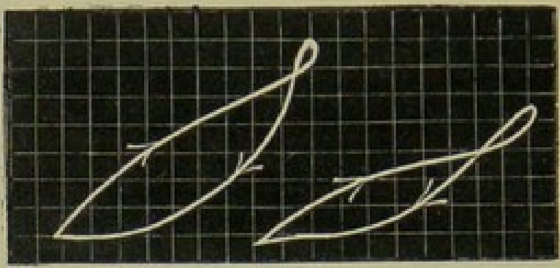


FIG. 44.—Same case, seventh ribs.

as we descend, and show the extent to which the expiratory muscles were able to exert their power upon the lower ribs. We may, I think, reasonably suppose that a large part of

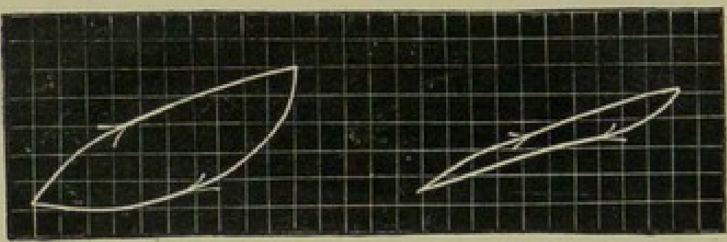


FIG. 45.—Same case, eighth ribs.

the indrawing of the seventh and eighth ribs was due to the action of the diaphragm.

Figs. 46, 47, 48, and 49 mark the differences in the healthy tracing produced in youth and in advancing years.

In the youth, from whom the tracings given in Figs. 46 and 47 are taken, considerable elasticity is apparent, and the curves also demonstrate the great freedom of movement possessed by the thoracic walls in childhood.

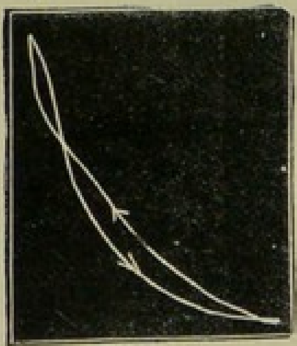


FIG. 46.

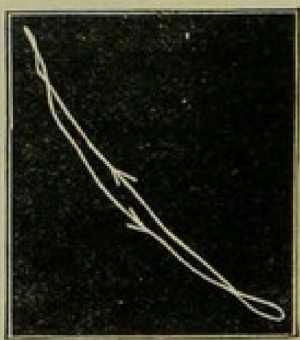


FIG. 47.

Movements of the third ribs in childhood.

In age there is an approach to the form of curve traced by the unyielding rib (Fig. 36), and the upward and downward track are nearly alike—showing the loss of elasticity with advancing years. This fact is well shown in Figs. 48 and 49 taken from the third ribs in a man æt. 60.

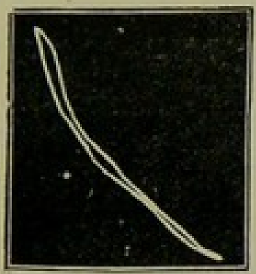


FIG. 48.

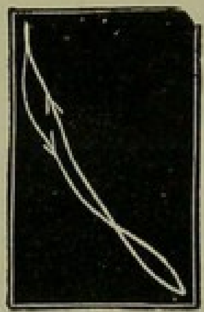


FIG. 49.

Movements of the third ribs in old age.

THE MECHANISM OF COUGHING.

In systematic experiments upon the spasmodic and partly involuntary action of coughing, an attempt was made in the first instance to discover what effect was produced upon the rib by the simple closure of the nose and mouth, followed by a strong expiratory effort, no air being allowed to escape from the lungs; the result was found to be, in some instances, simply a backward and forward motion of the pencil—somewhat irregular from the efforts put forth in the trial—and in others there was at the same time a slight raising of the lever, showing that the rib was pushed upwards by the underlying lung.

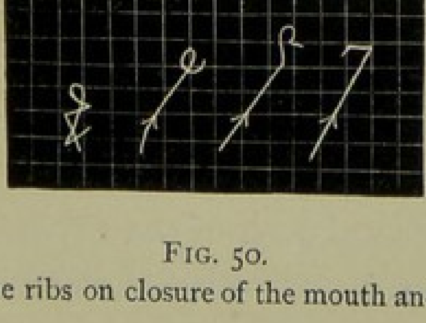


FIG. 50.
Forced movement of the ribs on closure of the mouth and nose after inspiration.

In another set of experiments, after an inspiration and sudden closure of the nose and mouth, the air was allowed to escape rapidly, as in the action of nose-blowing, and the results were as shown below (Fig. 51); curves *a, b,* and *c,* being the course taken by the third rib whilst the nose was blown once, and curve *d* when it was blown twice, during one expiratory effort.

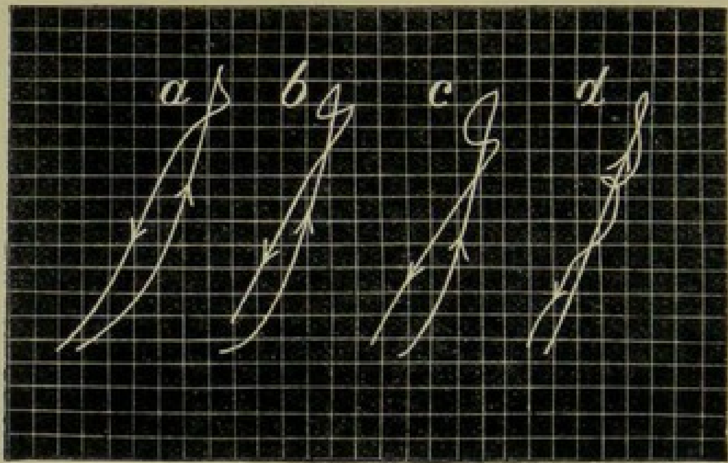


FIG. 51.—Action of the ribs in blowing the nose.

A series of short voluntary coughs was then made, with a general result such as may be exemplified by the four tracings here given (Fig. 52).

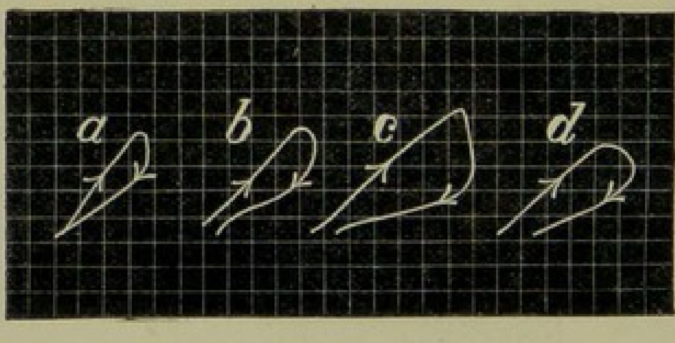


FIG. 52.—Single acts of coughing.

In all these instances it is remarkable that, after the first steady rise and forward push of the rib in inspiration, when expiration takes place, instead of following the same track back again, there is in every case along with the fall of the rib a distinct forward bulging, and in two instances, *c* and *d* (which are only examples of several others), this takes place to a considerable extent before the rib is allowed to draw back to its original position.

There are, in truth, two distinct modes of coughing—the first, in which closure of the glottis takes place immediately after inspiration; the second, in which the effort of violent expiration is commenced, and the glottis is not closed until the rib has made some progress in its descent. A stoppage in the exit of the air then occurs, the rib is first bulged forward, and then, on the opening of the glottis, is drawn inwards with a violent expulsive effort (Figs. 53 and 54 *a*).

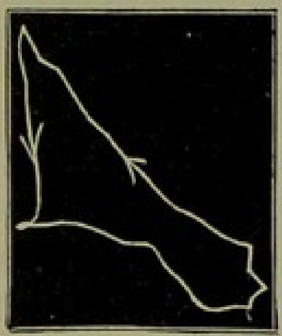


FIG. 53.—A single cough tracing.

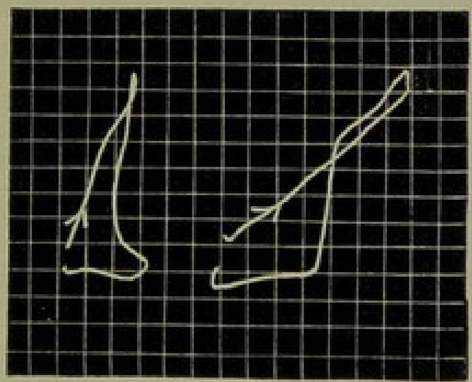


FIG. 54.—Varieties of cough.

In some cases it also seems probable that there is no complete closure of the glottis—but the air is driven forcibly through its narrowed aperture. (Fig. 54 *b*.)

These remarks will explain most of the variations that occur in the form of the single cough tracing, and also the more complicated curves produced by several acts of coughing taking place during one expiratory effort.

The following tracings of voluntary fits of coughing, with the exception of the first two, were taken in the physiological laboratory of Owens College, under Prof. Gamgee's superintendence.

They present a strong family resemblance—in most there is a slight forward bulging of the rib at the end of the inspiratory act, amounting in Figs. 55 and 56 to about 0·05 in.

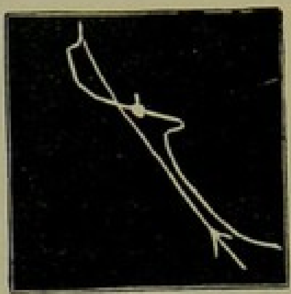


FIG. 55.—A double cough.

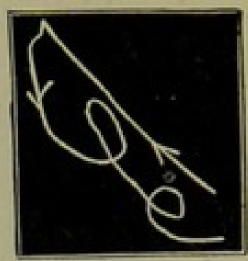
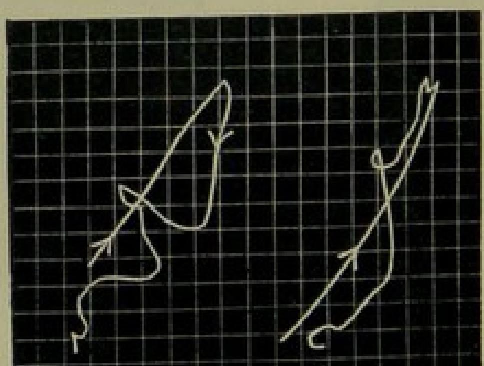


FIG. 56.—Three acts of coughing.

This appearance must probably be attributed to the expulsive efforts of the respiratory muscles, compressing the air in the chest and so forcing the ribs outwards. Immediately that the air is released, however, from the windpipe, there is at once a downward fall of the rib, for a space of from 0·2 to 0·5 in., with a barely perceptible incline inwards; then comes a sudden change in its course, and it is drawn inwards almost horizontally, until it is caught by the second sudden stoppage of the glottis. At the



a. *b.*

FIG. 57.—Varieties of cough.

commencement of a second act of coughing the motion of the rib is either arrested for the moment, as in Fig. 57, (*a*) or it is pushed forwards and even upwards by the compressed air in the chest (Fig. 58); and then when it is again

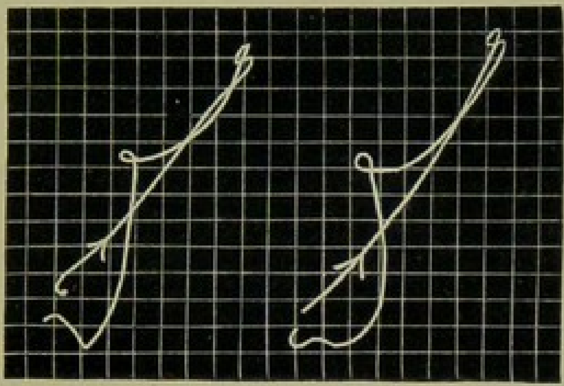


FIG. 58.—Varieties of cough.

released there is usually a still further bulging forward, together with a downward drop, and finally there is the almost horizontal indrawing of the rib.

It is interesting to note that the extent of the forward bulging is greater the lower the rib gets in its descent—as if the rib yielded to the pressure within the chest more easily in the position of partial expiration than in that of full inspiration. This is seen in Figs. 56, 57, and 58.

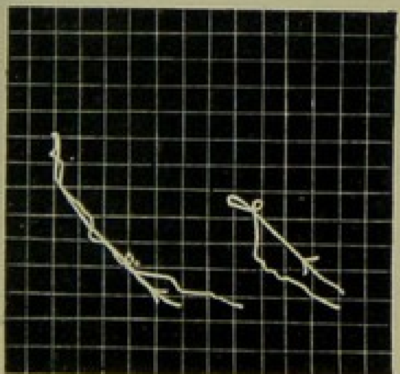


FIG. 59.—Spasmodic cough from laryngeal irritation.

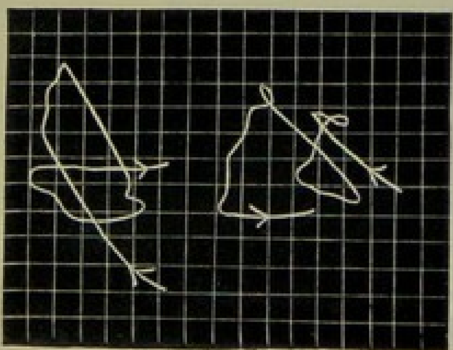


FIG. 60.—Cough in a case of chronic phthisis.

In Figs. 59 and 60 are given a few instances of still more complicated tracings of purely involuntary coughing: when they are unravelled they will be found to conform to what has been said above.

The other involuntary actions of sneezing, yawning, and laughing have also been included in the inquiry.

Sneezing.—In the act of sneezing, produced by snuff-taking, shown in Fig. 61, the course taken by the rib is remarkably like its track in coughing: there is first the almost rectilinear track of quick inspiration, and afterwards the downward drop of the rib, followed immediately by a very strong indrawing of its end. The differences observable are the absence of any stoppage at the commencement of expiration, and the much more complete indrawing in the second half of the expiratory act. The first position is strikingly similar in its course to the hypothetical curve, its ordinates being about 0·5 in. of downward drop, to 0·15 in. of indrawing; the ordinates of the curve shown in Fig. 34 are 0·8 in. downwards and 0·2 in. inwards.

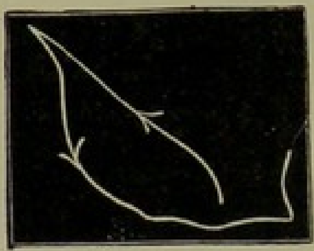


FIG. 61.—"A sneeze."

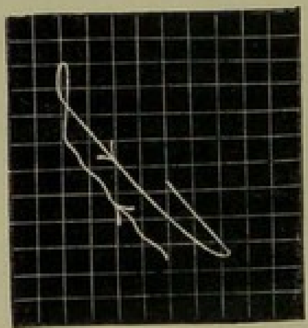


FIG. 62.—"A yawn."

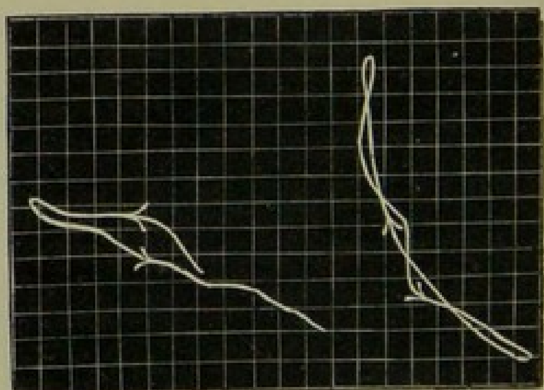


FIG. 63.—Tracing from the third rib during laughter.

Yawning.—In the tracing of yawning the irregularity of the upstroke well shows the wavering, half-gasping nature of the inspiration; and we may imagine that the steady, straight line of the expiratory line shows the satisfaction of the subject at the attainment of a perfect yawn.

Laughing.—It need hardly be said that the tracings of laughter (Fig. 63) are irregular: the intrusion of laughing into experimental research is itself an irregularity, but the result shows the truth of the poet's description of "Laughter shaking both its sides."

THE STETHOGRAPH IN DISEASE.

A few further tracings (Figs. 64 to 74) are given to show the effect of disease upon the form of the respiratory curves. Figs. 64 and 65 are from a female, æt. 21, suffering

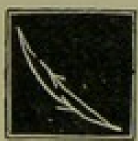


FIG. 64.

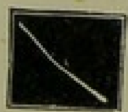


FIG. 65.

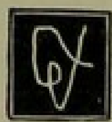


FIG. 66.

Movements of the third rib, in chronic phthisis (female).

from chronic phthisis of nine years' duration. Softening on both sides—a large contracting vomica on the left side.

Fig. 64 is from the third right rib. Fig. 65 from the corresponding point on the left side. Fig. 66 represents a cough-tracing taken from this patient.

FIG 67.

FIG. 68.

Movements in a male case of acute phthisis.

Figs. 67 and 68 are from the third rib in a male, æt. 26, also a case of phthisis, but of an acute character, with softening tubercle on both sides; the tracings being taken during an intermission in the disease.

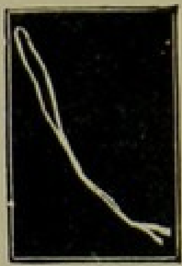
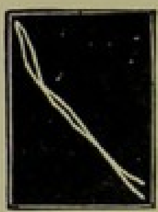


FIG. 69. FIG. 70.

Movements of the third ribs in chronic phthisis (male).

Fig. 69 is from the right, and Fig. 70 from the left side in a case of chronic phthisis, æt. 35, duration four years, in whom the left side was extensively consolidated, the right comparatively free.



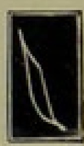


FIG. 71. FIG. 72. FIG. 73. FIG. 74.

Chest movements in pleurisy.

The four tracings (Figs. 71 to 74) are taken from a woman æt. 26, who had acute pleurisy with effusion nine months before, and in whom there was considerable contraction of the left side in consequence. The first two are from the third rib, the last two from the fifth. Figs. 72 and 74 are from the diseased side.

In all these cases the comparative feebleness of the respiratory act is to be noticed, and the want of elasticity of the chest is evidenced by the tendency to similarity in the upward and downward track of the end of the rib. In the case of acute phthisis there is also a degree of tremulousness in the original tracing, and the case of pleurisy displays the effect of the subsequent adhesions in the very small extent of the forward push on the affected side. It is interesting to notice that the phthisical cough pourtrayed in Fig. 66 is similar in its form to that of the healthy chest (Fig. 56), although so much smaller and more feeble.

THE THREE-PLANE STETHOGRAPH.

By applying to each of the movements of the three-plane stethometer, drums which will convey impressions to the pens of a revolving cylinder, it is not difficult to convert this instrument into a stethograph which will inscribe, in curves upon paper, each of the three motions of the chest.

This arrangement truly will not give us exact tracings of the course taken by the rib, such as are given by the stethograph just described, but the curves which are obtained by this method are interesting as showing the rhythm of each of the movements, the order in which they take place, and their relations to one another.

The following curves represent the ratio of duration and extent of the movements of the fifth right rib under the axilla in a male æt. 41 years.

The upper curve gives the upward, the middle the outward, and the lower the forward movement. The points at which the three pens were moving simultaneously, are marked by short vertical strokes in each wave. The arrows show the direction of the movement. The extent of each dimension, as drawn by the several pens, corresponds as nearly as possible to the actual degree of motions of the rib. Towards the end of the curve a series of three acts of coughing was made.

It is interesting to notice the greater breadth of the forward undulation as compared with the other two, and

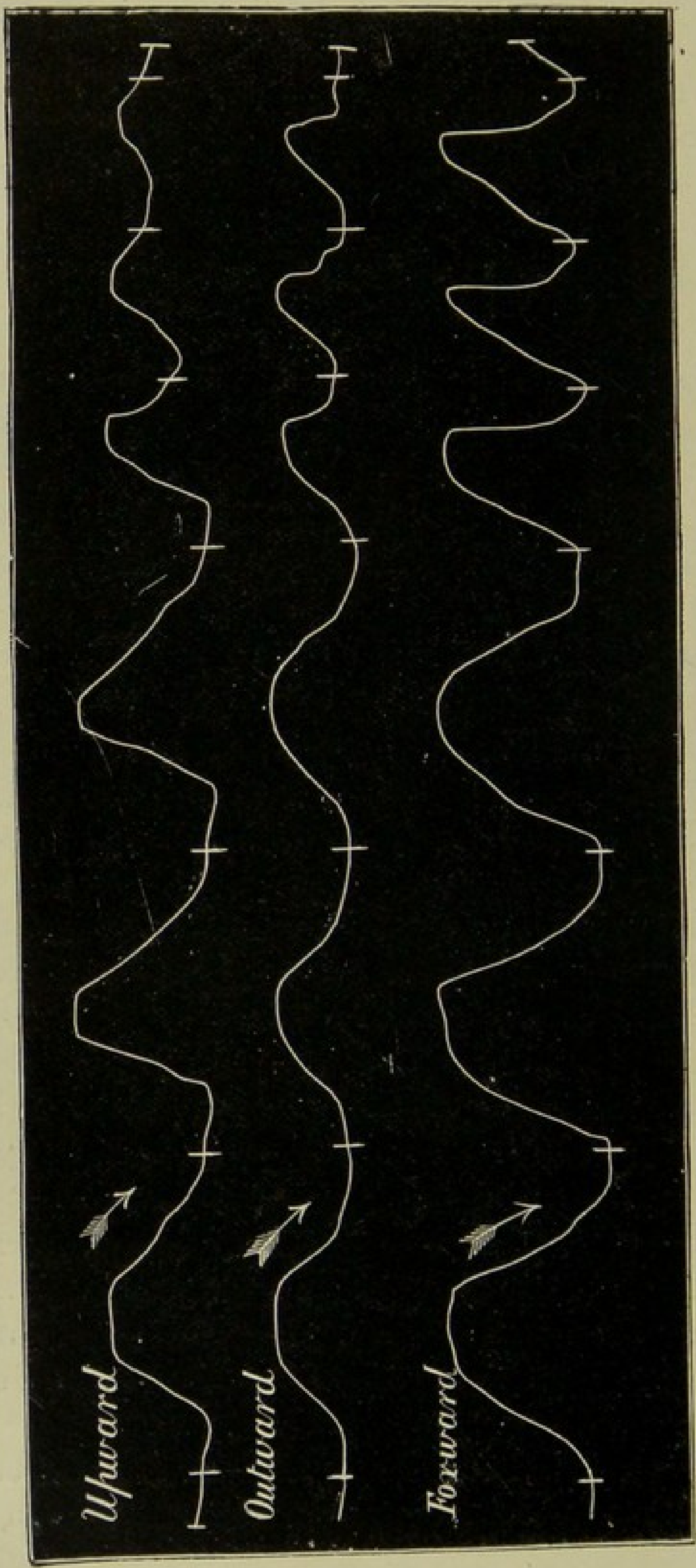


FIG. 75.—"3-plane" tracings from the fifth right rib (under the axilla), in a male, æt. 40.

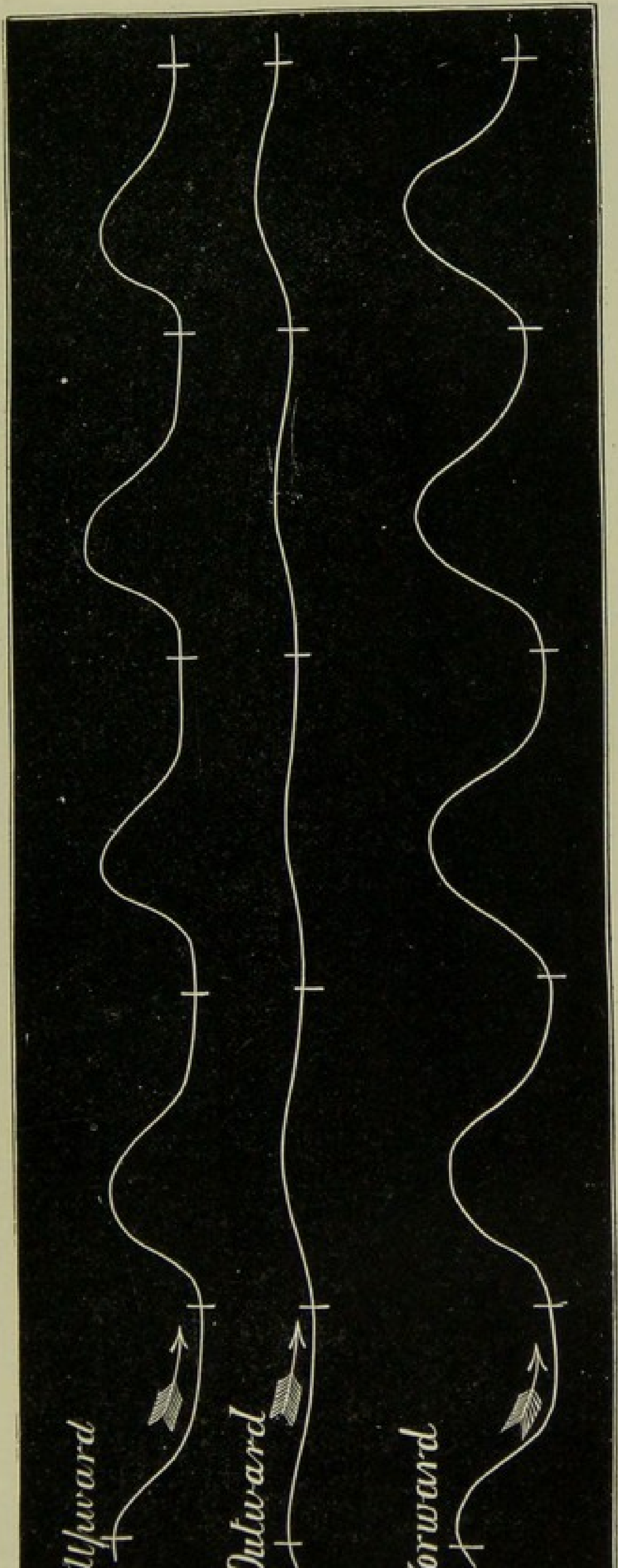


FIG. 76.—"'3-plane' tracings from the fifth right rib (at its articulation to the cartilage), same case.

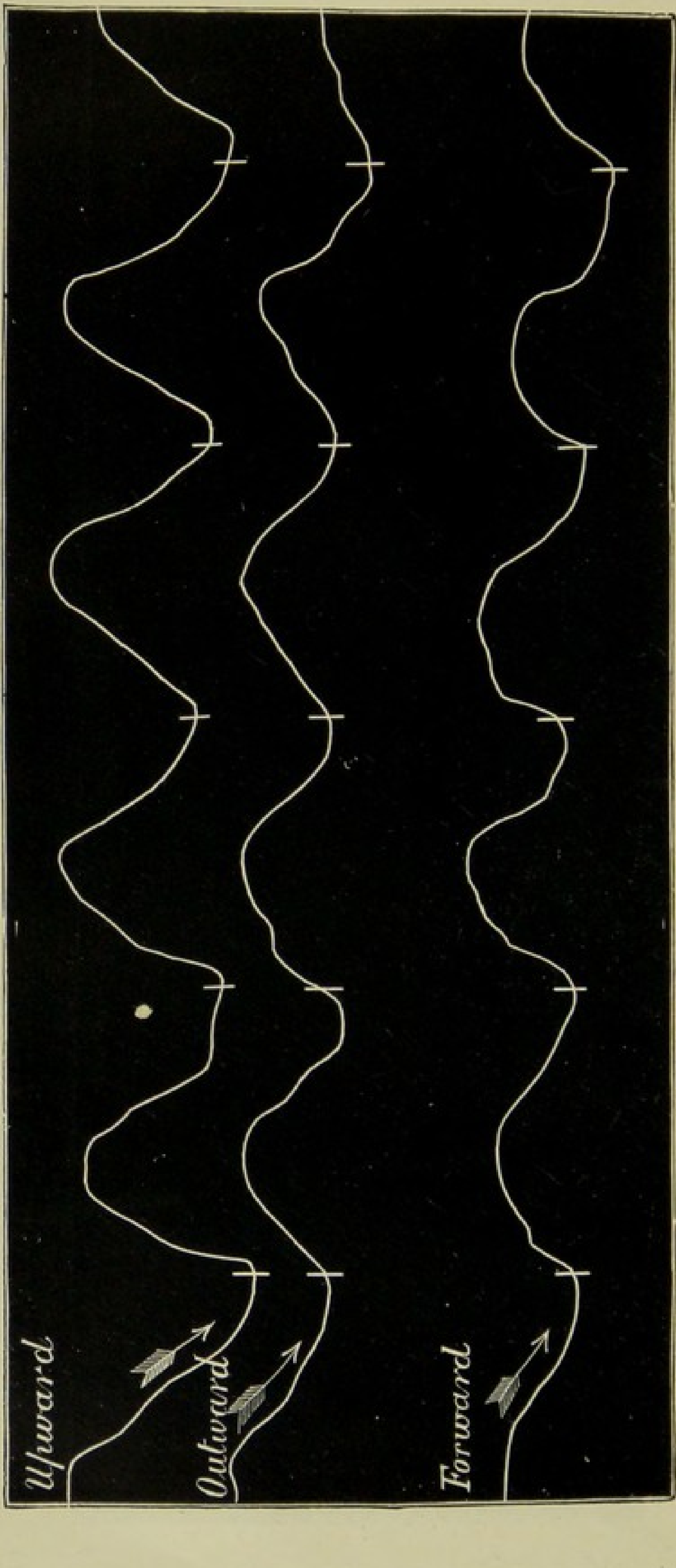


FIG. 77.—"3-plane" tracings from the left fifth rib (in the axilla), in a boy, æt. 12.

Figs. 77 and 78 respectively show the movements of the middle of the fifth rib, in a boy of 12 years, and in a man aged 61 years. In both there is some precedence of motion in the forward direction, but it is less in the old man than in the youth. The steadiness of age is also well contrasted with the irregularity of breathing in the child.

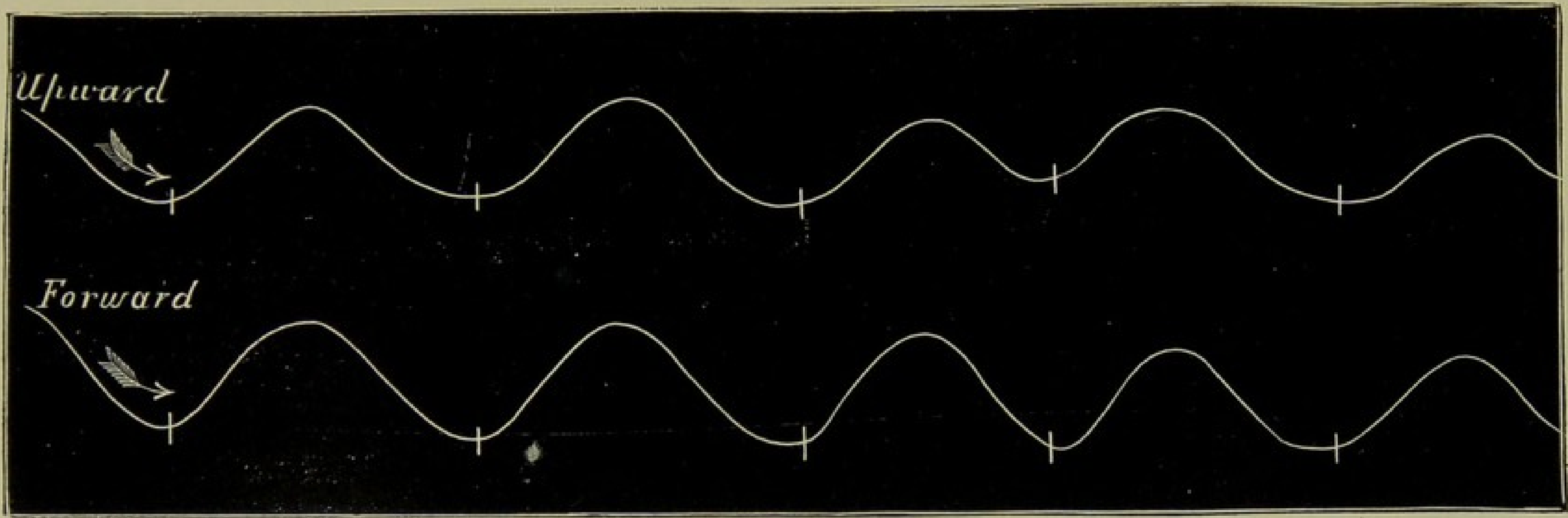


FIG. 78.—"3-plane" tracings from the left fifth rib (in the axilla), in a male, æt. 60.

also the decided precedence in its rise. In some of the undulations it commences to rise at least 0·2 in. before the other two.

This fact distinctly confirms the evidence given by the other two instruments.

In the act of coughing it may be noticed that the extent of motion in every direction is lessened, but that the forward movement is much less diminished than that in the other two directions. This phenomenon is also simply a confirmation of the view which the other stethograph gives of the actual shape of a cough-tracing.

In Figs. 75 and 76 an opportunity is afforded of comparing the movements of the end of the rib with those of its middle part. The small extent of the lateral dimension shows that we were justified in neglecting this movement in the other stethographic observations upon the ends of the ribs.

CHAPTER VI.

ON THE RESPIRATORY MOTIVE POWERS.

"Une espèce d'écueil, contre lequel vinrent se briser les efforts des *anatomistes* de tous les âges."—THÉNARD, *Ann. de Chimie* I. xlvi. 294 (slightly altered).

IT may perhaps be allowed that a sufficiently powerful array of evidence has now been brought to prove the truth of the view taken of the Mechanism of Respiration. The question naturally arises, by what means are the movements and changes of form of the ribs accomplished? And this is by no means easily answered.

That the forces concerned in moving the chest-walls are adequate to produce the effects which have been registered by means of the Stethometer, can hardly be doubted by anyone who has observed the extraordinary power of the respiratory muscles.

Mr. Hutchinson calculates that "in the mere act of *ordinary* breathing there is an elastic resistance, independently of the elastic force of the lungs, equal to more than 100 lbs., and this has to be lifted eighteen or twenty times every minute of our lives;" and in *forced* breathing, he estimates the force expended as from 400 to 560 or even 1,000 lbs.

It is interesting also in relation to the question of the expiratory inbending of the ribs, to note that Mr. Hutchinson found that the force of expiration is ordinarily one-third greater than that of inspiration ; and in one man, a glass-blower, he observed that it was four times as great.

Professor Haughton has more recently calculated the power of various muscles, and his estimates would fully bear out the calculation made by Mr. Hutchinson.

When, however, we come to analyse the forces concerned, it is somewhat difficult to assign to each its part, since it is probable that several of the muscles may respectively act in different ways, according to the fixed points from which they work—and one set of fibres may act in concert with, or in partial antagonism to, another set, and so produce most various results.

The action of the various motive powers must therefore be considered in detail, both when acting singly or together with other forces.

The purely mechanical forces of the elasticity of the lungs, and the resiliency of the thoracic structures, probably simply counterbalance one another in ordinary breathing.

The adjoining tracings (Fig. 79) given by M. Bert (*Leçons sur la Respiration*, p. 359) show the effects of opening the thorax (1) upon the air in the lungs ; (2) upon the ribs.

In this experiment a tube, placed in the trachea of a recently killed dog, is made to communicate with the drum of a polygraph, and at the same time a similar drum, resting in contact with the animal's thorax, moves another pen upon the cylinder. An incision being then made into the thorax, the elasticity of the lungs forces air through the tube, and produces curve No. 1, whilst the ribs spring outwards and pressing upon the drum produce curve No. 2. The similarity of these simultaneous tracings shows the close relations existing between the two forces. As M. Bert says, " l'équilibre à la fin de l'expiration, s'établit entre l'élasticité des poumons qui tire en dedans le diaphragme et les côtes, et celle du thorax, qui tend à ramener les côtes en dehors" (p. 360).

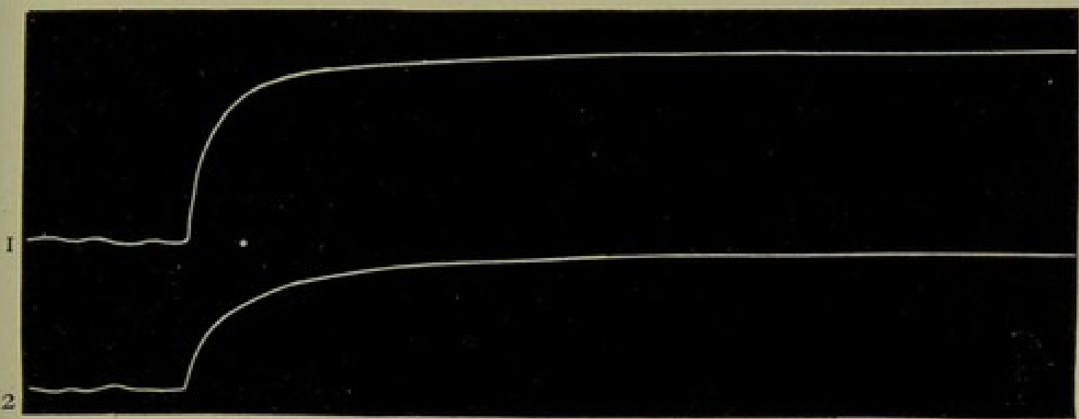


FIG. 79.—Effects produced by opening the thorax (1) upon the air in the lungs, (2) upon the ribs.

But it is obvious that both in forced inspiration and forced expiration the forces will, one or another or both, resist the unusual strain. Thus, in forced expiration, the compressed ribs tend to spring back to their former position and to draw the air into the lungs, and in forced inspiration both the elasticity of the lungs and that of the structures composing the thorax are put upon the stretch, and resist the efforts of the inspiratory muscles.

The action of the various muscular forces on the thorax is much more difficult to discern—so as to mark their influence, either separately or in combination. I believe, however, that with the exception of the levatores costarum, it will be found that all the *intrinsic* muscles of the thorax have some further power than that of merely raising or depressing the ribs.

First, the triangularis sterni muscle is probably more truly a constrictor of the chest, than an agent for depressing the ribs, or for altering the angles of the costal cartilages. The triangularis sterni and the transversales "combine to form one vast constrictor of the chest and abdomen." They may be described as "one muscle arising from the lower two-thirds of the sternum, the xyphoid cartilage and the linea alba—and inserted into all the ribs, except the first, close to their cartilaginous attachments." "The fibres of this vast web combine to narrow the space between all the opposite ribs,—they cause the costal cartilages connected with the sternum to bend on the ribs and on themselves, they constrict at once the space between the thoracic, intermediate, and diaphragmatic sides of the ribs, and indeed the whole chest and abdomen."[1]

This action would account for a good deal of the horizontal movement of the sternum and costal cartilages, and through them might perhaps affect the anterior ends of the ribs—but the ribs probably have their own agents for effecting their flexure.

Second, the intercostales externi and interni and the intercartilaginei.

Perhaps no muscles of the body have caused so much controversy as to their mode of action as the external and internal intercostal fibres.

Dr. Sibson considers that the external intercostals play a very complicated part in the inspiratory process, and that whilst the first seven of these muscles are inspiratory, the eighth and perhaps the ninth are neutral anteriorly, and inspiratory posteriorly. "The lowest three are inspiratory posteriorly, expiratory in the middle, when they act on the anterior portion of the ribs, and inspiratory when they pass from cartilage to cartilage."

Traube's experiments, on the other hand, whilst they are decisive as regards the inspiratory action of this group of muscles, seem to show, in opposition to the above view,

[1] Sibson, "On the Mechanism of Respiration."—*Phil. Trans.* vol. cxxxvi. p. 537.

that they have the same function both in the upper and the lower intercostal spaces.

So far as the upper six or sternal ribs, with which we have chiefly dealt, are concerned, it will be seen, however, that these eminent observers are agreed.

The internal intercostals must on the same authorities be regarded as depressors of the ribs, and the intercartilaginei muscles as mainlyactive in raising the costal cartilages.[1]

It is right to record that the functions thus ascribed to these muscles in the upper part of the thorax as a result of experiment and vivisection, are precisely those that are deduced by Mr. Hutchinson from the working of his well-known model, showing the action of oblique elastic fibres upon movable parallel bars.

But these views are by no means shared by all anatomists. Thus some investigators (of whom the most recent is Professor Humphry), following Haller, regard both the external and internal muscles as entirely inspiratory, drawing upwards the ribs towards the first rib, which they assert is nearly fixed during forced breathing; and others again, amongst whom we find Mr. Le Gros Clark, believe that both groups of fibres are inspiratory when the upper ribs are fixed, and that they are both expiratory and draw the ribs down when the abdominal muscles are in action.

Haller's argument from the fixity of the first rib is indeed of little value, since the question as to the forces drawing down the ribs, when they have once been pulled up to their highest point, is left quite unanswered.

Dr. Humphry also has argued that, owing to the obliquity of the planes of the intercostal spaces, the depressing power of the internal intercostal muscle must be so far reduced as to be almost imperceptible, but it will be found upon inquiry that the same effect is produced upon

[1] Gesammelte Beiträge, vol. i. p. 163.

both external and internal fibres, their power lessening somewhat, owing to their slanting position. For it may be permitted to resolve the forces exerted by an intercostal fibre, and to represent its influence in a vertical direction, either upwards or downwards, by a straight line, such as A B. In order then to compare the relative power of this fibre, when acting in an intercostal space (1) in a vertical plane, and (2) in a plane inclined at a certain angle, let the direction of the force, A B, be supposed to be rotated through the angle C A B. Let the force exerted by the fibre in the direction A B be called m; then it is evident that if we exert this force m in the direction A C, the vertical force in this case will be lessened, and will be equal to

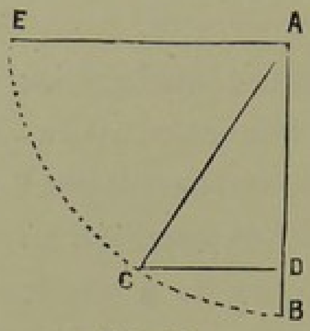


Fig. 80.

$$m \cdot \cos CAB.$$

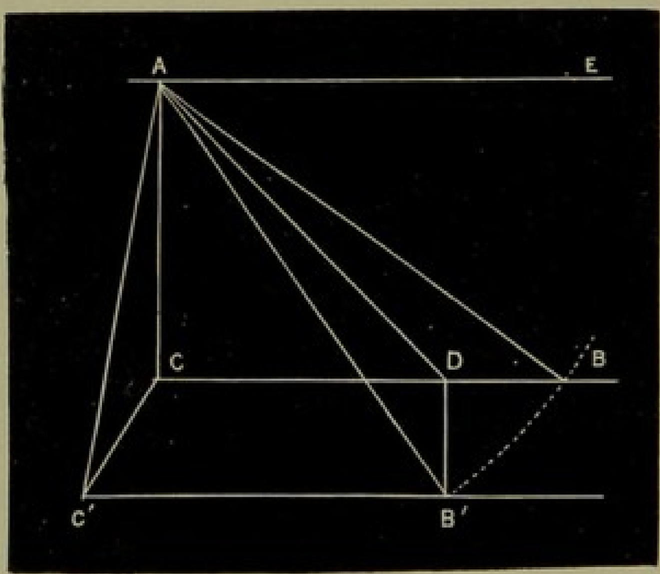


FIG. 81.

If the angle C A B be taken equal to 20° (an extreme supposition for any but the first two intercostal spaces), then the vertical force will be equal to about $m \times .94$. In other words, the vertical force exerted by the muscle will be diminished by about 6 per cent. If, indeed, the end B of the intercostal fibre were supposed to be rotated to B′ in the same horizontal plane, as shown in Fig 81, it might easily be proved that no change whatever in the vertical power of the muscle would take place. In any case, the influence of the slope of the intercostal space is so slight in this respect that it may be safely disregarded.

On the whole, then, there seems but little to invalidate the direct experiments of Hutchinson, Sibson, and Traube as to the independent actions of these muscles, and we may, without much risk of error, believe that if the external intercostals act alone they raise the ribs and separate their ends, being assisted in this action by the true intercartilaginei muscles; and when the internal intercostals alone come into play, they draw the ribs downwards, and press their anterior extremities towards one another.

But on the other hand it will probably be found that, when the muscles are acting in concert, each of the observers we have named may prove to be right, at least to a certain extent. Thus, when the upper ribs are fixed, both sets of fibres acting at once may serve as levator muscles, and again when the upper ribs are released and the lower ones drawn down and fixed by the abdominal muscles, both sets of fibres may draw downwards. But there is another function that may, I think, be fairly assigned to these muscles, namely, the indrawing or constriction of the walls of the thorax.

It is probable that no muscles are so advantageously placed for performing this duty as the intercostal fibres. When the first ribs are fixed by the cervical muscles, and the lower ribs are drawn downwards and even inwards by the abdominal group, then any fibres between the other ribs acting in concert, whatever their direction, will necessarily draw inwards the intervening bony hoops.

The shape of the thorax is such that, if the ribs below the first are capable of being bent, they must be drawn inwards by the contraction of muscles placed between them.

From the first to the seventh, the rib circles descend in widening diameters, and the planes of the intercostal spaces, instead of being vertical, are more or less inclined. The force exercised by the muscles in these spaces may therefore be resolved in a vertical and a horizontal plane, and the amount of power drawing inwards along the latter plane will, *cæteris paribus*, depend upon the obliquity of the intercostal plane, and will be greatest in the upper part of the thorax. The tendency throughout, wherever there is any slope at all, will, however, be inwards.

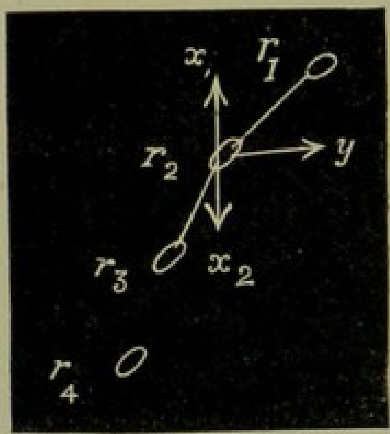


FIG. 82.

Let r_1, r_2, r_3, r_4, (Fig. 82) represent transverse sections of the 1st, 2nd, 3rd, and 4th ribs respectively, then any force acting between two ribs, r_1 and r_2, in the direction of the intercostal space, r_1 r_2 may be represented by the lines drawn in the directions x and y, at right angles to one another, and the lengths of these lines will depend upon the obliquity of r_1 r_2. The dimension of y will thus show the magnitude of the force drawing the rib inwards.

Moreover, the oblique direction of the fibres of the intercostal muscles adapts them still more especially for a constrictor action.

When two elastic bands (A B and C D, Fig. 83) are stretched crosswise between two bars (R P and R′ P′) capable of being bent laterally, *i.e.* from the plane of the paper, but not from above downwards, and which can only be approximated to a limited extent, then, when this approximation has been produced, the tendency of the further action of the bands is to draw together the ends of each bar. In the language of mechanics, the forces they exert may be resolved in the directions R R′ and R P, or R′ P′ and *vice versâ.* If the bars are quite straight, no moving effect will follow, since the bar cannot then yield to the forces acting along R P or R′ P′, but they will be in a position of unstable equilibrium, such that the slightest curvature in the bars will at once permit

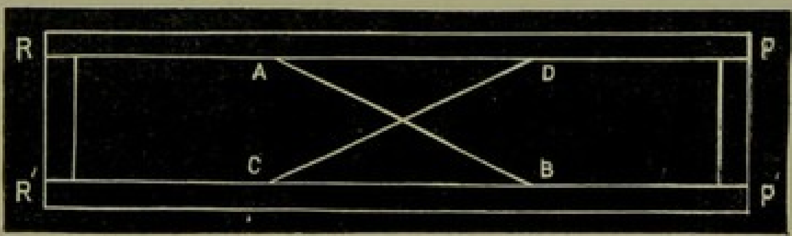


FIG. 83.

the bands to contract, and a further bending will take place in the direction of the curvature so introduced.

Now, this latter case is precisely that of the ribs when acted upon by both external and internal fibres at one time, and since the rib-levers are free to move at their anterior extremities, and are more pliable and thinner at these points, it follows that the chief bending action will take place in the anterior wall of the chest, and a general in-drawing of this part of the thorax will be the result. The effect of each fibre, or of each pair of fibres, is necessarily very small, but the aggregate power they can exert is probably quite sufficient for the purpose.

It is interesting to notice that in other parts of the body, wherever constriction of a cavity is required, there we find an oblique arrangement of muscular fibres generally in two layers running in opposite directions. In the abdomen, the external and internal oblique muscles; in the pharynx, the middle constrictor spreading fan-like, with its outer fibres directed across those of the upper and lower muscles. In the bladder and stomach the same arrangement is to be observed, and even in the heart, although the muscles are spiral in their arrangement, their fibres are so placed that they run in a similarly opposed fashion.

Viewed in this light, the intercostals may perhaps be regarded as two large muscles, having, like the rectus abdominis, ligamentous or bony portions placed at intervals in their course, modifying and in some ways increasing their power, but not altogether preventing them from exerting a combined influence, and so constricting the cavity of chest.

This account of the *united* action of the intercostal muscles, working in concert with the external muscles of expiration, does not clash with the doctrines just noticed respecting the inspiratory functions of the external intercostal and inter-cartilaginous muscles acting independently, or together with the cervical and levator muscles of the ribs.

Again, the rib-depressing power of the internal intercostal muscles acting alone would still be possible, and they might also combine with the abdominal muscles to draw down the ribs after they had been raised by the levatores costarum and the other inspiratory muscles.[1]

[1] On these points I would refer to Mr. Le Gros Clark's *Remarks on the Mechanical Respiration*, *Proceedings of the Royal Society*, vol. xx.

It would be an interesting question to determine whether the Diaphragm exerts any *expiratory* force by drawing inwards the ribs to which it is attached.

The extraordinary extent of indrawing of the seventh and eighth ribs in forced expiration, and also Traube's and Le Gros Clark's observations, would seem to show that it has this power, and it is conceivable that when the abdominal muscles are drawn inwards and firmly fixed, and the dome of the diaphragm is thus supported, it would be possible for the radiating fibres surrounding the central tendon to contract and thus draw inwards the xiphoid cartilage and the ribs to which they are attached.

p. 122 ; to a paper *On the Action of the Intercostal Muscles*, by Dr. Dwight, jun., in the *Boston Medical and Surgical Journal;* to the first of Professor Humphry's Lectures on *Human Myology*, delivered before the College of Surgeons, and to some remarks of my own *On the Action of the Intercostal Muscles*, in the *Brit. Med. Journal* for October 26, 1872.

CHAPTER VII.

ON STETHOMETRY AS A GUIDE TO DIAGNOSIS AND TREATMENT.

"Ubi Physicus desinit, Medicus incipit."—STAHL.

IN a work devoted exclusively to one mode out of many of investigating disease, there is some danger lest, in pointing out the usefulness of this method, I should seem to neglect others.

It is necessary, therefore, to state plainly that Stethometry is here regarded simply as an adjunct to other means.

In diagnosis it may be expected to give valuable assistance in forming a judgment upon many kinds of chest disorder, and in questions of treatment it may serve to point out certain dangers likely to arise, and may sometimes guide us to the means by which they may best be met ; but this is all we can expect from it.

We will first speak of the use of the stethometer in the diagnosis of disease.

It is in phthisis that we may look for the chief assistance to be given to us by this instrument.

In by far the larger proportion of cases of this disease we may, with much certainty, detect the existence and gauge the extent of the mischief by means of percussion and auscultation; but even in these cases it is often no small satisfaction to have the additional testimony of perceptible differences, capable of being expressed with precision in numbers, in the degree of movement on the two sides of the chest.

Tables XVIII., XIX., XX., and XXI. (pp. 175 to 178), show how constantly the readings of the stethometer point to the diseased side when only one lung is affected; and when both are diseased, the small extent of motion of the chest, besides the differences in its extent, will often of itself cause suspicion of something wrong.

Even when no other physical signs of disease can be discovered, there may be found in some cases sufficient warning in the abnormal weakness of the chest movements.

The following case may be taken as an example :—

C. F., a girl aged nineteen ; a brother had died of phthisis, and there was some other evidence of hereditary predisposition to this disease.

She had been losing flesh for some weeks, and was dyspeptic, but there was no pyrexia, and no trace of thoracic mischief could be discerned by percussion and auscultation, either by myself or by an eminent Manchester physician who saw her with me. The stethometric register in June, 1872, was as under :—

Direction of Movement.	Sternum.		Clavicles.		3rd ribs.	
	Upper.	Mid.	Right.	Left.	Right.	Left.
Forward	30	40	35	45	65	50
Upward	50	60	40	53	70	50
Outward	—	—	—	—	10	7

The small extent of movement in the upper part of the chest, and especially the defective working of the right clavicle, showed me that the case was one of much gravity; and the records enabled me to speak more decidedly to her friends than I could have done judging from the family history alone.

It was somewhat remarkable that shortly after this, in consequence of means taken to improve her nutrition (notably nutritive enemata), she gained flesh and strength, and seemed to be about to falsify the diagnosis given; but about the month of August, 1873, hæmoptysis set in; there was tubercular consolidation, first of the right, and then of the left apex, and she died in May, 1874. The *post-mortem* examination revealed extensive miliary deposits both in the lungs and in the abdominal organs.

Stethometry is also sometimes of service in supplementing the examination of the chest by other methods: it has thus several times directed attention to the presence of incipient disease, which would otherwise have been overlooked.

Thus, in the man from whom the following register was taken:—

Direction of Movement.	Sternum.		Clavicles.		3rd ribs.	
	Upper.	Mid.	Right.	Left.	Right.	Left.
Forward	15	30	25	15	30	80
Upward	50	60	50	30	50	70

I had examined the chest, and had found very extensive and softening disease on the right side; but I had failed to notice that under the left clavicle there was already commencing deposit of tubercular matter. The distinct diminution of movement of this bone at once called my attention to it.

In a case of pleurisy on the left side also, a male, aged twenty-seven, measurements were taken without any suspicion of further disease; but the following register showed a deficiency of movement on the opposite side of the chest under the clavicle and third rib; and a more careful examination with the stethoscope revealed the presence of incipient tubercular deposit on that side. The measurements were taken three months after the onset of the pleuritic attack:—

Direction of Movement.	Sternum.			Clavicles.		3rd ribs.		5th ribs.	
	Upper.	Mid.	Lower.	Right.	Left.	Right.	Left.	Right.	Left.
Forward	60	110	70	55	65	95	105	95	95
Upward	70	65	60	45	70	75	65	70	60
Outward	—	—	—	—	—	—	—	70	50

In not a few instances the effects of a previous attack of disease upon the movable structures of the chest last many years after all other physical signs have passed away.

The stethometer is then sometimes a more sensitive test than any other means of examination. In the following examples there can be little doubt that at some time or other phthisical consolidation had existed in the lungs. Statements to that effect had in every instance been made by men who are justly regarded as masters of physical diagnosis; and yet, when these cases came to be examined by percussion and auscultation, no symptom could be discovered showing the existence of disease. The stethometer alone showed that the lung affection had left a more permanent impression upon the hard than upon the soft structures of the thorax :—

TABLE XII.

Case.	Direction.	Sternum.		Clavicles.		3rd rib.		5th rib.	
		Up.	Mid.	Rt.	Lft.	Rt.	Lft.	Rt.	Lft.
Male, æt. 60. Thirty years before had vomica at apex of right lung	Forward Upward	10 15	30 30	15 30	20 30	35 30	30 30	— —	— —
Female, æt. 30. Two years ago, consol. under left clavicle ...	Forward Upward	25 25	25 20	25 40	22 30	— —	— —	40 55	45 50
Male, æt. 62. Thirty years ago, softening tubercle at apex of left lung	Forward Upward	55 90	90 116	45 110	20 100	75 100	75 120	68 100	75 130

Cases like these show how valuable an instrument the stethometer might become in examinations for life assurance, enabling us to detect the trail of the disease which had once fastened upon the constitution; and, taken along with other circumstances, the knowledge might warn us of future danger.

On the other hand, there are not a few cases which show that it is possible for every trace of disease to disappear ; and it is probable that a more favourable augury might be formed of the health of such subjects.

Two of the following cases had been pronounced distinctly phthisical by the same authorities as had certified to the existence of disease in the above cases; the third was also noted as consumptive by an eminent provincial physician :—

TABLE XIII.

Case.	Direction.	Sternum.		Clavicles.		3rd rib.	
		Up.	Mid.	Rt.	Lft.	Rt.	Lft.
Male, æt. 38. Six years ago, consolidation of left apex ...	Forward	28	50	18	20	90	95
	Upward	55	60	50	50	70	65
Male, æt. 45. Ten years before, pronounced phthisical ...	Forward	—	35	25	25	35	30
	Upward	—	60	60	60	50	60
	Outward	—	—	—	—	10	10
Female, æt. 32. Five years ago, stated to have tubercular consolidation on left side ...	Forward	35	55	20	20	65	68
	Upward	85	90	50	40	90	100
	Outward	—	—	—	—	15	20

Again, in the diagnosis of difficult and doubtful cases, Stethometry is often of great service and its evidence serves to turn the scale of judgment to one side or the other.

The following case is a striking example of this :—

October 1873. *Mrs. B.*—aged 45. Married, five healthy children. No definite history of phthisis in the family. Enjoyed good health, until five months ago, when she had a severe attack of asthma arising, she believes, from cold, which lasted several weeks. (She had never suffered from hay asthma.)

For the last three months she has lost flesh rapidly, and has had increasing shortness of breath. For about six or seven weeks she has suffered from a short irritable cough and has expectorated occasionally much frothy mucus—once or twice this expectoration has been streaked with blood—and is sometimes purulent in character. She states that she has not been feverish at any time, but she sweats profusely in the early morning.

She is much emaciated, is very short of breath, has an anxious, worn expression, and a bright spot of colour on her cheeks. The pulse is 92, the temperature (at 2 P.M.) normal.

The expectoration is now muco-purulent and adhesive and comes away chiefly in the morning. On physical examination the percussion note is natural on both sides in front and over the whole of the left lung—but on the right side behind, from 6 inches below the first dorsal vertebra there is slightly diminished resonance on percussion, with the exception of an oval space near the base of the lung. Over this space the percussion note is abnormally clear.

In this region also there is cavernous breathing and amphoric resonance of the voice, with whispered pectoriloquy, occasional gurgling crepitus, but no metallic tinkling or dropping is heard. Over the whole of the rest of the lung there is decidedly diminished breathing, but no moist sounds.

The heart's impulse is normal in position ; the record of chest-movements is as follows :—

Direction of Movement.	Sternum.		Clavicles.		3rd ribs.	
	Upper.	Mid.	Right.	Left.	Right.	Left.
Forward	28	38	35	35	50	55
Upward	70	85	75	80	105	115
Outward	—	—	—	—	20	30

Notwithstanding the asserted absence of fever in this case, it will probably be admitted that the general symptoms, and the physical signs rendered it highly probable that we had to do here either with tuberculosis, or with some very serious form of softening of a consolidated lung. The freedom and equality of the chest-movements, taken together with the history of the case, were however sufficient to induce me to regard it as one of bronchiectasis, originating in asthma, and I ventured to promise that with complete rest, and care to avoid coughing, she would ultimately be restored to health.

This opinion was justified five months later, when she visited me and reported herself strong and well. In the lung there was then only to be found a slight trace of the cavity.

The following case was probably of a similar character if we may judge from the freedom and extent of the chest-movements, but unfortunately it was not possible to verify the diagnosis by a post-mortem examination.

A. C.—female, aged 45—had no hereditary tendency to phthisis. Thirteen years ago had congestion of the lungs and some laryngeal affection, and since that has always suffered from cough. Seven years afterwards had pleurisy and pneumonia—is uncertain as to the side which was affected. About three years ago had slight hæmoptysis—blood streaking the expectoration—which was usually muco-purulent.

Is very feeble and much emaciated, is occasionally very feverish at night and perspires profusely.

There is no very perceptible dulness on percussion in front over the upper lobes, but there is diminished resonance behind on both sides to 5 inches from the apices of the lungs; below this point there is well marked amphoric resonance on both sides in the interscapular space.

On auscultation, there is diminished breathing, and in parts the respiratory murmur is almost absent in the upper lobes; no moist sounds, but in the lower lobes behind there is universal moist crepitation.

Direction of Movement.	Sternum.		Clavicles.		3rd ribs.	
	Upper.	Middle.	Right.	Left.	Right.	Left.
Forward	35	40	45	45	50	45
Upward	25	50	30	50	40	50

Six months after this examination she died, after ten days' illness, of acute pulmonary congestion.

It is possible also that, in the early stages of Fibroid diseases of the lung, some help in diagnosis from tubercular disease may be obtained from the stethometer.

These cases are not frequent, but the following measurements are from two patients in both of whom it was possible by post-mortem examination to ascertain that they were the subjects of the disorder in an early period of its course.

In the first—a male, aged 68—the register of chest movements observed three years before death, was as follows :—

Direction of Movement.	Sternum.		3rd ribs.		5th ribs.	
	Upper.	Lower.	Right.	Left.	Right.	Left.
Forward	35	35	30	25	25	40
Upward	57	40	50	50	40	50

Again taken four months before death they were :—

Direction of Movement.	Sternum.		Clavicles.		3rd ribs.	
	Upper.	Middle.	Right.	Left.	Right.	Left.
Forward	20	25	15	15	30	35
Upward	20	20	15	13	45	40

After death the upper half of the right lung was found to be affected by fibroid degeneration in an early stage, softening having commenced.

The particulars of the case are reported in the *Manchester and Liverpool Medical and Surgical Reports*, for 1875, p. 89.

The second instance was in a female aged 28, who died from uterine hæmorrhage. The apex of the right lung was condensed, interspersed with fibroid material, and covered by an adherent, much thickened pleura. The chest-measurements taken a year before death were as follows :—

Direction of Movement.	Sternum.			Clavicles.		3rd ribs.	
	Up.	Mid.	Low.	Right.	Left.	Right.	Left.
Forward	17	35	45	20	25	50	50
Upward	40	50	50	50	55	80	100

In neither of these cases was there any decided diminution of movement on the affected side, such as we find so constantly in the early deposition of tubercle.

It seems possible that in so chronic an ailment as this disease usually is, there may be less shrinking from movement on the part of the bones covering the affected lung. It is true that two instances are not sufficient to determine so important a point, but attention is called to it in the hope that other observations may be made upon the subject.

These cases will perhaps suffice to show that for purposes of diagnosis Stethometry is an important adjunct to other means. It assists in the detection of incipient pulmonary disease, and sometimes its indications precede all other signs. It will show the effects of previous disease, long after other physical signs have disappeared, and finally, in some doubtful cases, its evidence is all-important, on the one hand, as proving the existence of serious progressive mischief, on the other, as assisting to dispel suspicions aroused by other symptoms.

After what has been said at the beginning of this chapter it is hardly necessary to warn those who will employ the stethometer in diagnosis, that it is not probable that the nature of the chest-movements will enable us to discern the character of the disease without other assistance.

The following measurements were made on a case in which there was no disease of the lung whatever, but in which a chronic abscess under the left clavicle had caused immobility of that bone. It is interesting to notice also in this case the compensatory increase of movement of the left third rib.

Direction of Movement.	Sternum.		Clavicles.		3rd ribs.	
	Upper.	Middle.	Right.	Left.	Right.	Left.
Forward	30	50	23	7	45	55
Upward	50	45	30	14	50	60

It may be remarked that the immobility of the clavicle is greater in this case than in those of disease of the lung.

In the following case of thoracic tumour blocking up the left bronchus, the movements on that side of the chest were also greatly impaired.

Direction of Movement.	Sternum.	3rd ribs.		5th ribs.	
	Upper.	Right.	Left	Right.	Left.
Forward	15	40	15	45	25
Upward	40	70	30	70	65

These instances will be sufficient to show the need of attention to physical signs apart from Stethometry.

We may also look to Stethometry for some guidance in the treatment of chest disease. We have already seen how clearly it points out the dangers that are threatening, and warns us when to try to avert them, and we may reasonably anticipate that by watching the course taken by nature in her efforts at self-preservation, we may learn some lessons as to the means best calculated to aid these efforts.

The most important lesson to be learnt from the Stethometric register is the value of rest in the treatment of these disorders. I should not venture to draw this conclusion altogether from the records of such diseases as chronic bronchitis and asthma (Table XV. p. 158). It seems probable that in these complaints, the smaller degree of possible movement may be due to the general weakening of the muscular power all over the body—or it may be that the principle of economy of force demands, that there shall be less motion in forced breathing, to make up for the increase in ordinary respiration. In any case, in these diseases, the diminution of movement is slight in comparison with that noticed in many other disorders, and we certainly cannot draw from it the conclusion, that it is desirable still more to restrict the movements of the chest by any mechanical appliances. In emphysema again the diminution of motion is probably chiefly due to the gradual distension of the thoracic walls, and need not arise from any special adaptation of muscular power to the needs of the internal organs. It is chiefly a measure of the abnormal expansion and inelastic condition of the lungs.

In all these complaints we may, however, learn from the cough-tracings of the stethograph, the danger arising from the sudden indrawing of the chest-wall in the acts of coughing and sneezing.

In these involuntary actions, as we have seen, there is often a far greater degree of pressure exerted upon the lungs than is possible by the stimulus of the will.

This danger is also materially increased by some of the conditions to be found in certain morbid states of the lungs. In health, when the lung is compressed by the expiratory inbending of the ribs in coughing, this pressure takes place at the most favourable moment, when the lung is already partially emptied of air, and when the squeezing effect is comparatively harmless; but if there is any obstruction to the free exit of air, as in bronchitis or asthma, then the lung is caught in the position of partial inspiration, and, so to speak, is taken at a disadvantage, with all its cells distended with air, and ready to be forced into any inequalities in the compressing walls. Here we have an intensification of all the influences which have been considered as the expiratory causes of emphysema.

This knowledge should lead us to be more than ever careful to spare the patient from this convulsive effort, and it may induce us to check it, whenever possible, by the use of well-adapted sedatives, applied locally in the form of vapour or of spray, or else given internally in medicines.

In other more acute diseases of the lungs, however, so far as we can see, the diminution of movement of the ribs and clavicles over a diseased part is in direct ratio to the need of that part of rest. The more acute the disease, the greater is the instinctive shrinking from movement, and, in many cases, the loss of motion seems to be imposed upon the part by a kind of self-acting mechanism, such as has been shown to exist in the case of diseased joints.

Mr. Hilton, in his admirable work on *Rest and Pain*, boldly suggested the applicability to medical cases of the principle of mechanical rest, which is so important in the treatment of surgical disorders.

It is surely a rational proceeding to endeavour, as much as possible, to restrict the movements of the ribs over the portions of lung affected by acute inflammation or irritation.

As a practical suggestion of some value I may state that in cases of pleurisy or pneumonia, where there is no special need of moist applications, I have found a sheet of spongio-piline applied around the diseased side, and bound firmly about the chest, an admirable substitute for the linseed poultice. It enables firm pressure to be made, and at the same time preserves an equable temperature about the diseased part.

In phthisis the stethometer teaches us that still more definite mechanical treatment may be adopted.

In the first stages of this disease, it has been shown in Chapter III., that the ribs over the irritated lung substance are deprived of a large part of their power of motion in forced breathing, chiefly that in the forward direction. We have also seen (Chapter IV.) that this motion is mainly produced in healthy chests by an inbending of the rib in expiration. Now, although this loss of movement may be partly due to the consolidation or loss of elasticity in the lung tissues, yet, from the fact that it is one of the earliest symptoms of disease, and from the analogy of nature's operations in the case of other movable parts when they become inflamed, it seems highly probable that the want of motion is due chiefly to cessation of the action of the intercostal muscles, and that it is intended to give rest to the underlying parts.

There is, as we have seen (Chap. III.), ample proof that independent action on the part of these muscles is possible, and hence there may well be an independent cessation from action.

May we not then follow the guidance of nature in this respect, and endeavour as much as possible to restrict the movements of the ribs over the portions of lung affected by acute disease ?

Influenced by this reasoning, and unaware of the work previously done in this direction by others, I have for some time made use of restraining bands or strapping, such as are used in cases of fractured clavicle—apparently with benefit to the case, and certainly with great comfort to the patient.

I have since learnt that the use of "chest splints" was advocated by Dr. Dobell as early as the year 1866; and I would refer with strong approval to his remarks in the *British Medical Journal,* Nov. 22nd, 1873, on the conditions to be observed in the application of these restraints on breathing.

I may state that I have found a modification of Salmon & Ody's inguinal truss, a very simple and efficient form of "lung splint."

The records of the stethometer will greatly assist the judgment in deciding when and how far it is desirable to favour "rest in pulmonary consumption."

Few medical men, nowadays, will doubt the propriety of imposing temporary rest of the whole body in bed, upon a patient in whom the temperature and the physical signs denote the presence of acute inflammatory action in some portion of the lungs. But when the access of fever has passed away, the continued inaction of the bony levers over the affected part frequently shows the need that exists for some assistance to keep them free from motion.

Here it is that the stethometer is of so much service, showing first whether the whole lung should be condemned to inaction for a time; and, secondly, if not, it declares when the restraint should be more limited, and indeed, points out exactly where it should be applied, and finally, it tells when it is safe to discard all mechanical appliances.

In the chapter on Prognosis, reasons will presently be adduced for believing that a knowledge of the changes in the degree of movement of the ribs over an affected lung will help us even more in our directions to our patients. That it will assist to indicate when it is advisable to set patients free to hunt or shoot, to ramble in hilly districts and enjoy the pure stimulating air of the Engadine, and when on the other hand the soothing sedative influence of Torquay or Penzance is most required.

CHAPTER VIII.

ON STETHOMETRY AS AN AID TO PROGNOSIS.

" Till old experience do attain
To something like prophetick strain."—MILTON.

FEW questions connected with medicine are so difficult to answer, and at the same time so important as those of prognosis.

Medical men are expected to possess both gifts of healing and gifts of prophecy, and the power to make a correct forecast of the course of a disease is often taken as a measure of our knowledge of its nature. Whether justly or not it is certain that in general practice more discredit generally attaches to a failure in prognosis than even to non-success in treatment.

Any aid, therefore, in forming a judgment upon the future of cases of chest disease will assuredly be welcome.

There are three chief points in almost every case upon which some degree of foreknowledge would be desired both by attendant and patient.

1. As to the final issue of the disease ; 2. As to its rate of progress at any one time; and 3, its probable duration under certain varying circumstances.

Now no one will doubt that, in order to decide these points we require the fullest knowledge of the disease itself, of its antecedents, and of its surrounding conditions—and no method can do away with the necessity for a searching inquiry into all these circumstances.

But when the data have been collected and we are able to survey the grounds upon which a prognosis may be founded, it may perhaps be possible to assign to certain of the signs a high degree of importance, from their bearing upon several of the conditions of the problem, and to find in them firmer support for our opinion. In the case of chest affections I believe that we may place in this position of prominence the records of the movements of the walls of the thorax.

In these diseases, apart from general symptoms, and from such baleful contingencies as the concurrence of heart or kidney disorders, we need for prognosis,

1. The essential support of an accurate knowledge of the disease itself.

2. Some means of estimating the stage to which the complaint has already advanced.

3. The power of carefully measuring and recording the rapidity of its progress within a certain time.

4. During its recedence a measure of the progress of the chest towards a healthy standard, and

5. Some criterion of the vital power of the patient.

Now on all these points the stethometer is likely to render valuable information, for

1. No chest disorder can be said to be thoroughly understood until its effects upon the movement of its walls are known.

2. When these have been ascertained, the actual extent to which the disease has advanced; or, 3, its gradual recedence may sometimes be better determined by stethometric measurements than by any other means.

4. The rapidity of its advance and its inroads upon the

constitution of the patient may often be traced with great accuracy by successive measurements with the instrument; and, 5, the force of the chest muscles is frequently a very ready gauge of the vigour still remaining in the system.

In some affections of the lungs the degree of diminution of the motions of the chest-wall is a direct measure of the extent to which the disease has advanced.

In emphysema, and in complaints complicated by emphysema, such as some forms of asthma, and chronic bronchitis, this is especially the case. It may readily be perceived also why this should be so. The position of the emphysematous chest is that of full inspiration, or even an exaggeration of this position. The chest walls are pushed out to their extremest limits, and the more advanced the disease the greater is this distension, and the more immovable do the ribs become. In extreme cases they are so raised and pushed forwards and outwards that no lowering or indrawing in expiration is possible; hence we are quite

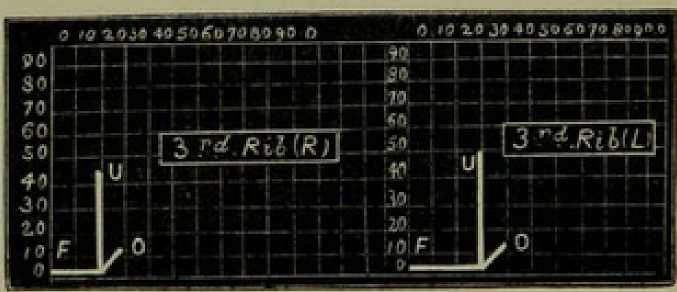


FIG. 84.—Case of emphysema, æt. 30.

prepared to find that not only is the total amount of movement reduced in these cases, to a very small fraction of the healthy standard, but the motions in each plane are equally affected, equally diminished, and their proportions to one another are unaltered. The diagrams in Fig. 84 demonstrate this fact in a striking manner.

It is not difficult, therefore, to see how stethometry may prove a very faithful guide to prognosis in these diseases.

A single measurement will often furnish data which when compared with the records of healthy movements, and, taken along with the age, history, and general character of the case, and its complications, will enable a very correct estimate to be made of the degree to which the disease has advanced, and a series of such examinations made at regular intervals will give the rate of its progress, and will enable the physician to give a better approximation to the probable duration of life than could be attained by any other means.

I can now adduce only a few cases, the results of which are known, in illustration of these remarks.

Tables XIV. and XV. contain respectively cases of emphysema, chronic bronchitis, and asthma. The several instances are arranged simply in the order of their degree of chest movement, those with the smallest motion being placed the first.

Notwithstanding this simple numerical guide in the construction of the table, there is very distinct evidence in the appended remarks, that the position of the case in the register accords closely with its degree of severity as judged by its subsequent history.

EMPHYSEMA.

In Table XIV. Case 1 must be regarded as displaying the worst symptoms of emphysema, not only on account of the very small degree of movement enjoyed by the thorax, and from the signs of distress given by the inspiratory indrawing of the chest-wall so high up as the fifth rib (indicated by the minus sign —), but also because the illness had lasted a comparatively short time, and because at the age of 30 years, a man of his stature ought to have displayed a much greater freedom of motion.

TABLE XIV.

Chest Movements in Cases of Emphysema (in 100ths of an inch).

		Top of sternum.	Middle sternum.	Lower sternum.	Clavicle (right).	Clavicle (left).	3rd rib (right).	3rd rib (left).	5th rib (right).	5th rib (left).	
1.	Forward	17	19	—	17	17	20	34	-3	20	*Male*, æt. 30. Advanced emphysema. Died 1 month after examination.
	Upward	36	45	—	45	36	45	45	21	30	
2.	Forward	15	10	—	5	10	15	15	—	—	*Male*, æt 60. Bronchitis 30 years. Died 18 months after.
	Upward	20	20	—	30	20	40	40	—	—	
3.	Forward	10	35	—	13	12	30	20	—	—	*Male*, æt. 82. Duration, 3 years.
	Upward	30	30	—	25	25	50	50	—	—	
4.	Forward	28	—	27	—	—	42	34	—	—	*Male*, æt. 59. Died 2 years after.
	Upward	51	—	51	—	—	60	45	—	—	
	Outward	—	—	—	—	—	27	24	—	—	
5.	Forward	—	—	—	39	34	42	41	—	—	*Male*, æt. 58. Emphysema with chronic bronchitis. Duration 4 yrs.
	Upward	—	—	—	57	36	57	54	—	—	
6.	Forward	25	—	—	25	20	30	60	50	50	*Male*, æt. 81. 10 years' chronic bronchitis, with emphysema. Died 2 years after.
	Upward	50	—	—	40	40	25	50	60	60	
7.	Forward	50	20	25	40	45	50	35	55	23	*Male*, æt. 26. 15 years' chronic bronchitis, incipient emphysema. Living.
	Upward	60	70	80	70	80	110	120	110	110	
	Outward	—	—	—	—	—	15	20	15	15	

The movements of the chest in Case 2 were still smaller, but the distress was less, and there was no indrawing of the ribs.

The aged Case 3 comes next, and although No. 4 actually died of congestion of the lungs only two years after the examination, yet his expectation of life was really greater on account of his age, and at the time of noting there was no heart or kidney mischief.

In Case 5, both mitral and aortic valves were already seriously diseased, and hence the prognosis was necessarily hazardous, but so far as the lungs were concerned it was evident from the degree of chest movement enjoyed, that he had still a large reserve of respiratory power to fall back upon. Case 6 was also far advanced in life, but the comparative freedom of the chest movements showed that his disease had not as yet seriously affected him. He lived in fact two years after the examination. Case 7, having already spent fifteen years in coughing with so little impairment of chest movement, is obviously the most hopeful of the group.

CHRONIC BRONCHITIS AND ASTHMA.

From our knowledge of the usual longevity of uncomplicated cases of chronic bronchitis and asthma, we might anticipate that the register of chest measurements would be likely to give less distinct indications of the degree of severity of the complaint, and this is undoubtedly true. Still I think that, so far as our evidence goes, it shows that even in these disorders, a large amount of power of movement may be regarded as a favourable augury for the case, and that whilst an increase in the measurements marks the improvement of the case, a rapid diminution usually foretells the approach of the end.

TABLE XV.

Chest Movements in Cases of Chronic Bronchitis and Asthma (in 100ths of an inch).

Case.	Direction.	Sternum.		Clavicles.		3rd ribs.		5th ribs.		Remarks.
		Upper.	Mid.	Right.	Left.	Right.	Left.	Right.	Left.	
1. Male, æt. 50.	F.	5	25	—	—	25	25	20	20	Chronic bronchitis and asthma with heart-disease, 1 year. Died in three months.
	U.	20	40	—	—	40	38	30	35	
2. Male, æt. 67	F.	35	35	—	—	30	25	25	45	Bronchitis 40 years; severe 8 years. Died 2 years after.
	U.	49	40	—	—	50	50	35	50	
3. Female, æt. 57	F.	30	30	15	20	27	25	—	—	Winter cough 16 years, with occasional asthma. Living.
	U.	40	30	20	30	23	30	—	—	
4. Male, æt. 60	F.	18	30	10	12	30	35	35	35	Chronic bronchitis and asthma 20 years. Severe hæmoptysis 10 years after. Living.
	U.	50	60	25	25	58	58	63	60	
5. Female, æt. 50	F.	35	40	25	30	40	40	—	—	Winter cough and asthma 13 years. Living.
	U.	50	45	50	50	70	70	—	—	
	O.	—	—	—	—	10	10	—	—	
6. Male, æt. 81	F.	25	—	25	20	30	60	50	50	Chronic bronchitis 10 years. Died 2 years after.
	U.	50	—	40	40	25	50	60	60	
7. Female, æt. 25	F.	30	45	25	20	55	55	—	—	Winter cough 18 years. Living.
	U.	50	60	50	50	80	80	—	—	
8 Female, æt. 47	F.	56	—	46	39	59	59	—	—	Chronic bronchitis 12 years, otherwise healthy.
	U.	39	—	45	45	48	36	—	—	
9. Male, æt. 30	F.	50	50	50	45	70	60	85	70	Winter cough 10 years, asthma 6 years, old pleurisy on left side. Living.
	U.	115	100	100	100	90	100	90	90	
	O.	—	—	—	—	18	18	20	25	
10. Male, æt. 40	F.	28	75	43	43	85	90	125	115	Winter cough 20 years, otherwise healthy.
	U.	70	120	80	80	110	115	180	180	
	O.	—	—	—	—	25	28	30	30	

It is evident that in Table XV. again the more serious cases occur in the early part, and that those low down in the series are either of less severity or have been affected for a shorter period; the apparent exception of Case 6, who died two years after examination, is sufficiently accounted for by his advanced age, and the marvel is rather that he should have been able to attain to the age of 83 years in spite of the bronchial affection.

PLEURISY.

In pleurisy, it has been remarked that stethometry shows the violence of the attack by the degree of immobility of the ribs, over the part affected, and that it marks the progress towards cure.

I have not myself used the instrument in the early stages of this disease, both on account of the pain occasioned by forced breathing, and because the movements of the chest-wall are so irregular in their extent. But when the attack is passing off, or when the effusion is subsiding, neither the general symptoms nor auscultation can show so clearly as the stethometer, the efforts which nature is making to compensate for the loss of breathing space, and the progress towards the restoration of the elasticity of the lung.

It might appear that as the abnormal movements of the ribs are dependent upon the presence of adhesions, and upon unabsorbed fluid in the chest, so the other physical signs of these conditions would prove to be just as useful as stethometry in affording a basis for prognosis—and to a certain period in the disease this remark is perhaps correct, although the signs of muscular vigour presented by the upward indications, are by no means to be despised as evidence.

But if, as the effusion passes away, and after its complete absorption, the chest movements on successive examinations, show a tendency to return to a healthy standard, with greater or less rapidity, then our fore-casts of the future can be made with much greater confidence than if we relied solely upon the general symptoms.

The illustrative cases of pleurisy are arranged in two series.

1st. Those in which the measurements were taken shortly after the attack; and

2nd. Those recorded upwards of a year after the illness.

In both tables the order of arrangement has simply been determined by the extreme differences in the movements of the two sides of the chest, those with the greatest degree of impairment of motion on the diseased side being placed 1st.

It is apparent from Table XVI. that even the earlier records of measurement foretell to some extent the degree of injury done to the system—those in whom there is least forward movement on the injured side continue to display weakness of constitution long after the attack, or even, as in Cases 3 and 5 succumb to tubercular disease, whilst those whose chests recover their action more speedily, are also quick in regaining their normal vigour.

From the data afforded by the 2nd table, there is still more reason to watch with anxiety those patients in whom the thoracic walls remain persistently retracted, and comparatively immovable after pleurisy. There is usually a less complete return to health and bodily vigour, when this is the case, than when the adhesions are less numerous and less tenacious in their hold.

The contrast between the remarks relating to the first and last four cases is sufficient to justify this warning; and to declare the value of stethometry in this regard.

TABLE XVI.

Extent of Movement of the Chest-wall in cases of Pleurisy (in 100ths of an inch).

Cases.	Direction.	Sternum.			Clavicles.		3rd ribs.		5th ribs.		Remarks.
		Upper.	Middle.	Lower.	Right.	Left.	Right.	Left.	Right.	Left.	
1. Male, æt. 39	F. U.	20 30	— —	— —	5 20	3 30	35 40	5 50	50 40	15 60	Three months, pleurisy left side; still fluid to fifth rib in front. Two years after, weak, unfit for work.
2. Male, æt. 31	F. U.	15 30	— —	— —	30 40	12 55	50 90	12 80	30 70	20 100	Four weeks, left pleurisy, effusion nearly absorbed. Two years after tubercular disease of left lung.
3. Male, æt. 54	F. U.	— —	— —	— —	15 40	50 50	— —	— —	— —	— —	Six weeks, right pleurisy. Died eighteen months after.
4. Female, æt. 30	F. U.	— —	20 20	23 20	— —	— —	40 70	15 40	50 65	16 50	Five weeks, left pleurisy, fluid absorbed. Sickly for two years. Three years after, completely recovered; at work.
5. Male, æt. 19	F. U.	39 75	— —	— —	68 80	29 66	54 99	39 84	51 135	25 60	Four weeks, absorption of pleuritic effusion on left side. Died three years after of phthisis.
6. Male, æt. 13	F. U.	35 45	55 50	— —	50 40	95 100	50 40	67 70	20 40	75 100	Three months after pleurisy with effusion on right side. Remained delicate for about two years, then recovered completely.
7. Female, æt. 29	F. U. O.	35 40 —	40 65 —	55 50 —	33 40 —	40 55 —	33 70 —	60 80 —	75 80 15	85 90 35	Four months, effusion on right side lasting one month. Nine months after completely recovered, strong, healthy.

TABLE XVII.

Chest Movements in Pleurisy (in 100ths of an inch) Measured some time after the Attack.

Cases.	Direction.	Sternum. Upper.	Sternum. Middle.	Sternum. Lower.	Clavicles. Right.	Clavicles. Left.	3rd ribs. Right.	3rd ribs. Left.	5th ribs. Right.	5th ribs. Left.	Remarks.
1. Male, æt. 21	F.	30	40	20	30	45	85	50	80	40	Thirteen years ago, had pleuritic effusion on left side. Now tall, thin, pale, weak; but no physical signs of tubercle.
	U.	70	70	70	75	90	90	100	120	100	
	O.	—	—	—	—	—	25	15	25	10	
2. Female, æt. 34	F.	30	45	—	—	—	40	70	65	70	Fifteen months since, effusion on right side, slow to retire. Now at work, but weak and delicate.
	U.	60	75	—	—	—	95	80	70	100	
	O.	—	—	—	—	—	—	—	15	12	
3. Male, æt. 34	F.	—	25	—	—	—	50	25	45	30	Two years ago, effusion on left side, rapidly absorbed. Now, tuberculosis commencing on the same side.
	U.	—	100	—	—	—	120	100	120	110	
4. Male, æt. 24	F.	15	10	10	25	25	55		65	45	Eight years since, lingering effusion on left side, and remains thin, stunted, delicate.
	U.	95	90	90	70	70	100	105	115	130	
	O.	—	—	—	—	—	—	—	20	30	
5. Female, æt. 30	F.	—	40	40	—	—	55	50	55	40	Three years since, effusion on left side, absorbed slowly; sickly for two years. Now strong, healthy.
	U.	—	70	70	—	—	90	95	70	60	
6. Male, æt. 30	F.	50	50	50	50	45	70	60	85	70	Twenty years ago, severe pleurisy, with effusion on left side. Has been asthmatic six years; is otherwise healthy.
	U.	115	100	90	100	100	90	100	90	90	
	O.	—	—	—	—	—	18	18	20	25	
7. Male, æt. 17	F.	40	60	—	50	30	50	70	80	75	Four years and a half ago, pleuro-pneumonia on right side; delicate for two years. Now stout, strong, healthy.
	U.	60	60	—	60	70	60	100	100	100	
8. Female, æt. 29	F.	35	45	70	37	40	50	55	80	80	Eighteen months since, effusion on right side lasting one month. Now completely recovered; strong, healthy.
	U.	60	75	90	70	75	90	90	115	100	
	O.	—	—	—	—	—	—	—	25	25	

It is quite possible that Case 3, which finally became phthisical, was from the outset tuberculous in its nature; but this fact would not in any way detract from the importance of the indications given by the stethometer. If confirmed by subsequent experience, it would simply show that tubercular pleurisy affects the movements of the thorax more decidedly than the simple disease, and would thus assist not only the prognosis, but also the diagnosis of the case.

It may be remarked that the forward or outward motions are probably of chief value as guides to our judgment on these points. The excessive upward motion may be some criterion of the compensatory power possessed by the muscles of the thorax, but it also may be a sign of the tightness of the bands which are impeding the expansion of the chest-wall in other directions.

PHTHISIS.

The prognosis in phthisis is well known to be extremely difficult, especially as to the probable duration of life under the various states of the disease. After a certain degree of disorganisation has been produced in the lung, it may be easy to pronounce the sentence of incurable upon it; or again there may be symptoms of acute tuberculosis or certain complications which will enable us to predict a rapid course and a speedy ending, but there remains a very large number of cases, by far the largest part of consumptives—of whom it is most difficult to prophesy.

It has been well remarked that in phthisis, there are usually traces of several independent forms of chest disorder associated in each case. Inflammations of various kinds, acute, chronic, scrofulous, or perhaps syphilitic; congestions, pleurisies, abscesses, hydro- or pneumo-thorax, fibroid, cirrhotic or melanotic disease.

It may well be, therefore, that prognosis in such a disease should be correspondingly difficult—and certainly in no disorder is it more needful to take into account all the circumstances of the case.

But, even in this complex disorder, whilst the difficulties of the task must not be understated, yet it is probable that stethometry will give auguries which are by no means to be despised. Much more study will be needful in order to attain this aid, than in the case of the more simple lesions produced by other disorders.

The influences affecting the movements of the chest-wall are necessarily too varied, for the discovery of any simple relation between them and the gravity of the disease such as we have found in pleurisy or emphysema.

Thus in most cases there is not only diminution of motion from simple loss of elasticity of the underlying lung, but there are often tough fibrous bands limiting the action of the ribs, and associated with these impediments there is usually loss of muscular power, both local and general, and a weakening of the whole respiratory energy.

Even uncomplicated phthisis, running its course of localized asthenic inflammation, and consolidation, with subsequent softening and excavation, produces very diverse effects upon the motions of the chestwall, different degrees of diminution of the general movement, out of all relation to the extent of the disease, altered proportions in the degree of upward or forward motion, the upward rise being sometimes increased sometimes lessened, and the forward thrust showing equal variations in its extent.

But with all this variation in the results of chest measurement, it can hardly be doubted that the records obtained bear some relation to the circumstances of the case, and the very fact that the movement-registers cannot be directly connected with the extent of the disease of the lungs, as revealed by auscultation, may permit us to hope that they indicate something of the constitutional vigour of the patient, and something perhaps of his power of resisting the inroads of the disease.

Many more cases will need to be measured by the three-plane stethometer before we can arrive at thoroughly trustworthy conclusions, respecting the meaning of all the variations of the movements which may be found in phthisis. All that can be said at present is, that it is clear that these variations may become aids to us in our judgment upon individual cases.

There is, however, one precaution that must be taken in acquiring the needful records from which our conclusions are to be drawn, and that is, that the mensuration must in all the cases be performed at a time when the disease is not in an active state, *i.e.*, when irritative fever and other signs of acute inflammation and irritation are not present. It must have occurred to most practitioners to have attended cases, in which abscess forming in the lung, as a result of scrofulous consolidation, has simulated rapid softening and disorganization of the part, and the accompanying fever and emaciation may have caused grave apprehension of a speedy termination by death, and yet, in certain of these instances, after a more or less protracted discharge of purulent matter, the abscess has either healed or dried up, the patient has recovered, and sometimes for years has enjoyed a very considerable degree of health, and has returned to his ordinary avocations.

In these difficult and doubtful cases, it is needless to say, that stethometry can afford little, if any, aid to prognosis; but afterwards in judging of the progress towards recovery it probably gives more distinct guidance than any other symptom.

Even in less urgent forms of the disease it is not desirable to run the risk of fallacy arising from the circumstance of its being in an active period of its course.

In all the measurements here given this caution has been as much as possible observed.

In collecting the data for prognosis from the stethometric records of phthisis, there are two methods that may be employed.

1. We may compare the movements of the chest in those who have already lived a long time, and in those who have speedily succumbed to the disease, the measurements being made at epochs in the complaint when the apparent mischief in the lungs, in the two classes of cases, is about the same, or even when it is less developed in the acute than in the chronic class ; or,

2. We may endeavour to appreciate the rapidity of the progress of the disease in different individuals, and may then note the degree of motion enjoyed by the slow cases as contrasted with those that are rapidly advancing.

I propose to adopt both these modes of inquiry.

In the first method it will be necessary to give extracts from the notes of the cases, as brief as possible, but yet sufficiently full to enable the reader to judge whether they are strictly comparable—and whether they may be placed upon the same level as regards the degree of disorganization of the lung.

The cases are arranged in pairs, one chronic, the other acute, and with the exception of the rate of progress, they have been selected so as to present as many points of similarity as possible.

CHRONIC CASE A.

Female, æt. 20, young lady. Height 5 ft. 2 in.; dark-complexioned; hereditary phthisis.

Physical signs.

Right side.—Slight diminution of resonance, on percussion, over and under clavicle to 4 in. Over this region, harsh breathing, prolonged expiratory murmur, heart sounds conveyed, bronchophony, no moist sounds or crackle.

Left side.—Dulness, on percussion, to 2½ in. in front; absence of respiratory murmur, no moist sounds. At back, amphoric resonance to 6 in.; cavernous breathing all over this region, strong pectoriloquy, slight gurgling rhonchus.

ACUTE CASE B.

Female, æt. 25, nurse, formerly factory hand. Phthisis hereditary. Height, 5 ft. 1 in.; dark complexion.

Physical signs.

Right side.—*Front*, slight dulness in supra-clavicular region, clear—almost tympanitic—resonance to 4 in., amphoric breathing, and pectriloquy, and variable bubbling rhonchus; *behind*, similar evidences of cavity.

Left side.—Slight dulness to 3 in., bronchial breathing, fine crackle above the clavicle, tolerably healthy breathing below 3 in.

Stethometric Measurements in 100*ths of an inch.*

Case A. F.	Case A. U.	Regions.	Case B. F.	Case B. U.
30	20	Upper sternum	15	50
35	30	Mid- ,,	10	40
30	30	Right clavicle	10	24
40	38	Left ,,	15	50
70	70	Right 3rd rib	16	55
55	60	Left ,,	22	55

The physical signs in these two cases indicate a very close resemblance in the extent of the lung disease, and in the degree of disorganization it had produced. The cases were also strictly comparable in their ages, height, and muscular power, but it will be seen that the movements registered by the stethometer differ very considerably, Case A enjoying a much larger amount of general movement than Case B, especially over the clavicles and ribs.

Can this difference be accounted for by the differing rate of progress in the two cases?

CASE A was pronounced phthisical, by the late Dr. Symonds of Clifton, in 1864, and since then has coughed more or less constantly. She did not, however, lose much flesh until three years ago, and she was still moderately-well nourished. She spat blood once slightly, in Oct. 1872. Menstruation regular, but scanty. The expectoration was variable, usually scanty and muco-purulent.

She died in the spring of 1874.

CASE B began to ail in April 1870. She ceased to menstruate, and there was consolidation under the right clavicle in the June of that year; she has spat blood several times since then. In January 1872 her digestion was much impaired, and she emaciated rapidly; in June 1872 the stethometric record was taken; in October she began to get worse rapidly, the disease advanced chiefly on the left side; and she died on December 19th, 1872.

In the following male cases, I have also endeavoured to approach to some degree of conformity in the extent of the lung mischief, but it will be found that on the whole there was less disorganization in the acute Cases D and F, than in the chronic Cases C and E.

CHRONIC CASE C.

Male, æt. 25, gentleman. Slender, dark complexion, pale; height, 5 ft. 9 in. Family history of struma, not of phthisis.

Physical signs.

Right side.—Dulness on percussion to 4 in. below clavicle, occasional fine crackle throughout this region, bronchial breathing and bronchophony. Similar signs at the back, the lower two-thirds healthy.

Left side.—Much contracted below clavicle and inferiorly; dull all round the base of the lung; clear, tympanitic percussion to 3 in. below clavicle, cavernous breathing, pectoriloquy.

ACUTE CASE D.

Male, æt. 27, gentleman. Slender, dark complexion, pallid; height, 5 ft. 8 in. Of strongly phthisical family.

Physical signs.

Right side dull on percussion above and to 3 in. below clavicle; fine crepitant rhonchus above clavicle; large moist crackle and bubbling at 2–4, pectoriloquy.

Left side.—Slight dulness above and to 1 in. below the clavicle; occasional moist crackle, harsh respiratory murmur, prolonged expiration.

Stethometric Record.

Case C. Case D.

F.	U.	Regions.	F.	U.
56	39	Upper sternum	18	38
85	45	Mid- ,,	25	50
85	41	Right clavicle	20	35
54	39	Left ,,	15	30
110	75	Right 3rd rib	30	50
68	39	Left ,,	25	40
110	75	Right 5th rib	—	—
68	39	Left ,,	—	—

The rates of progress of these two cases were as different as are their stethometric registers. The history of Case D is given in very few words. He was a delicate strumous youth, but had no lung affection until October, 1872, when he first commenced to cough. He then saw an eminent medical man in Manchester, who advised him to go to Ventnor, and on his return in January the above notes were taken, and although there was then no pyrexia, or evidence of active advance, the physical signs prove that the disease had made very rapid progress in four months.

Case C has a much longer history, and in order to make clear the severity of the case it will be necessary to give somewhat copious extracts from its notes.

He was a delicate, quick-growing lad, subject to strumous swellings in the neck. In February, 1865, whilst still at school, he had acute pleurisy on the left side, with abundant effusion lasting about nine weeks, which illness was followed by flattening of the left subclavian region, and much contraction at the base of the lung. On the right side, harsh and prolonged respiratory murmur was noted. He now remained in fair health for two years, but in March, 1867, he began to lose strength and flesh, had a cough, quick pulse in the evening, night-sweats and chills. Under the left clavicle there was dry crackle, and anteriorly for four inches moist crepitation and dulness on percussion. After a year of varying health he went to Australia, and on his return, excessively weak and emaciated, in the spring of 1869, he was found by an eminent London physician to be in an almost hopeless state. A chest examination gave,

Left Side.—Contracted below the clavicle and inferiorly dull all round the base—a well-marked gurgling rhonchus at the apex—the respiratory sounds faint but audible posteriorly along the scapula.

Right Side.—Very coarse, almost gurgling rhonchus under the clavicle, same signs in supra-spinous fossa—crepitus over half the scapula—the lower two-thirds of this lung were the only portions of the chest where anything like vesicular respiration was audible.

There was general pyrexia—occasional chills and night-sweats. Notwithstanding these most unfavourable symptoms however he gradually improved under home nursing. The fever left him, the chest signs improved, and in a few months' time even the crackle and the gurgling in the large vomica on the left side ceased, and he gained both flesh and strength. He died in the spring of 1875.

Yet another comparison may serve to show the contrast between acute and chronic cases in their power of thoracic movement.

CHRONIC CASE E.

Male, æt. 54. Height, 5 ft. 6 in.; dark complexion, pale. Phthisis not hereditary.

Physical signs.

Right side.—Clear, almost tympanitic, percussion-note to 3 in. below clavicle; below this, dull to 4½. Over the upper part, cavernous breathing and pectoriloquy; below, bronchial breathing and bronchophony. No moist sounds.

Left side.—Dulness on percussion to 1¼ in. below the clavicle; harsh murmur and prolonged expiration, heart sounds conveyed, no crackle.

ACUTE CASE F.

Male, æt. 45. 5 ft. 9 in. in height; dark, pale. Family history doubtful.

Physical signs.

Right side.—Diminished resonance on percussion to 6 in. in front; bronchial breathing and bronchophony, conveyed heart sounds and occasional crackle all over this region. Under the clavicle, gurgling rhonchus, and cavernous breathing, and pectoriloquy.

Left side.—Dulness on percussion to 2½ in.; moist crackle, harsh breathing.

Chest Measurements.

Case E. | Case F.

F.	U.	Regions.	F.	U.
51	45	Upper sternum	20	18
—	—	Mid ,,	30	20
—	—	Lower ,,	35	25
48	45	Right clavicle	15	20
51	39	Left ,,	15	10
67	66	Right 3rd rib	28	20
42	51	Left ,,	35	30
—	—	Right 5th rib	20	15
—	—	Left ,,	25	40

Case E was a man of active energetic temperament, thin, wiry, and fond of hunting. He was a merchant, and at the outset the case seemed likely to prove a serious one. It commenced in 1866 with laryngeal complications, and went on rapidly to consolidation of the right apex, and to certain premonitory signs of disease on the left side, *e.g.*, harsh inspiratory murmur and prolonged expiration.

In the spring of 1867 he went to Italy, where he was unfortunate enough to contract the Roman fever, and became much reduced in strength. On June 21 it was noted that, on the right side, for two inches below the clavicle and the upper third of the scapula behind there was very fluid crepitation, and on the left side there was slight diminution of resonance, dry crackle under the clavicle; there was no fever, but occasional night-sweats.

On October 17, in the same year, a well-defined cavity was found in the right apex, extending to the third rib, almost dry, but with some coarse crepitant sound on coughing, and fine crackle for four or five inches in front. The base of the lung was healthy, and on the left side the disease appeared to be stationary. He now went to Egypt and returned in May 1868, greatly improved in general health, and (with the chest signs much lessened in intensity) with apparently no secretion from the vomica. In the spring of 1869 the above measurements were taken, and at the present time the disease appears to be quite quiescent. He has retired from business, but he hunts and shoots, and performs all the outdoor duties of a country gentleman.

Case F had only suffered from a cough for two years. Before that time he had enjoyed good health, and he only began to get thinner twelve months ago, and spat blood.

Three months ago he had a sharp attack of laryngitis and he remained hoarse. When the examination was made he was weak and unable to work, but he was able to walk about a mile without difficulty; there was no fever, and he did not suffer from night-sweats. The case had evidently been of an acute form, but it was not then advancing, and there was nothing to foretell a very rapid decline, but shortly after the chest measurements were taken he took cold, and died after a few days' illness.

A very brief survey of the respective movement registers of these cases will suffice to show that there is a much smaller extent of general motion in the acute than in the chronic forms of the disease. In some respects also the differences are so striking, that even this small collection of measurements would be sufficient to justify further inquiry into the relations between the duration of life in phthisis and the degree of mobility of the chest wall.

In order to determine this relation satisfactorily, however, the second method of inquiry is likely to prove most useful, since it will show that the contrast, between the registers of acute and chronic cases, is not the result of a selection in accordance with a foregone conclusion, but that it holds good in a very large proportion of patients.

There are in the details of these illustrative examples, already given, several interesting peculiarities in the chest movements which may be found to have some bearing upon the question of prognosis—but these points also will be discussed with more force when a larger body of evidence has been brought forward.

The second method consists in arranging cases of phthisis of all grades of progress in two series—acute and chronic, and in noting any differences in the movements of the chest in the two sets of cases which might be likely to serve as guides to our judgment in other instances.

In the following tables (XVIII. to XXI.), the chronic cases have been selected simply in consequence of the length of time that they have lived, without reference to other circumstances. The acute series have been taken (1st) from amongst those who have speedily succumbed to the disease, and (2nd), from those in whom, from their history, it is manifest that the complaint though now stationary yet has been making rapid progress. As stated before, care has been taken to take the measurements as far as possible, during a temporary intermission in its activity.

Again, the normal movements in males and females differ both in their proportions and in their extent, and they cannot be directly compared without danger of fallacy. The two sexes are therefore separately contrasted; and in the four tables (XVIII to XXI.) I have arranged ten males and ten females affected by chronic forms of the disease and an equal number of acute cases of each sex.

It has not been possible to effect any other selection in regard to age, size, build or muscular strength. They are all necessarily grouped together, with the one relation between them of their common disease. In actual practice great assistance in prognosis often arises from our possession of these details, since the movements of the chest may then be compared with an estimate of what would have been their extent in a healthy individual of similar stature, age, &c.

They are here presented as the best examples of their kind out of a comparatively small range of patients, most of them having been seen in private practice or referred to me by the kindness of my medical friends. This fact has for the most part enabled me to give the final result of the cases.

If, with all these disadvantages, certain striking contrasts can be found between the two groups, and certain peculiarities occur only in the one or the other, then we may surely hope that with a wider experience something still more definite may eventually be discovered.

On comparing these groups of cases, it will be evident at once that the different degrees of movement, which we have found in the selected acute and chronic cases, are displayed quite as fully in the larger series.[1]

But attention must also be called to the details of these movements, some of which have an important bearing upon prognosis, and which may thus in other cases serve to show whether they are to be ranked as likely to advance rapidly to a fatal issue, or whether they may become chronic or even tend towards cure.

[1] It may again be observed that the degree of motion bears no direct proportion to the actual extent of the disorganization of the lungs. It has to do with other conditions, vital power, muscular force, and perhaps with the comparative safety with which the movements may be carried on, and hence we may hope that stethometry may guide us in our judgment better than even auscultation and percussion.

TABLE XVIII.—*Chest Movements in Chronic Phthisis (Males) in 100ths of an inch.*

Cases.	Direction.	Upp. sternum.	Mid. sternum.	Low. sternum.	Right clavicle.	Left clavicle.	Right 3rd ribs.	Left 3rd ribs.	Right 5th ribs.	Left 5th ribs.	Duration before.	Duration after.	Remarks.
1. Æt. 48 ...	F.	25	87	—	30	25	75	110	—	—	9 years	Living 3 yrs. after	(R.) Consolidation to 3 in. in front; quiescent.
	U.	55	82	—	45	40	90	100	—	—			(L.) Healthy; syphilitic nodes in 1st and 2nd ribs.
2. Æt. 29 ...	F.	25	30	—	50	15	100	70	70	45	4 years	Living 3 yrs. after	Commenced with chronic laryngitis, then pleurisy and pneumonia on left side; now softening, hæmoptysis.
	U.	45	40	—	50	25	60	60	60	40			(R.) Healthy.
	O.	—	—	—	—	—	10	12	25	10			
3. Æt. 61 ...	F.	42	60	—	34	54	69	85	—	—	4 years	Living 5 yrs. after	(R.) Deposit to 3 inches in front, cavity at apex.
	U.	69	70	—	69	57	93	105	—	—			(L.) Healthy.
4. Æt. 25 ...	F.	56	85	—	85	54	110	68	110	68	5 years	Died 3½ yrs. after	(R.) Upper lobe consolidated.
	U.	39	45	—	41	39	75	39	75	39			(L.) Large contracted vomica at apex.
5. Æt. 25 ...	F.	33	40	—	20	40	75	60	—	—	6 years	Living 2 yrs. after	(R.) Old quiescent deposit to 2 inches.
	U.	65	55	—	50	40	80	75	—	—			(L.) Consolidation to 3 inches, softening.
6. Æt. 54 ...	F.	51	—	—	48	51	67	42	—	—	2½ yrs.	Living 6 yrs. after	(R.) Large dry cavity to 3½ inches, quiescent consolidation to 4 inches.
	U.	45	—	—	45	39	66	51	—	—			(L.) Recent deposit to 1½ inch in front.
	O.	—	—	—	—	—	30	27	—	—			
7. Æt. 26 ...	F.	24	34	34	—	—	59	41	105	51	6 years	4 yrs. after	(R.) Healthy.
	U.	39	36	45	—	—	60	45	45	36			(L.) General infiltration of greater part of apex and posterior part of lower lobe; quiescent (originated in pneumonia).
	O.	—	—	—	—	—	30	15	30	20			
8. Æt. 26 ...	F.	20	30	—	25	40	38	60	40	65	4 years	Uncertain	(R.) Large dry vomica to 3rd rib, deposit to 5 inches.
	U.	38	60	—	38	50	65	95	83	70			(L.) Incipient consolidation to 1½ inch.
9. Æt. 57 ...	F.	25	35	30	25	20	55	35	50	40	Probably 10 years	Living 3 yrs. after	(R.) Superficial deposit to 2 inches, quiescent.
	U.	65	60	60	70	60	70	70	60	60			(L.) Upper lobe softening to 4 inches, vomica behind.
	O.	—	—	—	—	—	15	10	20	15			
10. Æt. 35 ...	F.	35	48	75	25	20	70	35	80	50	2 years	Died 2 yrs. after.	(R.) Incipient deposit to 2 inches in front.
	U.	70	70	80	45	35	90	65	100	80			(L.) Consolidation to 5 inches, softening.

TABLE XIX.—*Chest Movements in Acute Phthisis (Males) in 100ths of an inch.*

Cases.	Direction.	Upp. sternum.	Mid. sternum.	Low. sternum.	Right clavicle.	Left clavicle.	Right 3rd ribs.	Left 3rd ribs.	Right 5th ribs.	Left 5th ribs.	Duration before.	Duration after.	Remarks.
1. Æt. 46...	F.	20	35	35	15	20	45	45	55	45	1½ yr.	—	(R.) Vomica at apex ; behind, discharging.
	U.	35	50	50	30	35	60	30	60	40			(L.) Consolidation to 6 inches in front. Vomica at apex behind.
	O.	—	—	—	—	—	30	20	30	20			
2. Æt. 20...	F.	25	35	—	18	18	45	40	—	—	2 years	Died 1 year after	Commenced with pleurisy on both sides, now consolidation on both sides, softening on left.
	U.	25	40	—	25	25	80	40	—	—			
	O.	—	—	—	—	—	15	3	—	—			
3. Æt. 19...	F.	20	30	35	15	15	28	35	20	25	20 mnths.	1 month	Extensive consolidation on both sides, softening.
	U.	18	20	25	20	10	20	30	15	40			(R.) Vomica occupying apex, chiefly at back.
4. Æt. 22...	F.	12	15	—	20	13	30	28	—	—	4 mths.	Died 15 months after	(R.) Healthy.
	U.	20	35	—	35	15	60	50	—	—			(L.) Softening deposit to 3 inches.
	O.	—	—	—	—	—	10	10	—	—			
5. Æt. 45...	F.	20	20	—	15	20	35	25	—	—	18 mths.	Uncertain	(R.) Softening deposit to 6 inches, vomica under clavicle.
	U.	30	30	—	20	30	20	30	—	—			(L.) Softening tubercle to 2½ inches.
6. Æt. 27 ..	F.	18	25	—	20	15	30	25	—	—	6 mths.	—	(R.) Consolidation to 3 in., vomica in front becoming quiescent.
	U.	38	50	—	35	30	50	40	—	—			(L.) Active disease to 1 inch.
7. Æt. 21...	F.	25	20	—	3	20	20	40	45	45	4 mths.	—	(R.) Softening deposit to 3 in., with vomica under clavicle.
	U.	30	35	—	10	30	35	50	50	55			(L.) Consolidation to 3 in.
8. Æt. 36...	F.	10	—	—	10	15	30	20	—	—	18 mths.	—	Considerable hæmoptysis. (R.) Incipient deposit to 2 inches.
	U.	15	—	—	15	20	50	30	—	—			(L.) Softening tubercle to 6 inches, vomica at apex.
9. Æt. 30...	F.	15	13	—	—	—	23	15	—	—	18 mths.	1 year	(R.) Softening deposit to 4 inches.
	U.	30	30	—	—	—	38	30	—	—			(L.) Tubercular infiltration to 6 inches, large vomica at back.
10. Æt. 49...	F.	12	6	—	10	6	15	12	5	15	5 mths.	Not known	(R.) Consolidation at apex. (L.) Pneumonic consolidation of lower lobe, with tubercular infiltration, vomica under 5th rib.
	U.	—	5	—	—	—	30	12	6	8			

TABLE XX.—*Chest Movements in Chronic Phthisis (Females) in* 100*ths of an inch.*

Cases.	Direction.	Upp. sternum.	Mid. sternum.	Right clavicle	Left clavicle.	Right 3rd rib.	Left 3rd rib.	Duration before.	Duration after.	Remarks.
1. M. B. æt. 47	F. U. O.	50 70 —	55 70 —	40 60 —	43 40 —	65 70 10	58 65 10	8 years	Living 2 yrs. after	(R.) Softening deposit in upper lobe, dry vomica at apex. (L.) Consolidation to 1½ inch below clavicle.
2. S. W., æt. 31	F. U. O.	— — —	— — —	— — —	— — —	59 34 27	75 51 27	4 years	Died in 2 years	(R.) Incipient deposit at apex. (L.) Extensive consolidation, large vomica in upper lobe.
3. G. F., æt. 21	F. U.	30 20	35 30	30 30	40 38	70 70	55 60	9 years	Died in 18 months	R.) Consolidation to 4 in., and commencing softening. (L.) Deposit to 6 in., behind large contracted vomica back of lung.
4. G. B., æt. 50	F. U.	34 60	— —	17 60	24 27	42 60	42 51	3 years	Living 5 yrs. after	(R.) Deposit to 3 inches in second stage. (L.) Healthy.
5. S. B., æt. 38	F. U.	39 60	42 60	19 45	37 54	42 60	68 81	3 years	Died 2 yrs. after	R.) Contracted vomica under 3rd rib, extensive disease in up. and mid. lobes. (L.) Incip. deposit at apex.
6. J. R., æt. 23	F. U.	25 70	55 80	58 90	28 70	160 00	75 100	4 years	Living 3 yrs. after	(R.) Healthy. (L.) Quiescent deposit to 2½ inches in upper lobe.
7. M. G., æt. 28	F. U.	24 24	42 45	25 50	27 30	50 55	30 50	2 years	Living 3 yrs. after	(R.) Incipient consolidation to 3 inches. (L.) Deposit to 4 in. in front, softening vomica at apex.
8. J. S., æt. 30	F. U.	24 45	30 40	25 30	30 60	35 50	50 55	about 2 years	Living 3 yrs. after	(R.) Deposit to 3 inches in front, softening. (L.) Healthy.
9. M. J., æt. 30	F. U.	18 60	15 50	30 70	27 60	35 60	50 80	4 years	Living 1 year after	(R.) Consol. to 4 in. softening, small vomica at apex. (L.) Incipient deposit.
10. L. G., æt. 36	F. U.	25 50	30 50	30 60	25 60	35 75	35 75	3 years	Living 3 yrs. after	(R.) Healthy. (L.) Consolidation to 3 inches, quiescent.

TABLE XXI.—*Chest Movements in Acute Phthisis (Females) in 100ths of an inch.*

Cases.	Direction.	Sternum.		Clavicles		3rd ribs.		Remarks.
		Upper.	Middle.	Right.	Left.	Right.	Left.	
1. C.J. æt. 20	F.	15	15	20	25	25	12	$1\frac{1}{2}$ year. (R.) Upper lobe softening, large vomica at apex.
	U.	35	30	35	30	35	25	(L.) Consol. to 6 in. in front, vomica behind. (Result not traced.)
2. E.R. æt. 28	F.	15	35	15	12	35	15	18 months. (R.) Softening tubercle to $2\frac{1}{2}$ inches.
	U.	50	60	45	20	40	30	(L.) Dep. to 6 in., large vomica at apex in front. Died in 6 mths.
3. S.T. æt. 25	F.	15	10	10	15	16	22	20 months. (R.) Extensive infiltration, large advancing cavity.
	U.	50	40	24	50	55	55	(L.) Incipient softening tubercle. Died 4 months after.
4. E.H. æt. 24	F.	15	14	10	80	20	25	About 2 yrs. R.) Consolidation to 3 or 4 in., incip. softening.
	U.	10	10	5	—	35	20	(L.) Vomica at apex. (Duration not known.)
5. B.G. æt. 26	F.	10	12	13	15	30	22	Attacked 1 year before. (R.) Consolidation to 3 in. in front, softening, large cavity under scapula.
	U.	30	30	30	40	40	55	(L) Incipient deposit. Lived about 1 year after.
6. E.J. æt. 37	F.	20	38	25	15	35	25	Two years. (R) Incipient deposit to 4 inches.
	U.	50	60	40	28	60	50	(L.) Consolidation to 6 inches, vomica at apex. Lived 1 year.
	O.	—	—	—	—	15	10	
7. F.W. æt. 33	F.	15	35	30	12	35	30	Extensive consolidation on both sides, softening, the left lung most rapidly. Died 6 months afterwards.
	U.	25	30	20	20	35	20	
	O.	—	—	—	—	6	2	
8. S.H. æt. 47	F.	13	20	20	18	30	30	8 months. (R.) Consolidation to 3 in. in front, vomica at apex.
	U.	20	25	25	20	40	35	(L.) Softening tubercle to 5 inches. Died 1 year after.
9. E.M. æt. 32	F.	15	35	30	12	35	30	About $1\frac{1}{2}$ year. (R.) Healthy.
	U.	50	60	40	40	70	40	(L.) Advanced softening tubercle. Died in 6 months afterwards.
	O.	—	—	—	—	12	4	
10. L.A. æt. 19	F.	42	42	—	—	54	41	6 months. Softening tubercle under left clavicle.
	U.	45	45	—	—	45	39	(R.) Healthy. Died in 6 months.

1. If we take the third ribs as our guide as being the part of the thoracic framework most usually affected by the underlying disease, and compare its movements in the forward direction in the two sets of cases—we shall find that there is a much greater degree of motion in the chronic than in the acute cases.

The average extent of forward motion of the third ribs in the chronic cases recorded in Table XVIII. (Males) is 0·66 inches and amongst the female cases in Table XX., it is 0·50 inches.

If we take the worst side only in these cases amongst males the forward push is 0·53 inches, and amongst females it is 0·46 inches.

On the other hand, amongst the acute cases in males (Table XIX.) the average movement of all the third ribs is only 0·31 inches: and in females, (Table XXI.) 0·28 inches.

And on the worst side only the third rib moves forward 0·26 inches amongst males; and 0·24 inches amongst females.

2. The upward movement of the third ribs is also greater on the whole in the chronic than in the acute series. The average rise of these ribs in males, is in the chronic cases 0·73 inches; in the acute 0·39. Or if we take the worst side only it is in chronic cases 0·53 inches; and in the acute 0·31.

In females, in chronic cases, the average measurement for both sides is 0·65 inches; and for the worst side 0·60 inches. Whilst in the acute cases the respective figures obtained are 0·41 inches and 0·36 inches.

These great differences in the degree of movement, in the acute and chronic cases, are not to be accounted for by any less extent of mischief in the latter class, for in many instances the stage reached by the chronic disease was much more advanced than that attained by the acute malady.

They are most probably due to general systemic feebleness, to weakness of the respiratory muscles over the seat of disease; and to the inner sense of the organism that greater mobility would still further intensify the disease. In any case they afford great assistance in forecasting the probable issue of the cases, and in determining the category in which they are to be placed, whether chronic or acute.

3. When the forward motions in the chronic cases (Tables XVIII. and XX.) are carefully scrutinized, it will be found that in some instances, the horizontal movement is greater in the bones over the more advanced side than in those over recently consolidated lung. This occurs in the left clavicle of Case (5,) and in the right third rib of Case (6) in Table XVIII. amongst the chronic male cases. Amongst the chronic female cases of Table XX., it appears in the third right rib of Case (1); the left third rib of Case (2); in the left clavicles of Cases (3) and (7); and in the right clavicle of Case (9).

And when the history of these patients is obtained, it may be discovered that in every case of this nature, the increase of forward thrust takes place over a superficial vomica, which has been quiescent for a long period, and which has ceased to discharge purulent matter.

This increased motion may be due to the release of the ribs from their bonds, or to a renewal of the power of the costal muscles, or again to an inner sense of the organism of the safety of such movement, or even to some effort at compensation for the loss of air capacity elsewhere.

In any case the occurrence seems either to portend a slow advance of the disease or to assert its present quiescence—for it is remarkable that increased movement over a vomica is only found in one out of the twenty acute cases (No. 5, Table XIX.), and in this one the disease was probably not then advancing on that side.

4. It is worthy of notice that when the vomica is situated at the back of the lung it does not, even in chronic cases, necessarily confer any increased freedom of movement on the rib in front. Thus in Case 9 (Table XVIII.) the left lung, containing a cavity at the back, has the least extent of side movement.

This observation is perhaps such as might have been anticipated, but when the vomica is very large, as in Case (3), (Table XX.) the clavicle is allowed to move more freely on the most diseased side.

5. The upward movement of the ribs is also sometimes increased over the most affected lung—chiefly in chronic cases. Thus it is found over the right clavicle in Cases (1) (3), (5), and (6) of Table XVIII., over the right clavicle, and right third rib of Case (1), Table XX., on the left clavicle of Case (3) and the right clavicle of Case (9), also in Table XX.

It probably shows some degree of vigour of constitution, but it may also be a sign of the extent of the underlying contracted lung ; and so far may be rather an evidence of greater mischief.

This is true probably of the chronic case, No. 5, (Table XVIII.) in which the forward motion of the clavicle is much impaired, and it is found amongst the acute cases, in Table XXI. in the right clavicle of Case (1) and the left clavicle of Case (9).

6. I have already noticed the fact that in some cases of phthisis there is some attempt at compensatory increase of movement in portions of the thorax not immediately over active advancing disease in the lungs. But this supplementary motion is for the most part seen in chronic cases only.

Thus it occurs, as I have just shown, over diseased parts in the form of increased upward or forward motions of the bones, but it is also to be noted in Table XVIII. in the third right rib of Case (5), and in the fifth right rib in Case (8), and in Table XX. it is shown in Case (1), and Case (4), and perhaps Case (7) in the right third rib ; and in the left third ribs in Cases (6) and (9).

I do not think that any such increased motion can be traced amongst the rapidly progressing cases ; and hence, if this observation should be verified by subsequent measurements, we shall have in the circumstance another piece of evidence which will have some prognostic value.

It is not improbable that the power of compensation by other parts of the thorax is only possessed by chests in which the disease is advancing slowly, or in which it is even quiescent for the time.

8. It is scarcely necessary to point out that as in emphysema, so in phthisis, any indrawing of the walls of the thorax is necessarily unfavourable, as showing the great degree of the dyspnœa. It does not usually occur until the fatal termination of the case draws very near.

It only remains now to advert to any exceptions to these observations which have been noticed.

It seems probable that when phthisis occurs in early life a favourable prognosis cannot be founded upon the freedom of the chest-movements.

In youth, even when the morbid action is both extensive and rapid in its progress, the chest walls often seem to retain their great elasticity and thus prevent us from employing the stethometer as an aid to judgment.

I have selected the following instances of the concurrence of serious and advancing mischief in the lung, with considerable freedom of movement. (It will be observed that the most aged of these cases was only 19 years old) :—

TABLE XXII.—*Youthful cases of Acute Phthisis, with much movement of the Chest.*

Cases.	Direction.	Upp. sternum.	Mid. sternum.	Right clavicle.	Left clavicle.	Right 3rd rib.	Left 3rd rib.	Remarks.
Fem., æt. 16½	F.	30	50	45	38	75	50	6 months. (R.) Healthy. (L.) Consolidation to 5 in., vomica at apex.
	U.	50	60	60	50	70	60	
Fem., æt. 19 ..	F.	49	—	47	39	68	56	1 year. (R.) Healthy. (L.) Softening tubercle to 5 in. Died 10 months after.
	U.	57	—	75	36	63	45	
	O.	—	—	—	—	36	21	
Fem., æt. 17...	F.	42	42	—	—	54	41	6 months. (R.) Healthy. (L.) Softening tubercle to 3 in. Died 9 months after.
	U.	45	45	—	—	45	39	
Fem., æt. 16½	F.	58	55	65	55	92	70	18 months. (R) Healthy. (L.) Softening tubercle to 3 in.
	U.	95	80	120	120	110	75	
Male, æt. 15...	F.	23	50	15	25	65	78	10 months. (R.) Softening tubercle to 5 in., vomica at apex. (L.) Healthy.
	U.	40	70	40	45	100	130	

There is also some reason for believing that cases characterized by excessive hæmoptysis, and those complicated with syphilis, or of syphilitic origin, are not to be judged by the criterion of the degree of chest-movement.

TABLE XXIII.—*Hæmorrhagic and Syphilitic cases.*

Cases.	Direction.	Upp. sternum.	Mid. sternum.	Right clavicle.	Left clavicle.	Right 3rd rib.	Left 3rd rib.	Remarks.
Male, æt. 27...	F.	92	—	85	80	—	—	(R.) Healthy. (L.) Consolidation of upper lobe, commenced 1 year ago, after repeated hæmorrhages.
	U.	90	—	105	90	—	—	
Male, æt. 34...	F.	—	—	—	—	68	59	(R.) Commencing deposit. (L.) Consolidation to 4 in., commenced 1 year before, after syphilis, &c.
	U.	—	—	—	—	90	69	
Male, æt. 26...	F.	65	75	55	55	95	100	(R.) Consolidation to 7 in. from apex. (L.) vomica at apex, commenced 1 year ago. Had syphilis 6 times, hæmoptysis 5 times.
	U.	50	70	45	40	80	100	
	O.	—	—	—	—	25	30	
Fem., æt. 27...	F.	15	35	25	43	50	35	(R.) Consolidation at apex, with vomica. (L.) Tubercular infiltration throughout, except lower lobe behind.
	U.	30	50	25	35	60	80	

The movement-register in the cases in Table XXIII. on the preceding page is considerable, and yet they all succumbed at an early period after the measurements were taken.

Upon wider experience there may perhaps be found other sources of exception to the conclusions which I have ventured to draw from the limited number of cases so far examined. It is possible also that some of the peculiarities of motion which I have observed in phthisis may not be confirmed by others. The area of observation has undoubtedly been too small to afford a firm basis on which to erect a method of prognosis. But I submit that a case has at least been made out for further inquiry—and even if some of the conjectures here made should be contradicted by subsequent research, we may still confidently look to stethometry to furnish very valuable practical information not otherwise attainable.

APPENDIX.

APPENDIX.

ON THE NATURE AND QUANTITY OF THE ORGANIC MATTER CONTAINED IN RESPIRED AIR.

IT has long been known that other substances besides gases and watery vapour are exhaled from the lungs. The contamination of the breath by alcoholic drinks or volatile oils from such foods as garlic and onions would be sufficient to prove this. Careful experiments also on the subject have been made by Nysten, Orfila, Magendie, Milne Edwards, and Tiedeman. These observers found that such substances as camphor, phosphorus, musk and garlic, when injected into the veins, appeared in the breath almost instantaneously.

Tiedeman infers from these facts that the lungs act as "a genuine excretory organ for the venous blood," that volatile unassimilable substances, which have been conveyed into the blood from the food, which cannot serve in forming arterial blood, and are capable of evaporation, are thrown off in the cells and bronchi of the lungs, and removed with the expired air.

In all probability also the quality of the matter given off varies at different ages, in various diseases, and even at different periods of the day. Thus fasting breath is often very offensive, and the odour of the breath varies in children, adults, and in old age. "In the advanced stages of phthisis it is often disagreeable, sometimes putrid and ammoniacal. In malignant putrid fevers the breath is often fœtid. The breath of rickety, scrofulous children is said to have a sour smell, and in some advanced cases of kidney disease it has a distinctly noxious odour."

It seems possible also, to quote again from Tiedeman, that in certain forms of disease "a variety of miasmata or contagious particles are thrown off by the blood-vessels of the lungs, and that many of those remarkable changes called crises, which are occasionally observed in fevers, are effected in this way."—*Brit. and For. Med. Review*, 1836, p. 246.

These observations are sufficient to show that the presence of organic matter in respired air has been well known for many years. The *nature* also of some part at least of the organic matter, has been tolerably well ascertained.

It is stated in the *Dictionnaire des Sciences Médicales*, published in the year 1820, that the "sérosite animale," as the aqueous vapour of the lungs is there called, is charged with albumen, and that it putrefies when left to stand for some time, and it is mentioned that MM. Séguin and Juvine, in 1789, completely proved the close analogy between the cutaneous and the pulmonary transpiration.

More recently, *i.e.*, during the last twenty years, Dr. Angus Smith has included this subject in his elaborate researches on the air of towns, and has determined approximately the amount of organic matter in respired air, and he has also endeavoured to connect with them observations upon the occurrence of malaria and epidemic disease.

The actual quantity however of the organic matters contained in the breath, and its intimate nature, has only been very imperfectly ascertained as yet.

The quantity of "sérosite animale," according to the

Dictionnaire des Sciences Médicales, is given by Menzies as two grains per minute, and by others as twelve grains.

Valentin estimated the quantity of organic matter in respired air by the degree of coloration imparted to sulphuric acid by breathing through it, and he regarded it as questionable "whether under normal circumstances any ammonia is contained" in the breath. (*Text Book of Physiology*, by Brunton, p. 250.)

Dr. Angus Smith used his sepometer, and the test of permanganate of potash to determine the quality of breathed air, and Dr. B. W. Richardson demonstrated the presence of free ammonia by passing the breath over hydrochloric acid, and condensing the resulting muriate of ammonia in crystals upon microscopic slides, but it will be seen that no very accurate analyses of the breath could be expected from these methods of examination.

We have, however, recently been supplied by Messrs. Wanklyn and Chapman with a very ready and accurate method of determination of organic matter in aqueous fluids, and this means has the further advantage of estimating separately the free ammonia, the urea, and other such compounds, and the more complex organic matters.

The following analyses of the amount of organic matter contained in human breath were made by this method. The aqueous vapour of the breath was condensed in a large glass flask, surrounded by ice or snow, and salt, by which a temperature of several degrees below zero was obtained. In the first essays the number of breaths was counted, and the flask washed out with distilled water, but this was soon found to be unsatisfactory, as the extent of the expirations varied so greatly. The aqueous vapour was then collected and measured, and tested as follows :—

If enough fluid had been obtained, a certain quantity (generally about 20 minims) was mixed with 50 C. C. of distilled water, and tested for free ammonia by means of the Nessler test. An equal portion of the fluid was then mixed with 30 minims of a saturated solution of carbonate of soda, and about 10 oz. of pure distilled water, ascertained, by further distillation, to be free from ammonia. The mixture was then distilled, and the distillate tested for ammonia until it ceased to give any indications of its presence. This testing would give all the free ammonia, together with any of this gas arising from the action of the carbonate of soda—for instance, from the decomposition of urea.[1]

Fifty C. C. of a strong solution of permanganate of potash and caustic potash were then added to the retort and distillation again continued ; the quantity of ammonia now given off would arise from the destruction of organic matter. The results of these examinations are given in the following tables ; Table I. giving the records relating to healthy breath, Table II. of breath from persons affected by various disorders.

In both Tables, are given in successive columns, (1) the number of the observation, (2) the nature of the case, (3) the period of the day, and (4) the extent of breathing ; then follows in milligrammes, the amount of free ammonia or ammoniacal salts determined, (5) directly by the Nessler test, and (6) by distillation with carbonate of soda, a column (7) is then provided for any difference between these two readings, giving the ammonia from urea, or other matter decomposible by the weak alkali. The ammonia obtained by oxidation of the organic matter comes next, (8) then the total amount of ammonia obtained, (9) and (10) a calculation of the quantity of ammonia to be obtained from 100 minims of the fluid collected—finally a note is appended to those cases in which any peculiar microscopic appearances were observed.

[1] See Water Analysis, by Wanklyn and Chapman, Trübner and Co. p. 55.

TABLE I.

Amount of Ammonia obtained from Healthy Human Breath by Messrs. Wanklyn and Chapman's Method of Water Analysis (in milligrammes).

No.	Case.	Age.	Time.	Extent of Breathing.	Free Ammonia.	By distillation with carbonate of soda.	Difference due to Urea, &c.	Organic ammonia from oxidation.	Total.	Amount in 100 drops of the fluid collected.
1	Male; healthy, strong, large	33	4 hours after late dinner	10 prlngd. breaths, about 2 in min.	—	Not separated	Not separated	—	0·06	—
2	Male; healthy, medium size	35	4 hours after late dinner	15 breaths, about 4 in minute	0·03	—	—	0·045	0·075	—
3	Male; healthy, medium size	35	5 hours after late dinner	20 breaths, about 4 in minute	—	0·	—	0·10	0·10	—
4	Male; healthy, medium size	35	1 hour after late dinner	25 breaths, ♏xx collected	♏x. 0·03	♏x. 0·03	0·	0·05	0·08	0·400
5	Male; healthy, medium size	35	1 hour after late dinner	20 prlngd. breaths	—	0·035	—	0·05	0·085	—
6	Male; healthy, strong	31	1 hour after breakfast	20 breaths, ♏xxv. collected	—	0·035	—	0·06	0·095	0·370
7	Male; healthy, undersized	40	1 hour after late dinner	7 minutes, ♏xx. collected	—	0·	—	0·085	0·085	0·425
8	Male; healthy, middle height, strong	18	4 hours after mid-day dinner	15 minutes, ♏xl. collected	♏xx. 0·02	♏xx. 0·02	0·	0·055	0·075	0·375

TABLE I.—(*continued*).

No.	Case.	Age.	Time.	Extent of Breathing.	Free Ammonia.	By distillation with carbonate of soda.	Difference due to Urea, &c.	Organic ammonia from oxidation.	Total.	Amount in 100 drops of the fluid collected.
9	Male ; healthy	9	1 hr. after dinner	20 minutes, ♏XLV. collected	♏XX. 0·02	♏XX. 0·02	0·	0·035	0·055	0·275
10	Female ; healthy, medium height	29	1 hour after luncheon	20 breaths, ♏X. collected	—	0·01	—	0·025	0·035	0·350
11	Female ; healthy, medium height	24	2 hours after six-o'clock tea	20 breaths, ♏X. collected	—	0·015	—	0·025	0·04	0·400
12	Male ; strong, healthy	30	9 o'clock P.M.	♏XL.	♏XX. 0·02	♏XX. 0·02	0·	0·045	0·065	0·325
13	Female ; small	28	3 o'clock P.M.	♏LXX.	♏XXX. 0·02	♏XXX. 0·02	0·	0·05	0·07	0·233
14	Female ; weak, delicate, otherwise healthy	31	7 o'clock P.M.	♏XX.	0·01	—	—	0·03	0·04	0·200
15	Male ; healthy, strong	34	7 o'clock P.M.	♏XXX.	♏XV. 0·015	—	—	♏XV. 0·035	0·05	0·330
16	Air of railway carriage (eight passengers) after fifteen minutes. Windows shut, ventilators open. About two cubic feet			Halitus condensed	—	0·03	—	0·03	0·06	—

TABLE II.

Showing the Amount of Ammonia obtained from the Breath in different Diseases (in milligrammes).

No.	Case.	Age.	Time.	Extent of Breathing,	Free ammonia.	By distil. with carb. of soda.	Differnc. due to Urea, &c.	Organic ammonia from oxidatn.	Total.	Amt. per 100 drops of fluid collectd.	Special microscopic objects.
1	Female; measles, 10th day	19	After breakfast	15 minutes ♏XLV.	♏XX. 0·	♏XX. 0·	0·	0·03	0·03	0·150	Small-celled conferva after 18 hours
2	Male; measles, 6th day	28	Noon	8 minutes ♏XV.	—	0·005	—	0·02	0·025	0·175	Small-celled conferva
3	Male; measles, 5th day	28	Noon	♏X.	—	0·005	—	0·01	0·015	0·150	
4	Female; phthisis, much expectoration	33	1½ hour after breakfast	20 minutes ♏LX.	♏XXX. 0·01	♏XXX. 0·01	0·	0·04	0·05	0·165	
5	Female; phthisis, much expectoration	28	Afternoon	15 minutes ♏L.	♏XX. 0·01	♏XX. 0·01	0·	0·03	0·04	0·200	Vibriones and spores after 24 hours
6	Fem.; advanced phthisis both sides	28	Afternoon	20 short breaths	—	0·	—	0·05	0·05	—	
7	Fem.; advanced phthisis, scanty expectoration	18	11 A.M.	♏VIJ.	—	—	—	0·02	0·02	0·290	
8	Female; catarrh, pregnant 6 months	29	1 hour after luncheon	15 minutes ♏XLV.	♏XX. 0·005	♏XX. 0·01	0·005	0·03	0·04	0·200	Vibriones and spores after 18 hours
9	Male; slight catarrh	7	Shortly after dinner	10 minutes ♏XX.	—	♏XX. 0·01	—	0·03	0·04	0·200	Very perfect epithelium
10	Male; slight catarrh	32	Half hour after tea	40 breaths ♏XXX.	♏XV. 0·	♏XV. 0·	0·	0·045	0·045	0·300	
11	Female; diphtheria, 6th day, improving, no albumen in urine	28	10 A.M.	♏LXX.	♏XX. 0·	♏XX. 0·	0·01	0·03	0·04	0·200	Straight-celled conferva

TABLE II.—(*continued*).

No.	Case.	Age.	Time.	Extent of breathing.	Free ammonia.	By distil. with carb. of soda.	Differnc. due to Urea, &c.	Organic ammonia from oxidatn.	Total.	Amt. per 100 drops of fluid collectd.	Special microscopic objects.
12	Fem.; whooping-cough 4 weeks	10	1 hour after dinner	25 minutes ♏XC.	♏XX. 0·01	♏XX. 0·01	0·	0·05	0·06	0·300	Small-celled conferva after 12 hours
13	Fem.; whooping-cough 4 weeks	8	1 hour after dinner	15 minutes ♏XLV.	♏XX. 00·1	♏XX. 0·01	0·	0·045	0·055	0·275	
14	Male; typhus fever, 19th day	20	3.30 P.M.	10 minutes ♏XX.	—	♏XX. 0·02	—	0·04	0·06	0·300	
15	Female, ozœna	34	3 P.M.	♏L.	♏XX. 0·02	♏XX. 0 02	0·	0·08	0·10	0·500	
16	Female; severe ozœna. Breath emerging from condenser free from odour	15	10 A.M.	♏XX.	—	♏XX. 0·03	—	0·04	0·7	0·350	
17	Male, senile gangrene	70	7 P.M.	♏XX.	—	0·01	—	0·02	0·03	0·150	
18	Female; phthisis, abundant expectoration. Incipient albuminuria (Dr. Roberts)	17	4 P.M.	♏XXIV.	♏XIJ. 0·005	♏XIJ. 0·02	0·015	0·06	0·08	0·666	
19	Male; albuminuria, slight, under hydropathy	68	11 A.M.	15 minutes ♏XL.	♏XX. 0·02	♏XX. 0·02	0·	0·08	0·10	0·500	
20	Male; albuminuria, uræmia impending. P.M. week after, large white kidney (Dr. Roberts)	13	4 P.M.	♏XL.	—	♏XL. 0·12	—	0·21	0·33	0·825	

TABLE II.—(*continued*).

No.	Case.	Age.	Time.	Extent of breathing.	Free ammonia.	By distil. with carb. of soda.	Differnc. due to Urea, &c.	Organic ammonia from oxidatn.	Total.	Amt. per 100 drops of fluid collectd.	Special microscopic objects.
21	Male; albuminuria, dropsy. P. M. in 2 weeks. Large white kidney (Dr Morgan)	45	4 P.M.	♏ XL.	♏ XX. 0·045	♏ XX. 0·08	0·035	0·10	0·18	0·900	
22	Male; albuminuria, heart disease, congestion of lungs, hæmoptysis (Dr. Roberts)	40	4 P.M.	♏ XXIV.	♏ XIJ. 0·025	♏ XIJ. 0·025	0·	0·04	0·065	0·545	
23	Female; rheumatic fever, 12th day	35	3 P.M.	♏ X.	—	♏ X. 0·01	—	0·02	0·03	0·300	
24	Female; ozœna	40	4 P.M.	♏ XXIV.	♏ XIJ. 0·01	♏ XIJ. 0·01	0·	0·035	0·045	0·375	Dark epithelium
24	Female: diphtheria, no albumen in urine	15	8 P.M.	♏ XXIJ.	0·01	—	—	0·02	0·03	0·240	
26	Female; albuminuria, heart disease, dropsy	35	4 P.M.	♏ XXX.	♏ XV. 0·015	♏ XV. 0·02	0·005	0·04	0·06	0·400	
27	Male; albuminuria, phthisis, copious expectoration	31	5 P.M.	♏ XV.	0·025	—	—	0·03	0·055	0·366	Conferva, granular epithelium
28	Female; scarlet fever, 7th day	15	7.30 P.M.	♏ XV.	0·000	—	—	0·03	0·03	0·200	Very granular yellow epithel.

The number of examples I have collected is still small, but they are brought forward now in the hope that others may be induced to undertake the same inquiry. It is one hich requires many observers, and I think that the results, so far as they have been obtained, justify the attempt to enlist others in the work.

I. HEALTHY BREATH.

The breath of fifteen healthy persons was examined, and the quantity of aqueous vapour was ascertained in eleven instances. The persons examined were of different sexes and ages, and the time of the day at which the breath was condensed varied.

It may be observed that the amount of free ammonia varies considerably, and I have not so far been able to connect the variation with the time of the day, the fasting or the full condition.

It has been stated by more than one observer that urea is sometimes present in the breath ; it was therefore sought for in nineteen instances, five healthy persons, and fourteen cases of disease, but it was only found in three cases of kidney disease, in one case of diphtheria, and a faint indication of its presence occurred in the breath of No. 8 Table II., a pregnant female suffering from catarrh.[1]

The quantity of ammonia arising from the destruction of organic matter also varies somewhat, possibly from the oxidation of albuminous particles by the process of respiration, but it may be noticed that in healthy persons there is a remarkable uniformity in the total quantity of ammonia obtained by the process. Amongst male adults the maximum quantity per 100 minims of the fluid collected was 0·45, and the minimum was 0·325 milligrammes. Amongst females there is some reason to believe that the aqueous vapour contains a smaller percentage of organic

[1] No albuminuria was present in these last two cases.

matter, and the variation is somewhat greater, the lowest amount being ·2, and the highest ·4 of a milligramme. It is not easy to estimate the total quantity of organic matter thus got rid of by the lungs of even healthy persons.

We are told by Messrs. Wanklyn and Chapman that every part of organic ammonia discovered corresponds to about 10 parts of albuminous matter, but, on the other hand, the quantity of aqueous vapour carried off by the breath varies with age and season. If, however, we take the ordinary quantity of this fluid, for an adult, to be about 10 oz. in the twenty-four hours, and the average amount of ammonia given off as 0·4 of a milligramme in every 100 minims of fluid, then we obtain the rough approximation that in ordinary respiration about 0·2 of a gramme or 3 grains of organic matter is given off from a man's lungs in twenty-four hours.

At first sight this seems to be a very minute quantity to be thus disposed of; but when it is considered that the most impure water examined by the authors of the process contained only 0·03 of a gramme of organic matter per *litre*, it will be allowed that there is ample quantity to permit of putrefaction, and to foster the growth of organic germs.

We cannot doubt that the diseases which arise as a consequence of overcrowding find at least a starting-point in the impure vapours arising from the lungs and the general surface of the body.

II. IN DISEASE.

In diseased states of the system we find a much greater variation in the amount and kind of organic matter given off. The breath of 27 cases of disease was examined. In 3 cases of catarrh, in 2 of measles, and 2 of diphtheria, the total ammonia obtained was much less than in health; a result which is probably due to the abundance of mucus in those complaints by which the fine solid particles of the breath were entangled. The cases of whooping-cough were children, and therefore the deficiency noted in the organic matter given off by them may be due to age—and this is the more probable since the only healthy child's breath examined contained about the same quantity (0·275 of a milligramme) of organic ammonia, as in the cases of whooping-cough. In two cases of phthisis with abundant expectoration, the total ammonia was also less than in health, but in one case of this disease with abundant purulent sputa associated, however, with Bright's disease, a large amount of organic matter was given off. We cannot doubt, however, that the albuminuria which was present in this case had an influence upon the result. A portion of the ammonia was in fact due to urea or to some kindred substance; and we may perhaps ascribe the general excess of organic matter to some peculiarity in the breath due to the kidney disease.

It is in fact in kidney diseases that the largest amount of organic matter of all kinds is to be found in the breath. Seven cases suffering from these diseases are recorded. In three cases urea was found, in two it was not sought for and in two others it was absent. The free ammonia in all the cases is abundant; in two of them (Nos. 20 and 21) excessively so, and the organic ammonia is also large in amount. The total quantity of ammonia found is in excess in all the cases except in one (No. 27) a male, who was also phthisical and had much expectoration. In one case it rises as high as 0·9 milligrammes in 100 minims of fluid, and in another to 0·825.[1] Probably if the sputa in these cases had been examined, a much larger proportion of matters decomposible by carbonate of soda would have been found. I would suggest that the pre-

[1] These facts are opposed to the experience of Dr. Lionel Beale, who (p. 191), on Urinary Diseases, states that he has several times examined the breath of patients affected by kidney disease, and that he has not obtained indications of more NH_3 than in healthy persons.

sence of these substances either in the bronchial mucus, or in the aqueous vapour of the breath, would be a fair indication that their elimination by the kidneys and skin was deficient, and that measures should be taken to improve the action of these organs. In one case of ozœna, the total quantity of ammonia obtained was greater than in any of the healthy subjects, but the free ammonia did not seem to be in excess. In another case, however, a girl of fifteen, whilst the total quantity of the gas was probably not much greater than normal, the free ammonia formed nearly half the amount collected. In a third case, a female, there was no noticeable peculiarity.

The case of typhus fever was obtained in the fever wards of the Manchester Royal Infirmary; but it was scarcely a fair example of this disease, since it was already convalescent. There was, however, apparently a deficiency in the total amount of organic matter got rid of from the lungs. I might have attributed this fact to the feebleness of respiratory power, the blast of air being insufficient to carry with it much foreign matter, had not the cases of kidney disease (Nos. 18, 20, 21, and 23) been equally if not more feeble. This explanation is, however, still a possible one, and it is strengthened by the fact that in the case of senile gangrene, a feeble old man, but without catarrh, the organic matter of the breath was very small in quantity.

The case of rheumatic fever showed no very definite peculiarity; the organic ammonia was slightly less than in health.

As a matter of curiosity the air of a railway carriage, containing eight persons, was examined, after fifteen minutes' occupation, with the windows shut and the ventilators open. In this instance the breath was inspired through the apparatus, about eighty inspirations being taken; probably between two and three cubic feet of air would thus pass through the freezing mixture. Very little moisture was condensed, but what was obtained was strongly charged both with free ammonia and organic matter. (See Table I, No. 12.)

In the year 1857, in consequence of a letter in the *Times* newspaper signed "Investigator," I exposed glass plates covered with glycerine in different places, amongst others in the Manchester Infirmary, and in the dome of the Borough Gaol, Manchester. In this latter establishment, all the air from the cells is conducted by the system of ventilation employed into the dome. The plates were afterwards carefully searched with the microscope, but at that time I could recognize little except fibres of cotton and wool, and shrivelled epithelial scales; there were also some singular-looking bodies, but these I found afterwards were contained in the glycerine used to cover the slips of glass.

Upon another occasion during a crowded lecture at the Free Trade Hall, about 3,000 persons being present, I drew the air from one of the private boxes (raised about 40 feet above the audience) by means of exhausting bellows, through a system of narrow tubes, filled with distilled water, the operation being conducted for a space of about two hours. The water was emptied from the tubes, allowed to settle for thirty-six hours, and the sediment was examined microscopically. The following objects were noted at the time, and sketched under the microscope, the quarter-inch power being used:—fibres; separate little cellules; nucleated cells, surrounded by granular matter (about six in one drop of water); numerous scales like degenerated epithelial scales.

I have also searched with the microscope most of the specimens of aqueous vapour from the lungs. In all of them epithelium, in different stages of deterioration, was abundantly present; and a difference in the appearance of the scales could be marked according to the age of the patient, those from young persons being notably the most perfect and fresh-looking. In one case of kidney disease, the only one examined (No. 27), they had a granular appearance, and in one case of ozœna they were darkened in colour. Probably a large portion of the organic matter of the breath consists of these epithelial particles. Very few spores were found in any fresh specimen ; but, on the other hand, after the fluid had been kept, in some instances for only twelve hours, even in a cold room, myriads of active vibriones and many spores were found. In one case of diphtheria, straight-celled, greenish-coloured confervoid filaments were noticed ; and in four other cases, two of measles, and one of whooping-cough, and one of phthisis with albuminuria, abundant specimens of ,a small, round-celled conferva, were found, resembling the penicilium glaucum, and these were seen to increase in numbers and in size for two days, after which they ceased to develop.

It may be interesting to note that the fluid in which these objects were found was neutral or slightly alkaline, whereas the mould-fungus generally prefers a slightly acid fluid.

These differences in the nature of the bodies met with are interesting as showing some occult differences in the nature of the fluid given off in the several cases, but many additional observations would be needed before we could draw any inferences from them.

They certainly do not as yet afford any proof of the germ theory of disease, nor do they justify the alarming doctrines, which have been rife of late, as to the presence of organisms in the breath. They simply show the readiness with which the aqueous vapour of the breath ferments or putrefies, and the consequent danger of overcrowding, and the paramount importance of ventilation.

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