COLLECTED WORKS

OF

FRANCIS SIBSON, M.D.

VOL. II.

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OF

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ON THE MOVEMENTS OF RESPIRATION IN DISEASE, AND ON THE USE OF A CHEST-MEASURER.

THE incomparable Laennec says, "L'inspection du thorax pendant la respiration est très peu utile." Well did Dr. Forbes remark, in translating this passage, that Laennec underrated the inspection of the motions of the chest as a means of diagnosis.

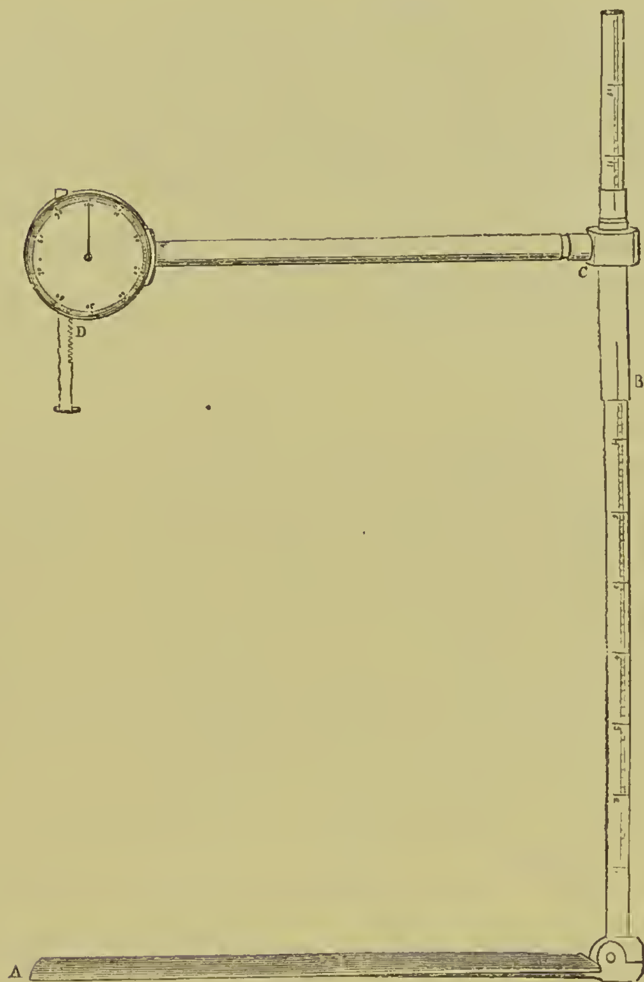
Notwithstanding this opinion of Laennec, almost all the principal subsequent authors on the diseases of the chest, such as, among others, Andral, Collin, Dr. Forbes, Dr. C. J. B. Williams, Sir James Clark, Dr. Stokes, M. Voilliez, M. Fournet, Dr. Watson, and Dr. Walshe, have successively investigated the respiratory movements in chest disease. There has been indeed, of late years, a growing sense of the importance of observing the motions of respiration in forming a diagnosis.

Impressed with the importance of the inquiry, and desirous of ascertaining the true value of the phenomena in diagnosis, I have for some years investigated the movements of respiration in health and disease. Many of my observations on this subject were published in 1844 in the *Transactions* of the Provincial Medical and Surgical Association, in a paper on "The Changes in the Situation of the Internal Organs;" and in 1846, in the *Philosophical Transactions*, in a paper "On the Mechanism of Respiration," which treated of the anatomy and movements of the breathing apparatus in man and other animals supplied with lungs.

In pursuing the researches comprised in those papers, I found the want of an instrument for accurately and minutely measuring the movements of respiration. About two years ago I succeeded, with the assistance of a patient in the Nottingham Hospital, and finally of Mr. Simmonds, in completing such an instrument. It is a *Chest-Measurer*, measuring the diameter of the chest, and indicating by the motion of the index on a dial any movement of respiration to the hundredth of an inch. It is in fact a micrometer of motion. It can be readily applied to any part of the body, and by successive applications of it over the chest and abdomen, all the movements of respiration can be ascertained with minute accuracy. The character as well as the extent of motion may be read off from the dial. It indicates the rhythm of respiration, showing whether the expiration be equal to, longer or shorter than, the inspiration.

The chest-measurer shows the exact amount of chest movement, both during tranquil breathing and the deepest possible inspiration and expiration. It thus tells indirectly the extreme breathing-capacity of the chest, which is rendered perfectly by the "spirometer" with which Dr. Hutchinson has made so many valuable observations. In this respect it is indeed a "pocket spirometer."

To assist in the inquiry into the movements of respiration, I have made diagrams from the dead—in health and in disease—of the position of the ribs and internal organs, both before and after the complete inflation of the lungs. I traced



THE CHEST-MEASURER.

A. Brass plate, covered with silk, on which the patient lies (see the figure at p. 13).

B. Upright rod, divided into inches and tenths, to indicate, by the slide at B, the diameter of the chest.

C. B. Slide, moving on the vertical rod B, and carrying the horizontal rod and dial C. D.

C. D. Horizontal rod, dial and rack (D). This rod can be drawn out like a telescope from C—an outer rod sliding on an inner; and as the outer rod can be rotated on the inner, the inclination of the rack and dial can be varied at will by the finger and thumb. This combination of slides forms a universal joint (see fig. at p. 13).

D. Rack and dial. The rack, when raised by the moving walls of the chest, moves, by means of a pinion, the index on the dial. One revolution of the index indicates an inch of motion in the chest; each division indicates the 100th of an inch.

The Chest-measurer packs into a pocket case.

the outlines of the organs with chalk on a piece of black lace, stretched on a frame, and placed over the body. I transferred these outlines to paper, and reduced them by a pentagraph. The tracing-frame and the pentagraph were the suggestion of my friend Dr. Hodgkin. Engravings from these diagrams were published, in the papers referred to above, in the *Provincial Medical and Surgical*, and the *Philosophical*, *Transactions*, and very recently in the *Medical Gazette*.

Mr. Kaim, of Nottingham, has taken for me the daguerreotypes which accompany this paper. The outlines of the organs in the tranquil state, and during the deepest possible inspiration, were previously traced on the skin. Two successive daguerreotypes were taken from each person, one showing the form of the chest and the position of the organs in the tranquil state; the other showing the changes produced when the lungs were expanded to the full.

PART I.

ON THE MOVEMENTS OF RESPIRATION IN HEALTH.

We cannot of course recognise the respiratory movements in disease, unless we know what they should be in health. I shall, therefore, detail what I have observed to be those movements in health.

The materials for the inquiry consist in the diagrams above referred to; tabulated observations of the position of the thoracic viscera in the tranquil state, and during a deep inspiration, in eighty persons, of both sexes and various ages, in whom the lungs and heart were healthy; and tabulated observations made with the chest-measurer, of the movements of the ribs and abdomen in fifty-seven persons free from organic disease. In many of these the capacity of the lungs was ascertained by the spirometer.[1]

In health, every part of the chest expands during each inspiration, whether the breathing be tranquil or exaggerated.

The costal motion in tranquil breathing is, in the robust man, exceedingly small. In a man whose chest was the finest in development I have seen, and who stands third among English runners (Westall, Case 12 in Table I.), the motion of the second rib, taken in the sitting posture, was, in tranquil breathing, ·03 to ·05 of an inch, while during the deepest possible inspiration it moved forwards 2·25 inches. Here the motion of the second rib was forty-five times greater when the chest was expanded to the full than it was in tranquil breathing. This man was about 5 feet 9 inches in height; his weight was about 12 stone; he expelled 290 cubic inches at one expiration, and the greatest inspiratory expansion of the circumference of his chest was $5\frac{1}{2}$ inches.

In this person, slight as were the costal movements during tranquil breathing, they were yet quite palpable over every part of the chest examined.

Dr. Hutchinson says, in his paper on the Respiratory Functions, "This is supposing a costal motion, which I believe rarely exists." In every person I have yet examined I have found the costal movements to exist, whenever respiration has not been controlled by volition. By the aid of the chest-measurer, any one may verify this observation.

[1] See the annexed Table I. In all the persons included in this table, the internal organs were, after careful examination, considered to be healthy. The majority of them were surgical and medical patients in the Nottingham General Hospital. I had two reasons for preferring such persons to those in perfect health; firstly, they were completely at my command; and, secondly, they were more nearly allied, in general health, to those cases of chest disease with which they were to be compared, but from which they differed in this— that their internal organs were healthy.

Without this instrument the costal motion in tranquil breathing can be observed with difficulty.

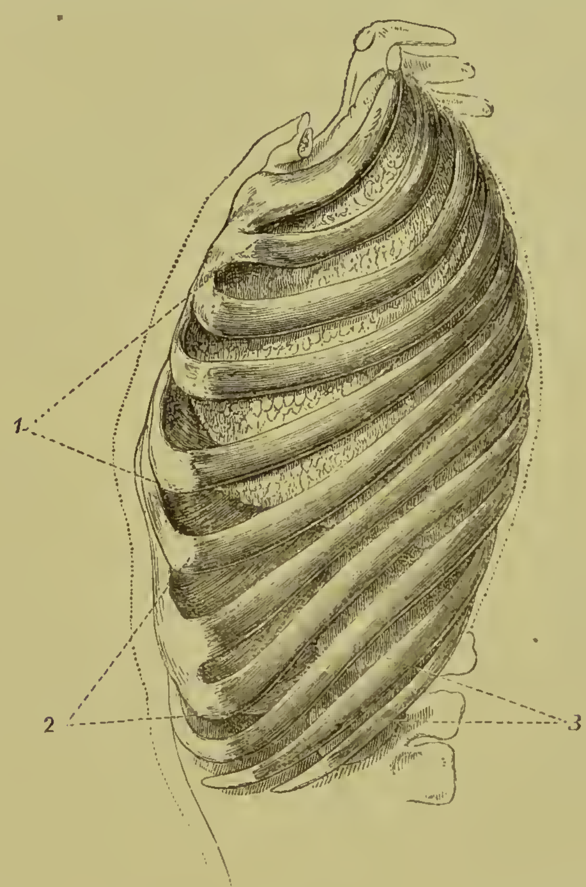
Division of the Ribs into Three Sets,—Thoracic, Diaphragmatic, and Intermediate.

Thoracic Set of Ribs—First, Second, Third, Fourth, and Fifth.—See the figure at the next page.—The lower margin of the right lung, and the lower boundary of the heart, are anteriorly just above the sixth costal cartilages. In front, the lungs and heart lie wholly behind the sternum and the five superior ribs, which I have termed, in the paper on the Mechanism of Respiration, THE THORACIC SET OF RIBS, and which form in front the true thorax. The motion of the thoracic set of ribs expands the superior and middle lobes. To the side, the lower margins of the lungs, as they spread outwards, pass successively within the sixth, seventh, eighth, ninth, tenth, and eleventh ribs.

Diaphragmatic Set of Ribs—Ninth, Tenth, Eleventh, and Twelfth.—The ninth, tenth, eleventh, and twelfth ribs protect the lower and back part of the lungs, and, in great part, the liver, stomach, and spleen. They give origin to the diaphragm, and when the diaphragm acts they move outwards and backwards to expand the lower and back part of the lung, and they form the *diaphragmatic* set of ribs.

Intermediate Set of Ribs—Sixth, Seventh, and Eighth.—The sixth, seventh, and eighth ribs are both diaphragmatic and thoracic in their position and action; they form the *intermediate set*, and expand the upper portion of the lower lobe, and, on the descent of it, the lower portion of the upper lobe.

The division of the ribs into the three sets of thoracic, diaphragmatic, and intermediate, which I proposed on anatomical grounds, I find of practical value in the diagnosis of disease, as I shall have to state more fully hereafter. The important practical point to bear in mind with regard to the



1. The Thoracic set of ribs.
2. The Intermediate set of ribs.
3. The Diaphragmatic set of ribs. The left lung, the heart, stomach, spleen, and left kidney are seen through the intercostal spaces.

The dotted lines indicate the outlines of the chest when the lungs are fully inflated (as they are during a deep inspiration).

respiratory movement of the different sets of ribs is, the portion of lung that each set expands.

During a deep inspiration, the anterior portions of the ribs move forwards and upwards, and through the intervention of their cartilages carry forwards and upwards the sternum;

while the posterior portions of the ribs move backwards, and push backwards the dorsal column.

The dorsal vertebræ form an arch, and as the ribs of the intermediate set, the sixth, seventh, and eighth, are longer than those of the thoracic set, they thrust backwards the middle of the dorsal arch further than those of the thoracic set push backwards the upper part of the arch ; the dorsal arch is consequently deepened, and therefore shortened.

The shortening of the dorsal arch, and consequent lowering of the head, during each involuntary inspiration, is very manifest to the eye in persons, especially in females, lying on the side, suffering from dyspnœa.[1]

[1] Dr. Hutchinson says (*Med.-Chir. Transactions*, vol. xxix. p. 191), "The head is protruded and lowered in the deep expiration," "raised and thrown back in the deep inspiration." I am satisfied that this is accurate as applied to those he observed, who were examined when erect, and who were desired to expire and inspire deeply ; as they were erect the straightening and lengthening of the lumbar curve counteracted the deepening and shortening of the dorsal curve. Besides this, their breathing was voluntary. They elevated the head with one set of muscles, while they expanded the chest with another. One thing is certain, that in the erect posture, although healthy men usually raise the head when they take a deep voluntary inspiration ; yet women in tight stays, whose breathing is markedly costal, and persons affected with emphysema, lower their heads when they inspire involuntarily, to the extent of ·01 to ·02 in. When I take a deep inspiration, I can either elevate the head ·50 in. or lower it ·40 in., or keep it perfectly still, so much control has will over the movements of respiration. In the tranquil breathing of men, the shortening of the dorsal arch is imperceptible, their costal respiration being so trifling ; but in females it may usually be observed. It follows from these observations, which can be readily verified, that Dr. Hutchinson's remark, that "The body is lowered or shortened in expiration," must be qualified ; as in the instances I have mentioned, the body was then markedly lengthened. During voluntary deep expiration, and during the act of coughing, the body is markedly shortened, as then the powerful abdominal muscles pull downwards and forwards the sternum and ribs, and through them, bend forward the lumbar vertebræ.

Each of the four or five superior ribs (the thoracic set) ascends during inspiration more than the rib above it; they consequently then move nearer to each other; while the diaphragmatic and intermediate ribs move further apart. This, as I have shown in my paper on the Mechanism of Respiration, is in great part due to the articulation of the ribs with a movable dorsal arch.[1]

[1] Dr. Hutchinson says, p. 215, "In inspiration the ribs diverge from each other, in expiration they converge towards each other." This statement, correct as regards reptiles and birds, requires to be qualified in regard to man, and the mammalia who possess, like man, a dorsal arch. It may be easily observed on a thin person, by placing one finger on the third and another on the first rib, that they converge during inspiration, while, by adopting the same plan, from the seventh to the twelfth, it will be found they diverge. The divergence of the diaphragmatic ribs is very great, and it is in part owing to their great divergence that the action of the middle parts of the tenth and eleventh external intercostals is expiratory; while it is owing to the great convergence of the upper ribs that the internal intercostals between the first and the third ribs are inspiratory, thus reversing in each instance the natural action of those muscles, the former of which is in the bird and reptile throughout inspiratory, and the latter throughout expiratory. I beg to refer on this interesting subject to the plates and description in the paper on the Mechanism of Respiration.

Postscript, August 1848.—It is interesting to notice that these views, which I hope to have an early opportunity of demonstrating, account for and reconcile the different views of the action of the intercostals, held by the great physiologists of the last century, who occupied themselves so warmly in what may be termed the battle of the intercostals.

Hamberger constructed a machine representing the sternum, the vertebræ, and two ribs, with threads interposed to imitate the external and internal intercostals and the inter-cartilaginous muscles. From this he inferred that the external intercostals are all inspiratory—the internal all expiratory, and that the inter-cartilaginous muscles are inspiratory.—(Haller, *de Respiratione. Opuscula Anatomica*, pp. 50, 92.)

Of this machine, Haller says, "Ponit nimirum CL. AUCTOR machinæ suæ costam utramque æque mobilem esse. Sed hujusmodi costas DEUS nobis non dedit."

In opposition to Hamberger, Haller observed that he had overlooked, among other things, the difference of mobility in different ribs—the second rib being five times more movable than the first, and so on;

When the thoracic set of ribs approach each other, their cartilages ascend and the inter-cartilaginous portions of their internal intercostal muscles act during inspiration.[1]

and he showed, from experiment, that during extreme inspiration the space between the first and second ribs diminished from ·85 in. to ·63 in.; and on extreme expiration it again increased from ·63 to ·89 (p. 52). He also showed that the ribs rotated on themselves, the lower edge moving outwards (p. 126). That the external intercostal and the inter-cartilaginous muscles were inspiratory, he agreed with Hamberger; but he differed altogether with regard to the internal intercostals, which he observed to be inspiratory in the superior intercostal spaces, especially in the first, in many experiments carefully conducted. He noticed that, below, the internal intercostals scarcely acted; but he laid it down as a rule that the internal and external intercostals combine to expand the chest during inspiration, thus agreeing with Mayow.

In this controversy both were right and both were wrong. Each was right in what he observed; but he did not observe the whole of the complex respiratory apparatus. Hamberger was right as to the lower ribs, for they diverge during inspiration. Haller as to the upper ribs, for they then converge. Hamberger, with Bayle, Fabricius, and Hoadley, was right in part, as to the separate functions of the outer and inner intercostals, the external being inspiratory, the internal expiratory throughout, behind and between the intermediate and adjoining ribs, at the side in man and the other mammalia, and throughout in reptiles. Haller was right in stating that the internal and external intercostals acted together in the upper intercostal spaces.

Dr. Reid, in an admirable article on respiration (*Cyclopædia of Anatomy and Physiology*, vol. iv. p. 333), says, the two lower ribs descend during inspiration. I observe that the lowest is stationary, the eleventh ascends, and both move backwards. From this relative motion of the two lowest ribs, whether on Dr. Reid's view or mine, the lowest external intercostal must be expiratory.

I imagine that Dr. Hutchinson's machine (which is like diagrams in Hoadley's, Bernoulli's and Monroe's works, and in my own paper) resembles Hamberger's, and that, like Hamberger, in acknowledging partial truth, he had been led into partial error.

[1] "The cartilaginous portions" "of the second, third, fourth, and fifth ribs" "are, during inspiration, raised and brought nearer to each other by the contraction of the sternal and inter-cartilaginous portions of the deep intercostal muscles."—The Author, on the "Changes in the Situation of the Internal Organs," *Provincial Medical Trans.*, vol. xii. p. 354.

The movements that take place during a deep inspiration are these:—the scapulæ are raised; the anterior portions of the ribs, the sternum and the clavicles, move forwards; the posterior portions of the ribs and the dorsal and lumbar vertebræ move backwards; the sternum and the dorsal arch become, both of them, more curved; the third, fourth, and fifth costal cartilages at each side of the sternum advance more than the sternum, and the anterior prominences formed by those cartilages become fuller; the angles of the ribs move backwards more than the spine, and the deep space formed for the lung to each side of the spine increases in depth; the ribs expand laterally to a great but varying extent, the diaphragm descends, and the abdomen protrudes considerably, often more than an inch.

These movements of thoracic expansion are necessarily attended by the expansion and descent of the lungs and heart, and the compression and descent of the liver, spleen, and stomach, and all the abdominal and pelvic viscera.

The lungs of course spread wherever the space is increased for them. The bulk of the upper portions of the lungs is in front, and of the lower portions behind; and, in conformity with this arrangement, the inspiratory movements of the superior ribs, or the thoracic set, is chiefly forwards and upwards, while that of the inferior or diaphragmatic set is chiefly backwards, (see the dotted lines in the figure at page 13, which indicate the thoracic expansion anteriorly and posteriorly,) the lower ribs not ascending so much as the upper, and the lowest of all having scarcely any ascending motion.

The diaphragm, in its descent during a deep inspiration, first flattens its own convexity, especially on the right side, and then descends from an inch to an inch and a half. It consequently, lessens the concavity at the base of each lung, especially the right, and draws down the whole base of each lung; in front, the right base descends from the lower end of the sternum to the lower end of the xiphoid cartilage, and both bases descend from the sixth costal cartilages to the seventh. At the side and behind, the descent is in the same proportion. The contraction of the central muscular fibres of the diaphragm draws down its central tendon from three-quarters of an inch to an inch. The heart is necessarily drawn downwards to the same extent; while the lungs spread into the space previously occupied by the heart, and cover it to an increased extent, so that the exposed portion of it is diminished. The heart is now shielded by the left lung at the fourth and fifth intercostal spaces, and its impulse is no longer felt there, but it is felt instead, behind, below, and to the left of, the xiphoid cartilage.

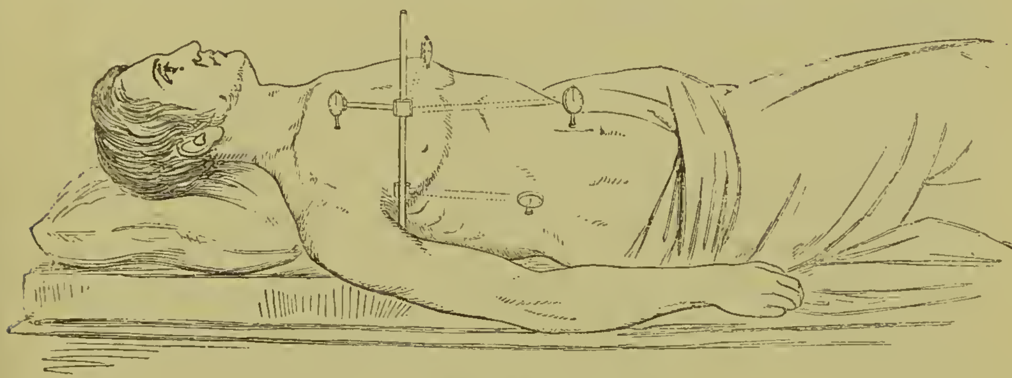
While the descent of the diaphragm lengthens the thorax it compresses the abdomen. The liver, stomach, spleen, pancreas, kidneys, and all the abdominal organs, the uterus (the inspiratory descent of which has been felt by Dr. Frederick Bird), and all the pelvic viscera, are pushed downwards during a deep inspiration; at which time the perinæum protrudes more than it does in the tranquil state.

These inspiratory movements of the diaphragm have doubtless an important physiological action on the abdominal organs, in thus displacing and compressing them. The blood, which accumulates during expiration in the solid viscera, is, during inspiration, drawn off, and the hollow viscera have their innate contractile force assisted.[1]

[1] Dr. Hutchinson says, op. cit., p. 187, "It appears to me a matter of doubt whether the diaphragm in the act of inspiration descends at all." This doubt has arisen from the falling in of *a part* of the abdomen during voluntary deep inspiration in the erect posture. In healthy persons when recumbent the abdomen between the xiphoid cartilage and the umbilicus

On the Employment of the Chest-Measurer in Health.

The immediate indications afforded by the chest-measurer in health must be considered during ordinary involuntary respiration, and during the deepest voluntary respiration.



CHEST-MEASURER APPLIED.

By placing the instrument in the manner here represented, the patient lying on the flat plate forming the basis of the instrument (see fig. at p. 3), the rack and dial, by a little adjustment, can be successively applied over the various parts of the chest and abdomen without disturbing the patient.

The patient should be desired to look at the ceiling, that his attention may not be directed to the dial, by watching which his inspiratory movements are inevitably disturbed.

The instrument should be steadied by the hand holding the slide carrying the rod and dial, the finger and thumb having hold of the outer rotating tube of the horizontal rod (see fig. at p. 3).

To make a complete examination, the rack and dial may be successively applied over the different parts of the chest and abdomen, in the manner detailed in the note in the opposite page.

In almost all cases I employed the chest-measurer when the patient was lying on the back, perfectly straight, in bed. The instrument was thus perfectly steadied by the patient

moves forward, during an ordinary inspiration, ·3 in., and during a deep inspiration from ·5 in. to 1·5 in.

Any one may readily prove to himself the extensive descent of the diaphragm during a deep inspiration. Percuss over the lower margin of the right lung, ascertain its boundary, and mark it ; desire the person to lying on the horizontal flat plate that forms its basis: the whole antero-posterior motion was conveyed to the index on the dial; and the examination was made in the manner usually most convenient, especially in hospital practice. It mattered little, however, whether the recumbent or sitting posture was adopted, so long as all the observations were made in the same manner.[1]

take a deep breath, and hold it; then percuss downwards, and the hepatic dulness will be replaced by pulmonic resonance to the extent, in the adult, of an inch or an inch and a half. Notice the seat of the heart's impulse, first during ordinary breathing, and then during a deep inspiration; it will be displaced from the intercostal spaces, and will be felt behind or even below the xiphoid cartilage,—a manifest proof that the extensive descent of the central tendon of the diaphragm draws down the heart. Notice the forward movement of the abdomen between the xiphoid cartilage and the umbilicus during a deep inspiration both in the recumbent and the erect posture; taking care not to be led astray by the irregular and volitionary play of the abdominal muscles that often takes place, especially when the person is erect.

No other proof of the descent of the diaphragm during a deep inspiration is needed than the inspection of Dr. Hutchinson's own accurate silhouettes, p. 186, 191. In diagram 16, p. 191, the abdominal organs from the ensiform cartilage to within a shade of the umbilicus are considerably more prominent during a deep inspiration than in the tranquil state, and they are everywhere more prominent than they are during a deep expiration.

1 To observe the motion of the sternum and the thoracic set of ribs, and the expansion of the upper lobes, the middle lobe of the right lung, and the heart, I applied the instrument successively to the upper and lower end of the principal bones of the sternum, to the second rib, and to the fourth or fifth costal cartilage within and below the nipple;—to ascertain the motion of the intermediate ribs, and the expansion of the upper portion and bulk of the lower lobe and the lower portion of the upper, it was placed over the sixth rib in front and to the side, and the eighth ribs to the side;—to discover the motion of the diaphragmatic set of ribs, and the expansion of the lower portion of the lower lobe, and the displacement of the abdominal organs through diaphragmatic breathing, it was applied over the tenth ribs. Finally it was applied to the abdomen in the centre, between the lower end of the sternum and the umbilicus, and at each side, to ascertain the motion of the diaphragm.

Many and various applications of the instrument, of course by no means required in actual practice, were adopted in my inquiry, with the view of bringing the subject of the respiratory movements in health and disease to the test of accurate and general observation.

Motions observed by the Chest-Measurer during an Ordinary Inspiration.

In robust healthy males from the age of 12 to 45, the motion of the first six ribs (the thoracic and the uppermost of the intermediate set) was found to be trifling, but still in every case and everywhere some slight motion existed.

The motion of the upper end of the long bone of the sternum is usually from ·02 to ·06 in.; that of the lower end is about the same. The motion of the upper end is often greater than that of the lower; but the reverse is sometimes

After taking these observations successively, and in the latter cases simultaneously on the two sides with two chest-measurers, I repeated them all, after desiring the patient during each observation to take as deep a breath as possible, and blow out as far as he could.

I then took the actual diameter of the chest from dorsum to sternum, and from side to side, at the fifth, eighth, and tenth ribs.

I also measured each side, at various places, with tape, from sternum to dorsum, observing the mobility of the ribs during the deepest possible inspiration and expiration.

Finally, the number of respirations in the minute, the extreme capacity of the chest, as tested by the spirometer, and the height and weight, were taken.

I also described the form of the chest and its surfaces, the position of certain of the viscera, and the changes induced in the seat of them, and the heart's impulse during a deep inspiration. (These notes are in my possession, and are accessible to any one interested in the subject.)

It was necessarily only the healthy *males* that underwent all this examination, and indeed only a portion of them. The Tables and the Cases in the Appendix will tell which were complete and which incomplete, as far as regards their examination.

the case. The motion of the second ribs near their costal cartilages is a little greater than that of the corresponding portion of the sternum. The sternum is, indeed, pushed forward by those ribs through the medium of their cartilages; but a part of the force is spent in slightly bending the cartilages, and consequently the forward motion of the second ribs is necessarily greater than that of the sternum; thus, while the movement of the sternum is from ·02 to ·06 in., that of the second rib is from ·03 to ·07 in.

The advance of the sixth costal cartilages usually corresponds to that of the lower end of the sternum, being from ·02 to ·06 in.

The movement of the fourth and fifth costal cartilages is usually scarcely equal to that of the second ribs.

The lateral expansion of the sixth rib is in almost all cases less than the forward motion of the sixth costal cartilage; but in this comparison the lateral expansion of each sixth rib is taken separately, while the whole forward movement over the sixth cartilage is observed from dorsum to sternum: the whole lateral expansion of the chest, from sixth rib to sixth rib, is equal to, or even greater than, the whole antero-posterior expansion of the chest over the sixth costal cartilage.

Owing to the presence of the heart, the motions of the left fourth, fifth, and sixth cartilages, and the sixth rib, and indeed of all the left lower ribs, are less than those of the right; the difference being most usual and greatest over the fourth and fifth cartilages, and at the lateral expansion of the sixth rib.

The motions of the five superior or thoracic ribs are, with the exceptions stated, everywhere pretty nearly equal.

The lateral motions of the eighth and tenth ribs are almost invariably greater than those of the thoracic ribs and cartilages, so long as the breathing is quite tranquil, and the motion of the thoracic ribs small; the lateral expansion of the eighth and tenth ribs ranges usually from ·05 to ·1 in., while the motions of the thoracic ribs and cartilages vary from ·02 to ·05 in. It will be remarked, that if the motion of the thoracic ribs be greater than usual, say ·06 to ·1 in., the lateral motion of the eighth and tenth ribs is not increased, and then all the costal motions are nearly equal.[1]

There is very little difference between the exact motion of the ribs in healthy robust boys and in men, from the age of 10 upwards to 45. This rule does not, however, obtain with regard to the diaphragm; for while in man, during tranquil respiration, the advance of the centre of the abdomen between the xiphoid cartilage and the umbilicus is from ·25 to ·35 in., in boys and youths it is from ·2 to ·25 in.

The movements of the abdomen to each side is about the same in boys and men, being usually from ·08 to ·12 in.

It is manifest, from these observations, that in tranquil breathing diaphragmatic respiration far outweighs costal, in the proportion of about 30 to 5. It is also evident that the eighth and tenth ribs have a greater expansion than the throracic ribs, owing to their action being auxiliary to that of the diaphragm.

Respiratory Movements during the deepest Voluntary Inspiration.

When a person takes as deep an inspiration as possible, the motion both of the ribs and diaphragm is everywhere much greater than during tranquil breathing, but the increased motion of the ribs is much greater than that of the diaphragm.

As I have stated above, the greatest observed difference

[1] See Stevenson, Case 32, Table I.

between the motion of the second ribs during tranquil breathing and their motion during the deepest possible inspiration was in the runner ·05 in. and 2·25 in., or in the proportion of 1 to 45. This was, however, a man of unusual thoracic mobility and breathing-capacity, and his was in every respect an extreme case. The amount of increased motion evidently bears a ratio to the capacity of the lungs and the mobility of the chest. Contrast the third of the following cases with the other two :—

Number in Table.	Name.	Height.	Extreme capacity of lungs.	Motion of second rib during	
				Tranquil breathing.	Deepest Insp.
		Ft. In.	Cubic Inches.	In.	In.
17	O'Connell	5 $8\frac{1}{2}$	170	·03 to ·07	·50
6	Nettleship	5 $4\frac{1}{2}$	190	·02 to ·07	·50
12	Westall, the runner .	5 $8\frac{1}{2}$	290	·05	2·25

In all these cases I felt satisfied that there was no chest disease.

The eye, on running down the columns of the respiratory movements in ordinary and exaggerated breathing in health (Table I.), will observe that in some cases where the breathing-capacity is small, the extreme costal motion is considerable, while in others, where the capacity is great, the extreme costal motion is comparatively but little. I do not doubt, however, that, if a sufficient number of cases were collected, it would be found that the extreme respiratory motions, as indicated by the chest-measurer, will, as a general rule, agree with the sound and important conclusions to which Dr. Hutchinson has arrived with regard to the breathing-capacity and the influence upon it of height, mobility of chest, age, weight, and other circumstances.

One thing is certain, that the extreme range of motion may vary considerably in persons whose chest and general system are perfectly sound. This is, I take it, in great part due to the inability of many persons, when recumbent, to inspire and expire deeply when directed so to do. In practice we shall find that healthy persons when recumbent may have a range of extreme respiratory motion varying from one-half or three-quarters of an inch to about an inch and a half, or even two inches.

The various ribs have nearly the same amount of motion during extreme respiration, but the lateral motion of each rib is less than its anterior motion. The extent of motion of the diaphragm is about the same as that of the ribs, since it descends about an inch ; and that of the abdomen, between the lower end of the sternum and the umbilicus, is also about an inch, sometimes more and sometimes less.

The motion of the lower or diaphragmatic ribs and the eighth rib, which in tranquil breathing is greater, is in extreme respiration less than that of the thoracic ribs.

Many persons in perfect visceral health, affected with pain or injury, or some peculiarity of constitution, have an ordinary costal expansion of ·08 to ·12 or ·14 in.: in such persons the diaphragmatic motion is from ·20 to ·25 in., and the motion of the diaphragmatic ribs and the eighth ribs, instead of being greater, is often only equal to or even less than that of the thoracic ribs. (Table, Cases 28—37.)

In one man—Clay, (Table I., Case 30)—who had suffered from sciatica, the breathing, instead of being natural, was rather a succession of irregular sighs about nine in the minute ; the second ribs had during inspiration a motion varying from ·1 to ·2 in., the abdominal muscles (diaphragm) advanced ·9 in. to 1 in., and the eighth and diaphragmatic ribs moved outwards from ·3 to ·4 in. In extreme inspiration the second rib advanced 1 in., and the abdomen (diaphragm) 1·60 in.

Respiratory Movements in Boyhood and Old Age.

In boys the cartilages are more flexible, and the costal mobility is greater than in adults. The extreme costal motion is in them greater in proportion to their breathing-capacity than in adults. Thus in Coupe, (Table I., Case 25,) aged 11, whose height was 4 ft. 7½ in., and breathing-capacity only 110 cubic inches, the ordinary movement of the second rib was ·06 in. and the extreme movement 1·30. Some boys, especially if they have been long in bed, have very little command over their inspiratory muscles, and in them the extreme movement may be slight. In Greenfield, (Table I., Case 27,) for instance, a boy of ten years of age, pale, having a diseased knee, but whose chest was healthy, the ordinary motion of the second rib was ·03 in., and sometimes 0, and the extreme motion ·3 in. Such boys, besides their irregular volition, are manifestly out of practice in the complete action of their ribs.

In old age (Table I., Cases 38—44) each cartilage is ossified, forming with the rib one unbending piece. The costal motion is carried on by the lateral anterior and posterior thrust of the solidified rib and cartilage; and in old men, owing to the non-yielding of the cartilages, the advance of the sternum, both during ordinary and extreme inspiration, is often greater than that of the second rib. In this respect old age differs remarkably from boyhood, when, owing to the great flexibility of the cartilages, the costal advance is greater than the sternal.

For the same reason, namely, the completion into one unyielding piece of the rib and cartilage in the aged, the lower end of the sternum, owing to the sixth and seventh ribs being longer than the second, usually advances more than the upper portion; while in youth, owing to the flexibility of the cartilage, the upper portion of the sternum usually advances more than the lower end.

In the aged, the lateral motion of the sixth rib is increased, during both ordinary and deep inspiration, while that of the diaphragmatic ribs is diminished.

The ordinary diaphragmatic breathing of the aged is rather above the average, being from ·3 to ·5 in., but its extreme movement is not remarkable.

The difference both in the ordinary and extreme respiratory movement of the left diaphragmatic and intermediate sets of ribs, as compared with the right, is usually more marked in old age than in youth.

In the adult period of life the younger man has more often those varieties of costal motion characteristic of the boy, and the older man more often those of old age.

Influence of Height on the Respiratory Motions.

Height has a preceptible influence on the extreme costal motion, following the important law laid down by Dr. Hutchinson, that the breathing-capacity increases with the height.

I feel convinced of the soundness of Dr. Hodgkin's view that the increased capacity with height is in great part due to the increased length of the dorsal portion of the spinal column. The long-bodied dwarf given by Dr. Hutchinson at p. 184 does not really militate against this view, as that man is evidently a deformity.

An additional reason for the greater capacity of the tall is, I conceive, the greater length of their ribs as well as of their other bones. If so, in the narrow-chested tall man of great breathing-capacity, the ribs will be more oblique than in a short man whose chest is of equal diameter but whose capacity of breathing is smaller. In such a case, the tall man will have a greater range of motion of his ribs, just as he has of his thighs when he raises them.

Respiratory Movements in the Healthy Female.

In the adult female, the form of the chest and abdomen, and the respiratory movements, are often undoubtedly modified by tight lacing.

The form of the chest and the respiratory movements do not differ preceptibly in girls and boys below the age of 10. Although the form of the chest remains nearly the same until the age of 12, the abdominal movement is then somewhat less, and the thoracic somewhat greater, in girls than boys. At this age, and earlier, stays are worn; and though they do not compress the body materially, yet they restrain the free expansion of the lower ribs during brisk exercise. After the age of 14 the form of the chest and the respiratory movements differ materially in females and males. The transverse diameter of the chest from seventh rib to seventh, instead of being greater than that from fifth rib to fifth, as it is in males, is in females considerably less. This difference is greater or less, in proportion as the stays are worn more or less tight. There is a great difference in the respiratory movements, when the stays are on, and when they are off. When they are on, the thoracic movement is very much exaggerated, the second ribs then moving forward from ·06 to ·2 in., while when they are off, they only move forward from ·03 to ·1 in. On the other hand, the movements of the lower ribs and diaphragm are much more restrained when the stays are on (the abdominal movement being then ·06 to ·11 in.), than when they are off (the abdominal movement being then from ·08 to ·2 in.). During a deep inspiration the disproportion in the abdominal movement, or rather that at the so-called waist, is still greater, being about ·1 in. when the stays are on, and from ·15 to ·4 in. when they are off. The difference at the waist, when measured with the tape, is very striking, the increased measurement during an extreme inspiration being ·05 to ·3 in. when they are on, and from ·6 to 1·5 in. when they are off. I have found the circumference at the waist from one to two inches less when the stays were worn than when they were taken off.[1]

[1] The form of the chest in Ann Winfield, aged 6, (Table I., Case 52,) and Eliza Elsom, aged 11, (Table I., Case 49,) did not materially differ from that in boys of about the same age and size; and in M. Daft, aged 17, (Table I., Case 48,) but whose form and development was that of a girl of 14, the difference in form was inconsiderable.

In Winfield, during inspiration, the upper end of the sternum advanced	·05 in.;	the abdomen	·25 in.
In Elsom, the second rib advanced	·10	„	·20
In Daft „ „	·06	„	·18 to ·20

Elsom and Daft both wore stays, and though the stays were loose, yet I conceive that their influence upon the chest had already commenced.

Jane Goodall, aged 33, (Table I., Case 45,) had at one time worn very tight stays; in her, while the lower part of the chest over the intermediate and diaphragmatic ribs was remarkably compressed, the seventh costal cartilages of the opposite sides below the sternum, being pressed near each other, the upper part of the chest was excessively developed. The diameter of the chest from side to side was from fifth rib to fifth rib 10·2 in., and from eighth rib to eighth rib 9·5 in. Compare this with Elsom's chest, in which these measurements were respectively 8·4 and 8·6 in., and with Daft's, in whom the influence of stays was more pronounced, and in whom the measurements were respectively 9·5 in. and 9·3 in.

In Goodall the second rib advanced, during each ordinary inspiration with stays on ·12 to ·2 in., and the abdomen ·08 in., (as well as it could be ascertained,) and the waist expanded during the deepest possible inspiration only $^1/_{10}$th of an inch. When she had her stays off, the second rib advanced ·06 to ·08 in., the abdomen ·12 to ·2 in., and the extreme expansion of the waist was about 1 in.

In Eliza Ball, aged 25, (Table I., Case 47,) who had always worn loose

These observations render it certain that the wearing of stays materially influences the respiratory movements, lessening the movement of the diaphragmatic ribs, and exaggerating that of the thoracic. Even comparatively loose stays tend to produce this effect; since, though they may allow the ordinary movements of the diaphragm and the lower ribs, yet they do not permit their normal extreme movement, and they prevent the outward displacement of those ribs when the stomach and intestines are distended. I think it probable that in females, even if they wore no stays, the thoracic respiration would be relatively greater, and the diaphragmatic less, than in man; but this is only surmise.

The expansion of the lower ribs is much more impeded by stays than the descent of the diaphragm; indeed, I observed in one instance an increased movement over the lower part of the abdomen when the stays were on, to make up, apparently, for the diminished expansion of the lower ribs.[1]

stays, the chest was not so excessively full above and contracted below as was that of Goodall; the upper and lower diameter being respectively 11·7 in. and 11·2 in. The motion of the second rib with stays on was ·05 to ·11 in.; with the stays off ·12 to ·25 in. In Ball, though the stays were loose, they prevented the full expansion of the lower ribs during a deep inspiration; since, when they were on, the extreme expansion of the waist was $^3/_{10}$ths of an inch, and when they were off, an inch and a half. Here, although the stays were loose, there was an inch of compression, and the expansion which ought to have been an inch and a half, was only $^3/_{10}$ths of an inch.

In Julia Green, (Table I., Case 45,) the amount of compression from stays was two inches, although the stays were not so tight as usual.

[1] In Goodall, (Table I., Case 45,) the waist could only expand the tenth of an inch, while the lower part of the abdomen expanded $^7/_{10}$ths, when her stays were on; yet, when they were off, the waist expanded an inch and a half, the abdomen only half an inch.

Respiratory Movements in Children.

The respiratory movements in children are difficult to observe, owing to their irritability and constant motion.[1]

Although, in children, the inspiratory movement of the abdomen, indicating diaphragmatic respiration, is greater than that of the upper part of the thorax, yet it is not nearly so much so as it is in the adult: in children, the abdominal movement being from ·06 to ·15 in., and the thoracic, at the second ribs, from ·02 to ·12, or even ·15 in.

The respiration of children is notably different in this circumstance, that in them the lower end of the sternum and the adjoining cartilages, instead of advancing during inspiration, usually fall backwards. This is especially remarkable during rapid or sobbing inspiration.

The inspiratory falling back of the lower part of the chest is much more marked when the abdomen is large, its amount bearing a ratio to the abdominal prominence.

In children the abdominal organs are of greater bulk than the thoracic; and when, owing to the descent of the

[1] In a child one day old I found the thoracic expansion to be ·03 in., and the abdominal ·03 in.; but the latter was more continuous than the former.

In J. Drake, aged 2 months, (Table I., Case 53,) a perfectly healthy child, observed when asleep, the upper portion of the sternum and the second rib moved forwards during inspiration ·02 to ·04 in., while the lower end of the sternum and the sixth cartilage fell back from ·01 to ·02 in., and the lateral motion of the sixth and eighth ribs fell in ·01 in.; the abdominal advance was ·08 to ·15 in., and the diaphragmatic ribs, auxiliary to the diaphragm, moved outwards ·03 to ·04 in.

In Smith, aged 6 months, in perfect health, the upper ends of the sternum advanced during inspiration ·01 to ·03 in., the second rib ·1 to ·15 in., and the abdomen ·1 in.; while the lower end of the sternum and the sixth rib in front and at the sides fell back, during inspiration, from ·01 to ·08 in.

diaphragm, the latter replace the former, the walls of the chest collapse wherever the smaller thoracic replace the larger abdominal organs.

If the disproportion between the thoracic and abdominal organs be slight, and the inspiration gradual, the lower part of the chest may possibly not recede.[1]

When, owing to the inspiration being deep, the lungs enlarge considerably, the lower end of the sternum and the adjoining cartilages advance. When this is the case, they usually recede at the beginning of inspiration, and advance during its progress.[2]

If the cartilages and ribs be yielding at their junction, as in rickety children, the sixth, seventh, and eighth ribs and their cartilages bend inwards at the side, close to their point of junction, during inspiration, and in this case the lower end of the sternum is thrust forward.[3]

[1] In M. A. Scott, (Table I., Case 56,) a well-formed child, comatose, and occasionally breathing freely, who eventually died, and in whom the chest was full and the abdomen moderate in size, the lower as well as the upper end of the sternum, the sixth cartilages, the eighth and tenth ribs, all moved forwards or outwards from ·02 in. to ·05 in., the abdomen advancing ·08 to ·12 in. In this well-formed child, when the breathing was exaggerated, the sixth rib at the side fell in ·01 in. to ·02 in., although during tranquil breathing it moved somewhat outwards.

[2] In Susan Hotter, aged 2 years 8 months, a healthy child, with a fractured thigh, in whom the abdomen was rather large, the sixth rib, which fell in ·03 in. during tranquil breathing, moved outward ·06 in. when she breathed deeply. In her, when the larger abdominal organs were replaced by the smaller lungs, the ribs over them fell back, but when the lungs were enlarged by a deep inspiration, they became larger than the abdominal organs, and then the ribs moved outwards.

[3] In Mary Wain, (Table I., Case 57,) an emaciated child of 2 years of age, thirsty, having a remarkably large abdomen and a small but prominent chest, the upper portion of the sternum moved forwards ·4 to ·5 in., and the lower portion ·12 to ·2 in., the sixth and eighth ribs and their cartilaginous portions on each side fell in ·02 to ·2 in., at the same time the abdomen moved forward ·15 to ·2 in., and the diaphragmatic ribs outward from ·05 to ·15 in.

Summary of the Respiratory Movements in Health.

In the healthy, robust male, the movement of the sternum and of the thoracic and intermediate ribs, from the first to the seventh, is from ·02 to ·07 in. during an ordinary inspiration, and from ·5 or ·7 in. to 2 in. (the amount varying with the extreme breathing-capacity) during a deep inspiration. The ordinary abdominal movement (diaphragmatic) is from ·25 to ·3 in.; the extreme, ·6 to 1·6 in. The ordinary lateral expansion of the diaphragmatic or lower ribs is greater, and the extreme expansion is usually less than the respective ordinary and extreme expansion of the thoracic or upper ribs. The expansion of the second ribs is usually alike on both sides; below, all the inspiratory movements, especially those over the heart, are usually somewhat less on the left side than on the right, both during ordinary and extreme inspiration.

In the healthy boy, owing to the greater flexibility of the costal cartilages, the extreme movement of the thoracic ribs is greater in proportion to the breathing-capacity than it is in the adult: the upper portion of the sternum advances more than the lower end during a deep inspiration; but there is little decided difference during tranquil respiration.

In the old man, owing to the consolidation of the cartilages, the motion of the sternum during inspiration is usually greater than that of the ribs (in youth it is less), and the lower end of the sternum usually advances more than the upper.

In females the thoracic expansion is exaggerated, and that of the diaphragm and the lower ribs is restrained, owing, in great part, to the use of tight stays. The difference is much greater when the stays are on than when they are off.

When the stays are on, the thoracic movement at the second ribs is from ·06 to ·2 in.; the abdominal, from ·06 to

·11 in. When they are off, the thoracic movement is from ·03 to ·1 in.; and the abdominal from ·08 to ·2 in.

The restrained movement of the lower ribs during a deep inspiration is much greater when the stays are on than when they are off.

In infants the thoracic expansion is considerable, being from ·02 to ·12 in.; while the abdominal is from ·06 to ·15 in. The lower end of the sternum and the adjoining ribs usually recede during inspiration, especially if the abdomen be large and the inspiration quick or sobbing.

The Rhythm of Respiration in Health.

In the perfectly tranquil respiration of the adult, inspiration and expiration are of nearly equal length. The inspiration is slow at the beginning, gradually quickens, and towards the end again becomes slow. The pause between inspiration and expiration is rather a transition than a pause; expiration, like inspiration, begins slowly, soon quickens, and towards the end of the act again becomes slow, gradually passing into the inspiratory act. In many healthy persons the duration and character of the two acts is exactly the same, each beginning slowly, quickening in the middle, and gradually becoming again slow towards the end. A perfectly normal respiration is, in the adult, exactly pendulum-like in rhythm.

In general, the expiration begins more rapidly and ends more slowly than the inspiration.

In females and children this is almost always the case; in them the inspiration is usually rather quick; the expiration starts off quickly and becomes very slow towards the end. This is especially the case if they be excited or the breathing hurried from any cause whatever. The inspiration is quick and loud. The expiration rushes off at the beginning with an audible gush, and then becomes gradually slower.

	Duration of Inspiration beats.		Duration of Expiration beats.
In the perfectly tranquil breathing of adults the inspiration is equal to the expiration, or as	6	to	6
Frequently in adults the inspiration is to the expiration as	6	to	7
In the tranquil breathing of women and children, inspiration is to expiration as .	6	to	8 or 9
In the hurried breathing of females, as .	6	to	10 or 12
In old age the expiration becomes again prolonged, and inspiration is to expiration as	6	to	8 or 9

When the expiration is prolonged, it usually begins quickly and ends slowly; and it may be observed that, in this case, the diaphragm ceases to act before the end of the expiration, while the costal contraction continues, however slightly, to the end of the act.

In many healthy persons having prolonged expiration, the expiratory action of the diaphragm begins, perceptibly, before that of the ribs.

PART II.

CAUSES THAT DISTURB THE RESPIRATORY MOVEMENTS, THE LUNGS THEMSELVES BEING HEALTHY.

SECT. I.—*Cases in which the Motion of the Ribs on both sides is restrained.*

In posterior curvature at the fifth and sixth dorsal vertebræ the motion of all the ribs above the curvature, and of the upper portion of the sternum, is restrained though not annihilated, while that of the ribs below it, and of the lower end of the sternum, is exaggerated; the action of the diaphragm being much increased.

If the curvature be at the last dorsal vertebra, the motion of the ribs immediately above is restrained, while that of the thoracic ribs and the abdomen (diaphragm) is exaggerated.[1]

SECT. II.—*Cases in which the Motions of the Ribs on one side may be restrained.*

These are, lateral curvature of the spine; injury or disease of the ribs; of the intercostal muscles, including pleurodynia;

[1] Effect of posterior eurvature of the spine on the respiratory movements:—

In the two cases observed with the chest-measurer, the motion of the ribs superior to the curvature was much interfered with. In the boy Bulwer, (Table II., Case 58,) in whom the first five dorsal vertebræ were perfectly horizontal, and all below the sixth quite vertical, the motion of the second rib was ·05 in., and of the fourth costal cartilage ·02 in., while that of the right eighth rib was ·1 in., and the left ·12 in., and that of the right diaphragmatic rib was ·18, and the left ·07. The motion of the sixth rib, which was immediately below the curvature, and the usual motion of which is less than that of the second, was, in Bulwer, even greater than that of the second. The lower end ot the sternum, which was considerably more prominent than the upper, moved forward ·15 in., while the upper part of the long bone moved forward only ·05 in. This great increase in the motion of the lower end of the sternum is due to the greatly increased range of motion of the lower ribs. The motion of the abdomen, which was greatly increased at the sides, was but little affected in front, the movement at each side being ·18 in., while that in the centre was only ·2 in. In the case of a youth, (Table II., Case 59,) obligingly shown to me by Mr. Hare, whose posterior curvature had been (as shown on a cast) very great indeed, but was then very materially lessened, the motion of the lower end of the sternum, which protruded considerably, was ·1 in., while that of the upper end of its long bone was only ·02 in. The abdominal motion was in this case very great anteriorly, being, in tranquil respiration ·5 in., and on deep inspiration 1·5 in.; but the lateral abdominal movement was only ·1 in. on the right side, and ·07 in. on the left.

of the mamma; or of the axilla, shoulder, or arm, and probably hemiplegia.[1]

A.—*Effect of Lateral Curvature of the Spine on the Respiratory Movements.*—In excessive curvature with the convexity to the right, the left lung is very small, and the left ribs are all approximated, while the right ribs are unusually far apart. During inspiration, the whole costal and diaphragmatic expansion of the left side of the chest is restrained, while that of the right side, especially of the diaphragm and diaphragmatic ribs, is exaggerated.

If the convexity be to the left, the motion of the right side is restrained and that of the left exaggerated.[2]

[1] Effects of hemiplegia on the respiratory movements:—

I have made a cursory examination of several cases of hemiplegia, but have not met with one in which the amount of respiratory movement was palpably affected.

Dr. Todd favoured me with the examination of the case of Williams, (Table, Case 72,) at King's College Hospital, who had, in addition to hemiplegia, mitral regurgitation. In this poor woman, the left second rib moved ·08 in., while the right moved ·06 in., consequently this rib was not affected by the paralysis; over the fourth and sixth ribs, and, to a less degree, over the diaphragmatic ribs, the motion was lessened, and, at the sixth rib, was reversed on the left side; but this was manifestly due, not to the paralysis, but to the heart disease.

In the child, E. Brooks, (Table II., Case 73,) who suffered from left hemiplegia, there was little or no marked difference between the motion of the two sides.

Although I have not yet met with a case of paralysis in which the respiratory movements were affected, I think it likely that such cases exist. Paralysis of the voluntary muscles is complete in chloroformization, and yet the respiratory movements remain if the inhalation be not pushed too far. It is therefore clear, that even in complete hemiplegia of the voluntary muscles there may be no hemiplegia of the respiratory muscles. Under chloroform the diaphragm continues in action after the costal respiration has ceased. I think it probable that the same state of things may obtain in some cases of hemiplegia; that there may be hemiplegia of the costal muscles while the diaphragm on the affected side remains active.

[2] Movements of respiration in excessive lateral curvature:—

The ribs articulating with the concavity of the curvature are approxi-

If the curvature be inconsiderable, the costal motion may not be modified, though that of the diaphragm may, that side of it having the greatest motion which is in the direction of the convexity.[1]

B.—*Effects of Injuries or Diseases of the Ribs or parts contiguous to the Ribs on the Respiratory Movements.*—Non-motion or diminished motion of one side of the chest may exist, and yet the lungs may be perfectly healthy. The cases given below[2] prove that the respiratory motion of the

mated, as is well shown in the figure in Mr. Bishop's papers on deformities, in the *Lancet*, p. 63, July 1846 (while those articulating with the convexity of the curve are separated). In a girl, Jane Clifton, having extreme lateral curvature to the left side, of whom I have a diagram, the lower end of the sternum was drawn over, as well as the curvature, considerably to the left; the right lung was greatly diminished in size (it weighed 7 oz., while the left lung weighed 15 oz.), and the right belly of the diaphragm was much lessened.

In the case of a young person (Table II., Case 61) having extensive curvature to the right, (with the examination of whom Mr. Hare favoured me, and in whom the curvature, when I saw her, had been much lessened, the motion of the right second rib was ·2 in.; left, ·1 in.: right fourth rib, ·15 in.; left, ·03 in.: sixth rib, right, ·15; left, ·08: tenth rib, right, ·15 in.; left, ·03 in.: and in the abdomen, that of the right side was ·15 in., and left ·03 in. The central motion of the abdomen was ·35; of the lowest end of the sturnum ·12, and the upper end ·15.

[1] In the case of Beaton (Table II., Case 62) the lateral curvature with the convexity to the right side was slight, affecting the lower dorsal vertebræ. The gastric bulge was almost obliterated, while the hepatic bulge was greatly increased. In him the motions of the left side were generally nearly equal to those on the high side, or that of the spinal convexity. The difference in the motion in this boy's left diaphragmatic ribs was more markedly lessened, being ·03 in tranquil, and ·15 in deep respiration, while on the right side these ribs had the respective motions of ·06 and ·35.

[2] Respiratory movements modified by injury to, or disease of, the parts contiguous to the ribs, the lungs being healthy :—

I have a diagram, taken from a boy who, some years since, had his arm almost dragged off by machinery; the arm was removed at the shoulder-joint; the chest was itself uninjured; the lungs perfectly healthy.

whole of one side of the chest, or of any of the ribs, may be restrained, prevented, or reversed ; by the fracture of a

The whole of the left side had shrunk in, and, so far as the eye could judge, was motionless, while the right side was capacious and moved freely. The lower margin of the right lung descended during a deep inspiration nearly an inch, while the descent of the left lung was not perceptible, and the heart descended five-eighths of an inch. In this boy, as the wound healed, the size and motion of the left side gradually increased, until at length it was equal to, or probably even greater than, that of the right side. Here there was no injury to the ribs, and no affection of the lungs, yet the ribs adjoining the injury did not move.

In the case of a woman, aged about 40, admitted into the hospital, there was deep-seated cellular inflammation around the left scapula and shoulder-joint. She had a cough, expectorated frothy mucus, and had diminished motion, with falling in, and partial dulness on percussion over the second and third ribs below the left clavicle. The question presented itself, Did this dulness on percussion and non-motion depend upon disease in that part of the lung, or on the extensive and painful disease in the contiguous structures ? There were varying mucous and sonorous rhonchi in different parts of the chest, not more so at one part than another, and the presumption that the external disease was the cause of the non-motion was confirmed by the autopsy, which revealed extensive suppurative inflammation around the scapula and general bronchitis ; but there was no perceptible disease in the upper part of the left lung.

In Severn, (Table II., Case 63,) a lad in whom the left shoulder and left side of the neck and head were severely injured in a coalpit, but in whom there was no perceptible injury to the lungs or even to the ribs, the left second and third ribs fell in ·06 in. during inspiration, while the right second rib moved forward ·03 to ·06 in. ; the movements of the left diaphragmatic ribs and the left side of the abdomen were but little less than those of the right side. His recovery was slow. Several months after the injury, being then well, he was again examined, and it was found that the movement of both second ribs was alike. The exact injury was never ascertained in this case ; but from the complete recovery of lost motion, it is almost certain that his ribs were uninjured.

In the case of Frost, (Table II., Case 64,) extensive deep-seated cellular inflammation of the left arm ; in that of Bingham, (Table II., Case 65,) fracture of the left arm ; in that of Lane, (Table II., Case 66,) erysipelatous abscesses in the right axilla ; and in that of Mrs. Barker, (Table II., Case 67,) an extensive scirrhous ulceration of the mamma,—caused in each instance restraint in the motion of the contiguous thoracic ribs to an rib, abscesses in the intercostal spaces, local pleurodynia, inflammation of the axilla, shoulder-joint or arm, or fracture of the arm; in short, by any injury or affection of the

extent varying in proportion to the severity of the injury or disease. In the case of Ward, (Table II., Case 68,) there was an irregularity in the second rib from the union of a fracture inflicted years before; during tranquil breathing, though not during a deep inspiration, the motion of that rib was less than that of the corresponding rib on the left side. In the case of Parker, (Table II., Case 69,) there was an abscess between the second and third costal cartilages, and there were good reasons for thinking that no disease existed in the lung itself. The various motions of the second, fourth, and sixth ribs, were materially less on the affected than on the sound side, while those of the diaphragmatic ribs were quite normal. Sketchley, (Table II., Case 70,) a stout fellow, a porter, suffering habitually from bronchitis, was brought lately into the hospital with emphysema diffused through the cellular tissue of the body and right arm and hand; the third left rib was broken, causing a loud jerk during each inspiration. There was no pneumothorax; noisy rhonchi were audible over the whole chest. In this man the ribs of the injured side fell in during inspiration, while those of the right side in part moved forward. This case is, of course, complicated both with disease of, and injury to, the lung; but the side on which the injury was seated could be fixed upon, without the aid of any other sign, by the reversed motion of the affected side. The injured side in this case was indeed discovered by this sign before the precise injury was made out.

In addition to the causes just illustrated, pleurodynia may restrain the local respiratory movement, as the case of John Moore (Table II., Case 71,) evidences. He complained of a violent intolerable pain between the fourth and fifth left costal cartilages on moving or taking a deep breath, or rising in bed, or making any quick motion; indeed, his involuntary cries were very loud and agonising, and were accompanied by universal violent contraction of all the expiratory muscles.

The respiratory movements during tranquil breathing were everywhere normal, except at the region of the pain, over the left fourth and fifth costal cartilages, the motion on the right side was ·04 in., and that on the affected side ·005 in., sometimes ·03 in.

In this man there were no signs either of lung or heart disease, and the pain was evidently exclusively muscular. The normal character of all the other movements, except at this isolated patch, was in itself a demonstration of the soundness of the thoracic organs.

ribs or of the parts contiguous to the ribs. Whenever, indeed, the motion of one or more ribs would give pain to or injure either the ribs, the intercostal muscles, or any neighbouring part, their respiratory movements may be restrained or arrested.

SECT. III.—*Cases in which the Motion of the Ribs on one side may be permanently exaggerated.*

This happens from the loss of an arm, and certain congenital or acquired malformations.

When an arm is cut off, the weight with which it formerly bore upon the thoracic ribs is necessarily removed, the ribs are less restrained in motion on the mutilated than on the sound side, and the movements of those ribs are consequently exaggerated.[1]

In some persons there is excessive development of the right third, fourth, and fifth costal cartilages ; the respiratory movements may then be abnormally great over the unusually developed costal cartilages.

[1] Effects of the permanent loss of an arm on the respiratory movements :—

The removal of an arm necessarily lightens the weight with which it bore upon the ribs. The thoracic ribs are less compressed on that than on the opposite side. In W. Glossop, (Table II., Case 75,) a boy whose left arm was removed below the deltoid some weeks before, for an injury, the motion of the right second rib was ·15 in. to ·4 in., while that of the left was ·1 in. to ·3 in. The whole of the rest of the movements were quite normal. I do not doubt that this isolated case is a perfect type of its class ; it is so reasonable that the ribs should move more freely after the removal of the greater part of what was before a compressing weight.

SECT. IV.—*Cases in which the Motion of the Diaphragm, both during tranquil and deep Inspiration, is restrained.*

The motion of the diaphragm is restrained throughout by peritonitis, abdominal tumours, especially those connected with the diaphragm, and aortic aneurism. It is restrained on the right side only by greatly enlarged liver, from abscesses or hydatid cysts, and adherent liver.

A.—*Effect of Peritonitis on the Respiratory Movements.*—In peritonitis there is always great intestinal distension. The diaphragm is raised, and the lungs and heart are in consequence compressed upwards. The descent of the diaphragm and the abdominal movements are very much restrained, especially at the centre, where they are, indeed, sometimes annihilated. The diaphragmatic or lower ribs partake of the diminished movement of the diaphragm, to the action of which they are auxiliary. The motion of the superior or thoracic ribs is very much augmented. The movement of the lower end of the sternum is scarcely altered, its tendency to diminished motion, owing to the restrained diaphragmatic movement, being a little more than balanced by the exaggerated forward movement of the thoracic ribs.

The motion of the abdomen at the side is not so much lessened as it is in front, especially, I conceive, if the peritonitis do not seriously affect the serous surfaces of the diaphragm, and the liver, spleen, and stomach.[1]

[1] Effect of peritonitis on the respiratory movements :—

The diaphragm in peritonitis is nearly at rest, as during each inspiration the diaphragmatic movement would necessarily rub the inflamed surfaces upon each other, and thereby increase the affection. We consequently find that in peritonitis the diaphragmatic motion is very much restrained.

In the case of Barratt, (Table II., Case 76,) a man in the hale and

In *diffused* peritonitis the restrained abdominal movement is central and diffused; when the inflammation is *local*, the motion of the contiguous abdominal walls is lessened.

prime of life, affected with extensive peritonitis following the operation for hernia, the central abdominal expansion in tranquil breathing, which ought to have been ·3 in., was ·01 to ·05 in., and the costal breathing at the second rib, which ought to have been ·02 in. to ·04 in., was ·16 in. to ·22 in. In the same way, in Kew, (Table II., Case 77,) a young man with retention of urine and universal peritonitis, the abdominal movement was ·06 in., and that of the left second rib was ·3 in.; and in Hussey, (Table II., Case 78,) a female with peritonitis, the abdominal movement was ·03 in. and that of the left second rib ·4 in. In all these cases the central abdominal movement was slight, while the thoracic respiration was much exaggerated. The diminution of the abdominal and exaggeration of the thoracic breathing being in an inverse ratio to each other, as the one falls the other rises, until the actual amount of each may be exactly translated, the abdominal movement falling from ·20 in. or ·30 in. to ·03 in. or ·06 in., and the thoracic movement rising from ·03 in. or ·06 in. to ·20 in. or ·30 in.

In the case of Severn, (Table II., Case 79,) a spare young man who had chronic peritonitis with abdominal effusion, and from whom the effusion had almost but not entirely disappeared, the diminution of the central abdominal movement was proportioned to the mildness of the disease, it being ·08 in. to ·13 in., while that of the second ribs was ·1 in., and of the upper sternum ·13 in.; the proportion of diminished abdominal and increased thoracic movements being here, as in the extreme cases, strictly kept.

We may refer to Simpson's case, (Table II., Case 81,) in which the same ratio obtained, owing to an abdominal tumour, without peritonitis, the abdominal advance being here ·15 in. and the thoracic ·10 in. or .08 in.; and to the case of Clarke, (Table II., Case 84,) with abdominal distension, in whom the abdominal advance was ·20 in. and the thoracic ·08 in. or ·09 in.; and to that of Barton, in whom, from hepatic or abdominal adhesions, the abdominal movement at the centre was ·10 in., preceded by falling in, and the costal advance was on the left side ·30 and on the right ·19 in., the left movement being further exaggerated in his case by the restrained movement of the whole right lung.

Indeed, this important law of compensation obtains in every disorder of respiration,—when the movement is restrained in one part it makes up for it, and often more than makes up for it, in another. Besides this, in peritonitis, the demands on respiration, owing to the severity of the

Owing to the great exaggeration of thoracic respiration,

disease, are increased, and the respirations are not only more frequent but deeper.

It will be observed that in all the cases of peritonitis given, three of which were fatal, the lateral abdominal movement was but little lessened, being—

	At the sides of the abdomen— Right.	Left.	While at the centre it was—
In Barratt	·02 in.	·0 in.	From ·01 in. to ·06 in.
In Kew	·07	·08	·06
In Hussey	·07	·06	·03
In Severn	·1	·1	·08 " ·13
In healthy males . .	·09	·09	·25 " ·3
In healthy females .	—	—	·1 " ·2

[The figures denote the forward movement during inspiration.]

The case of Barratt, the only exception, is the best proof of the completeness of the law, that, when peritonitis is local, the motion of the contiguous abdominal walls is lessened. The peritonitis in this case followed the operation for strangulated femoral hernia on the *left* side, and there was no lateral motion whatever on the left side, while on the right it was ·02 in.

While the motion of the thoracic ribs was exaggerated, that of the diaphragmatic ribs was diminished. This is in accordance with the whole auxiliary function of those ribs.

The sixth rib has a slightly increased motion. Being the superior of the intermediate set, it partakes more of the increased motion of the thoracic than of the diminished motion of the diaphragmatic ribs.

In the subjoined Table the abdominal movement may be compared with that of the diaphragmatic ribs, and contrasted with that of the second ribs, and both may be compared with that of the sixth costal cartilages.

	Abdominal movement.			Diaphragmatic ribs.		Second ribs.		Sixth costal cartilage.	
	right.	centre.	left.	right.	left.	right.	left.	right.	left.
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
1. Barratt . . .	·02	·01 to ·06	·00	·06	·06	·16 to ·22	·16 to ·22	·08	·06
2. Kew	·07	·06	·08	·05	·03	·20	·30	·06	·06
3. Hussey . . .	·07	·03	·06	·02	·02	·33	·40	·07	·08
4. Severn . . .	·10	·08 to ·13	·10	·05	·05	·10	·10	...	·05
5. Average male .	·09	·25 to ·30	·09	·10	·10	·03 to ·07	·03 to ·07	·03 to ·06	·02 to ·05
6. Average female	...	·10 to ·20	...	...	...	·05 to ·10	·05 to ·10	·03 to ·05	·02 to ·05

[The figures denote the forward movement during inspiration.]

the head, in peritonitis, is visibly lowered during each inspiration.[1]

Rhythm of Respiration in Peritonitis.—In one case only, that of Barratt, was the rhythm noted, and in him inspiration was longer than expiration. The abdominal expiratory muscles are, in peritonitis, always tense; they offer, in consequence, resistance to the diaphragmatic movement, and they support the inflamed surfaces. Even during inspiration the expiratory muscles act, resisting and retarding the inspi-

We see that the sixth intermediate cartilage has an intermediate amount of motion; and we also find that the advance of the lower end of the sternum bears a close ratio to that of the sixth costal cartilage. Consequently, while the motion of the upper portion of the long bone of the sternum is greatly exaggerated, that of the lower end is about the same as in the healthy state, as is well illustrated by the actual movements in the above cases.

	Upper end of sternum.	Lower end of sternum.	Sixth costal cartilage.	
			right.	left.
	inch.	inch.	inch.	inch.
Barratt	·10	·05	·08	·06
Kew	·15	·04	·06	·06
Hussey	·20	·05	·07	·08
Severn	·13	·05	...	·05
Average healthy male	·03 to ·06	·02 to ·06	·03 to ·06	·02 to ·05
Average healthy female	·06 to ·10	·03 to ·06	...	...

[The figures indicate the forward movement during inspiration.]

[1] Local peritonitis :—

Ch. Osborne had, when suffering from fever, lasting pain over the head of the colon. There were, unquestionably, ulcerations in the mucous follicles, in the first instance; and, afterwards, partial peritonitis. This is inferred from the fact of the partially restrained motion over the seat of the head of the colon. In cases of fever attended by ulceration of the inflamed mucous membranes, there is usually no restraint of abdominal motion. In Osborne's case, contrast the motion over the head of the colon, ·06 in. to ·08 in., with that over the corresponding region of the opposite side, which is ·15 in., and at the centre, from ·10 in. to ·15 in. Here the motion was restrained fully one half.

ratory act ; while, during expiration, the momentum is, as it were, already in action, and the expiration is shortened.

Shortened expiration may be regarded as one of the effects and signs of peritonitis.

B.—*Effect of Abdominal Tumours and Aortic Aneurism when contiguous to the Diaphragm on the Movements of Respiration.* — Abdominal tumours will have a greater restraining effect on the movements of respiration the higher they are, and the more closely they are attached to the diaphragm. In Simpson, (Table II., Case 81,) a hard tumour, the size of a cricket-ball, was seated in the abdomen, between the sternum and the umbilicus ; it was raised at each aortic pulsation, though it had no lateral pulsation of its own. During inspiration the abdomen advanced ·15 in., being only half the normal movement. The motion of the diaphragmatic ribs was unusually small, being only ·05 in. ; while that of the thoracic ribs was above the average, being from ·05 to ·1 in.

In a case of abdominal aneurism (with the observation of which I was favoured by Dr. Burrows) pointing to the side of the left seventh costal cartilage, the contiguous abdominal movements were less than those of the corresponding parts on the right side.

C.—*Effects of Greatly Enlarged Liver on the Respiratory Movements.*—If the liver be simply enlarged it finds its way downwards and to the left, and therefore does not encroach much on, or embarrass the movements of, the diaphragm, especially in the erect posture.

If there be large adventitious deposits in the liver, as hydatid cysts, malignant tumours, or abscesses, the form of the organ is changed ; it then often protrudes upwards, displacing the diaphragm upwards and restraining its descent.

In such cases the descent of the right side of the diaphragm and the movements of the diaphragmatic and intermediate sets of ribs are very much restrained. The motion of the thoracic ribs of the right side, though often somewhat exaggerated, is usually much less so than that of the left thoracic ribs. The movements of the left thoracic and intermediate sets of ribs are much exaggerated. The motion of the upper end of the sternum is much greater than that of the lower end. The abdominal movement at the centre and on the left side is not materially affected.[1]

[1] I possess a diagram, taken from a young man in whose liver were several large abscesses. He had also peritonitis, and great intestinal distension. In this case the hepatic bulge is enormous. The heart is displaced upwards, and altogether to the left of the centre of the sternum, and the upper convexity of the liver rises as high as the second intercostal space, (Table II., Case 82.)

In the case of a young person whose habits had been athletic, but who was, when examined, much attenuated, the hepatic bulge was very large. The liver was of great size, encroaching, upwards, on the right lung ; forwards, on the costal cartilages ; and downwards, many inches below its usual site. Two rounded swellings, one of great size, evidently with fluid or semi-fluid contents (hydatids ?), in the substance of the liver, could be felt below the costal cartilages. The right lung was much duller on percussion than the left. Its lower lobe was evidently consolidated, while the upper was resonant and respiring. The heart was somewhat displaced to the left, evidently by the enlarged liver. The left lung was everywhere resonant, and expanded freely. In this case, the enlargement of the liver was complicated with consolidation of the lower lobe of the right lung. The effect of each morbid state on the respiratory movements was traceable. The whole of the respiratory movements of the right side were restrained or reversed, while the whole of those of the left side were exaggerated. The motion of the right diaphragmatic ribs, over the liver, was particularly affected, as they fell in ·02 in. to ·03 in., while those of the left side moved outwards ·05 in. The falling in, or non-motion, of these ribs may be considered the special effect of the enlarged liver. The motion of the fourth and sixth costal cartilages was 0 in. and ·01 in. on the right side, and ·04 in. on the left side. Here the influence of the consolidated right lower lobe combined with that of the enlarged liver to restrain the movements. The expansion of both upper lobes was exaggerated ; but, while the right second rib advanced ·10 in., If the liver be adherent, especially if the base of the right lung be adherent also, I infer from the cases referred to below[1] that the action of the right side of the diaphragm is much restrained, but more so in front than behind.

The extreme inspiratory movements and the breathing-capacity are much diminished in persons suffering from greatly enlarged liver, containing adventitious deposits, and also, I conceive, in those in whom the liver is adherent.

SECT. V.—*Cases in which the Action of the Diaphragm is slightly lessened during an ordinary Inspiration; considerably restrained during a deep Inspiration.*

These are cases of *general abdominal distension* from flatus, ascites, or extensively enlarged and adherent ovarian cysts.

In the extreme cases the motion of the diaphragm also is restrained during an ordinary inspiration.

Abdominal distension elevates the diaphragm, presses upwards the lungs and heart, and lessens their size.

The motion of the thoracic ribs is somewhat exaggerated during ordinary breathing; that of the diaphragm, except in extreme cases, being scarcely altered.

During a deep inspiration the increased motion of the diaphragm is unusually small, while that of the thoracic ribs is considerable.

the left advanced ·25 in., the motion of the right being restrained by the condensed lower lobe and the enlarged liver. The upper end of the sternum in conformity with the abnormal influences advanced more than the lower end, in the proportion of ·10 in. to ·04 in. The abdominal motion was not much lessened, being, at the centre, ·25 in.

[1] I believe that in Barton, (Table II., Case 83,) aged 32, and Stone, (Table II., Case 84,) aged 69, the liver was adherent to the diaphragm. In them the lower margins of the right lung and liver did not descend perceptibly during a deep inspiration, while the lower margin of the left lung descended freely.

If the stomach be greatly distended, the expansion of the left side of the chest is less than that of the right.[1]

[1] Effects of abdominal distension on the respiratory movements :—

In the case of Clarke, a lad who died from diabetes, caused and kept up by masturbation, the abdomen was much distended by *flatus;* the abdominal muscles were permanently rigid; the chest was flat, while the gastric bulge, and, to a less extent, the hepatic bulge, were unusually prominent ; the lower costal cartilages and ribs being pushed outwards, both to the sides and in front. The thoracic viscera were pushed up by the abdominal distension ; the lower boundary of the lungs and heart was high, being behind the fourth intercostal space, instead of the fifth. The motion of the left side of the chest was throughout less than that of the right, the chief abnormal difference being at the seat of the chief distension, which, as is well shown in the diagram now before me, was due to the enormously swollen stomach and colon. These encroached upwards on the left lung, and the heart more than the liver encroached on the right lung ; the movement of the right fourth and sixth cartilages and the sixth rib were respectively ·08, ·10, and ·09 in., while those of the left were ·05, ·05, and ·05 in. ; the right and left second ribs had the same motion, ·08 in., in tranquil breathing, but on deep inspiration the difference was marked, being over the right 1·10 in. and over the left 1 in. The abdominal motion was somewhat lessened in tranquil breathing, being at the centre ·20 in. ; but during a deep inspiration the increase was unusually small, being only ·50 in. In Clarke the left lung was perfectly sound, as the autopsy manifested ; and yet the anterior expansion of the left lung was considerably less than that of the right. This was due to the upward pressure of the stomach being more immediate than that of the liver, and to the comparative non-descent of the heart, which, therefore, could not be replaced by the anterior superior portion of the lung. In health the heart descends, as already stated, to a great extent, and makes way for the expanding lung.

The upper boundary of the liver, the highest part of its convexity, lay behind the third intercostal space, the liver being pushed upwards by the distended stomach and bowels.

The very small size to which the lungs are reduced by abdominal distension fully explains the distress occasionally seen in peritonitis and other affections.

I have not oberved any case of *ascites* with the chest-measurer ; but the general effect is undoubtedly the same with that from accumulated flatus. A greater amount of distension can usually be borne from ascites than from accumulated flatus, as the accumulation in the former is slow,

SECT. VI.—*Cases in which the Respiratory Movements are unaltered during both tranquil and deep Inspiration.*

Such are cases where there are ovarian cysts of moderate size free from adhesions; and the impregnated state, even to the last months.

Enlarged ovarian cysts, when they are free from adhesions, and of moderate size, do not modify the respiratory movements. When they are very large they restrain the extreme diaphragmatic movement; and when they are adherent they restrain that movement still more. The cysts descend freely, to the extent usually of an inch, when they are free from adhesions, but only to a slight extent when they are adherent. A test is thus afforded of the presence or absence of adhesions by the non-descent or the descent of the cyst during inspiration. Dr. Frederick Bird habitually avails himself of this test.[1]

and the system adapts itself to it, while in the latter it is usually quick; for the same reason the diaphragm can be forced higher in extreme eases of aseites than in distension from flatus.

In Frederick Green, the subjeet of ascites, a diagram of whom is given at p. 398 of my paper in the *Provincial Medical Transactions*, the diameter of the left side is an ineh less than the right. The cartilages of all the ribs are thrust outwards.

[1] Abdominal distension from ovarian dropsy:—

This state differs from aseites in that the tumour does not affeet the diaphragm in the earlier stages; and at the later stages only aets intermediately on it, pushing it upwards. From the enormous size sometimes attained by the ovarian eysts, they may elevate the diaphragm to the utmost extent. In one diagram in my possession, from a case of ovarian dropsy, in which the cysts were enormous, the upper eonvex boundary of the liver was just below the second rib. I have not observed any eases of this elass with the ehest-measurer; but I possess three diagrams taken from living eases.

In the case in which the ovarian cysts were very large the deseent of

In the pregnant state the respiration, whether tranquil or deep, is not interfered with ; indeed, I conceive that, in the present mode of dressing, the breathing is carried on with less interruption in the impregnated than in the unimpregnated state, owing to the requisite loosening of the stays. At the same time the increased demands on the vascular system in the pregnant state call then for increased respiratory movements.[1]

the diaphragm, though much restrained, was quite appreciable, and in the other two cases the descent was considerable, being in one scarcely diminished. In both these cases the inspiratory descent of the upper boundary of the tumour was at least an inch, manifesting that there were no adhesions. Dr. Frederick Bird informs me that he judges that the ovarian cyst is free from adhesion if its inspiratory descent be considerable.

[1] Influence of parturition on inspiratory movements :—

This is not of course a pathological influence ; but it is so closely analogous in its effect to some of the causes (ovarian dropsy) of abdominal distension that its effect can be most readily studied in this place.

I have before me two diagrams from women, one being in the sixth the other in the ninth month of pregnancy. In both of these the diaphragmatic descent, ascertained by percussion, was very little affected ; the lower border of the lungs and the liver descended on each side about an inch, and the upper boundary of the gravid uterus descended at each inpiration a full inch ; indeed, the impregnated uterus has a natural inclination to fall forwards out of the way of the abdominal viscera, thus making room for them during the displacement.

I observed two pregnant women, (Table II., Cases 86, 87,) with the chest-measurer. In both of them the costal movements were perfectly normal, being unexaggerated ; the motion of the second rib being in each only ·05 in., half the usual amount in women wearing stays. This tranquil state is, no doubt, due, in great part, to the impossibility of these persons wearing tight stays. In Sands the abdominal expansion at the centre was only ·10 in., somewhat less than that in health with the *stays off;* but the expansion over the whole abdomen was equal, there being a motion on the right and left side of ·10 and ·08 in. As the whole abdomen was increased in size the diaphragmatic descent diffused its effect over a more extended surface than in the unimpregnated state ; consequently we may infer that in these persons the diaphragmatic descent was

If the abdominal distension be very great in the impregnated state, I doubt not but that the diaphragmatic movements will be somewhat restrained.

SECT. VII.—*Effects of Disease external to the Thorax on the Rhythm of Respiration.*

The rhythm of respiration is not materially altered by any of the causes that affect the respiratory movements, when the thoracic organs are healthy, except peritonitis, in which the expiration is shorter than the inspiration.

The want of alteration in the rhythm of respiration in these cases is one of the means by which they may be distinguished from diseases of the chest.

PART III.

ON THE EFFECT OF DISEASES OF THE RESPIRATORY ORGANS ON THE MOVEMENTS OF RESPIRATION.

Having inquired into the movements of respiration in health, and into the abnormal causes which modify those movements, the heart and lungs remaining healthy, we now inquire into the modifications of the respiratory movements, caused by diseases of the respiratory organs.

SECT. I.—*The Effect of Obstruction to Respiration in the outer Breathing Passages on the Movements of Respiration.*

The obstruction to respiration may exist in the nostrils and palate, the fauces, the larynx, or the trachea.

fully equal to that in the unimpregnated. In Mrs. Key, whose abdomen was very much distended, the descent was not so great, being ·08 in. at the centre, and ·04, ·06, or ·08 at the side.

If the obstruction to respiration be considerable, the diaphragm is low, the lower boundaries of the lungs and heart are drawn down, and the chest is elongated, narrowed, and flattened. Owing to the falling back of the lungs to each side of the heart, a large portion of that organ is in contact with the walls of the chest, and its impulse is felt over a considerable space.

The efforts to inspire are powerful, but more or less inefficacious and struggling, in proportion to the amount of the obstruction. Inspiration and expiration are performed with a loud, harsh, hissing noise, often audible over the whole room.

The respiratory muscular efforts are powerful, but the motions are restrained.

The diaphragm, which is permanently low, descends during inspiration with great force; but the abdominal movement is seldom greater, and is often considerably less, than it is in ordinary healthy inspiration.

The Walls of the Chest recede during Inspiration.—The motion of the chest is very peculiar. Instead of the ribs and sternum obeying the inspiratory muscular efforts, in extreme cases, where the obstruction to respiration is almost complete, the sternum and the costal walls fall backwards, the whole chest collapsing during each inspiration. At the same time the abdomen protrudes, owing to the descent of the diaphragm; and the lower or diaphragmatic ribs, instead of falling in like the rest of the ribs, move outwards to a slightly exaggerated extent. The outward motion of those ribs is owing to their action being purely auxiliary to that of the diaphragm. It is only in extreme cases that the whole thoracic walls fall in: usually the upper thoracic ribs (the second) advance, while the lower end of the sternum and the adjoining cartilages and ribs recede. It is manifest that the costal muscles are powerfully exerted, but their force is overpowered by a stronger force, and, yielding in the struggle, the lower end, and sometimes perhaps the whole of the sternum and the thoracic walls, fall backwards, instead of advancing, during inspiration.

See the cases detailed below, illustrating this interesting subject.[1]

[1] Effect of narrowing of the outer breathing passages on the movements of respiration :—

I have before me two diagrams, taken from William Piner, one immediately before, the other some time after the operation for laryngotomy was performed. I extract the following from the report of his case :—

"May 18, 1843.—W. Piner, aged 34.—He breathes with difficulty and with a loud noise on expiration ; is very pale ; his countenance expresses distress, anxiety, and starvation. A very small quantity of air enters at each inspiration, to effect which the abdomen is much protruded, but the sternum falls backward about half an inch at the lower end, and one-eighth of an inch at the upper. This is due to the diaphragm, at its descent, dragging down the base of the lung ; and as air cannot rush in through the narrowed larynx to fill up the chest, the pressure of the external air forees in its walls : the pulse is just perceptible, 130. The soft palate and the pillars of the fauces are matted together, hard, cartilaginous, contracted, united apparently to the vertebræ, and forming one large contracted cicatrix.

"2½ P.M.—Mr. White forced a curved trochar and canula into the larynx, between the cricoid and thyroid cartilages ; the patient immediately inspired freely through the canula. The chest expands freely ; the sternum no longer falls back, but rather moves forward ; pulse much stronger ; face red, and surface warm ; heart's action pereeptible ; expression of anxiety gone. He soon fell asleep, when the respirations, previously 20, were 12 to 16 per minute."

In this man, *before* laryngotomy, the chest was flattened and narrowed, especially on the left side, the size of the right side of the chest being larger, owing to the presence of the liver. The lower margin of the right lung was behind the seventh cartilage, a full inch below its normal site. *After* laryngotomy, the lower margin of the right lung ascended a full inch. The chest became normally full and well developed, the chief increase being on the left side. The action of the diaphragm was no longer violent ; when he took a deep inspiration it descended three-quarters of an inch.

The cause of the collapse of the chest during inspiration is very apparent, and is well illustrated by an observation made by Professor Sharpey, which any one may repeat on himself. Pass a tape round the chest; close the glottis, so as to prevent the entrance of air during the inspiratory efforts, and then attempt to breathe with the diaphragm : the abdomen will protrude considerably, but the anterior walls of the chest will fall backwards, and the tape round the chest will show a diminution in circumference of from a half to one inch. In hiccough, the vocal chords are closed immediately after the beginning of a convulsive attempt at inspiration ; the descent of the diaphragm and the protrusion of the abdomen is great, and the chest is elongated, narrowed, and flattened. In hysteric struggling, the vocal chords come together during inspiration, and the same respiratory movements take place, the abdomen protruding unusually, and the chest falling in.

In another case of laryngitis, (the case of Daniel Bull,) in which Mr. White performed laryngotomy, and on which observations were made with the chest-measurer, the whole sternum, and sometimes the whole thoracic walls, fell in during each inspiration. Immediately after the operation the normal inspiratory expansion returned.

At whatever part of the air-passages the obstruction may be, the general effect will the same.

There will be the same difficulty to the entrance and exit of air through the air-passages, whether the obstruction be in the nostrils and palate, as in Robinson, from erysipelas ; or in the fauces, from enlarged tonsils, as in Chester, ill with scarlatina (Table III., Case 88) ; or in the larynx, from inflammation, as in Scattergood ; or from laceration of the trachea, as in Slater ; or in the trachea, from bronchocele, as in Mann and Maltby.

We have seen that in Piner's case the lower margin of the lung was drawn down, and the chest flattened : all the rest would possess, more or less, similar characteristics.

In all of them, the chest, especially the sternum, was flattened, while the abdomen was somewhat enlarged.

In Scattergood, as well as Piner, the lower margin of the lung was an inch lower than it is usually : no doubt varying degrees of this permanent descent obtain.

If we lengthen a closed india-rubber bottle, containing air, the sides of it collapse ; if we compress and shorten it,

In all of them the walls of the chest fell backwards to an extent varying in proportion to the obstacle.

Respiratory movement. Ordinary inspiration, where the contrary is not mentioned.	Abdomen.			Diaphragmatic ribs.		Lower end of sternum.	Sixth costal cartilage.		Upper end of sternum.	Second ribs.	
	right	centre.	left.	right.	left.		right.	left.		right.	left.
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
Piner, æt. 37, great obstruction in the fauces and larynx.	...	...	...	...	...	*·50	...	...	*·12	...	...
Ball — laryngitis .	...	rose	...	...	...	fell	...	...	fell	...	...
J. Chester, æt. 13, enlarged tonsils—scarlatina . . .	·18	·0	·25	·12	·15	*·14 to *·20	*·10 to *·15	...	*·06 †·20	·30	·25
J. Maltby, æt. 21, bronchocele . .	·18	·30	·10	·07	·06	*·04	*·03	*·03	*·03 †·005	*·03	*·02
Deep inspiration	...	...	...	...	...	*·10 †·20	...	...	...	...	*·10 †·70
J. Mann, æt. 13, bronchocele . .	...	·30	·03	·10	·09	*·02 †·02	*·03	*·03	*·02 †·05	·05	*·01 †·05
Deep inspiration	...	1·00	...	...	...	...	...	...	·40	·40	...
A. Scattergood, æt. 16, enlarged tonsils and laryngitis	·12	·12	·06	·10 to ·15	·10	*·04 †·07	·10	*·01 †·06	·08 to ·15	·10	·08
Deep inspiration	...	1·00	...	...	...	·50	...	...	...	1 00	·70
Robinson, æt. 25. obstructed nostrils and palate . . .	·05	·15	·10	·10	·09	*·06	*·01 †·05	*·02	*·02 †·04	·10	*·01 †·06
Deep inspiration	...	·20	...	...	...	...	...	...	·30	...	...
Ann Slater, æt. 27, lacerated larynx, hung herself . .	·02	·06	·02	...	...	*·02	·02	·02	·40	·06	·02
Deep inspiration	·20	·40	·20	...	...	*·30	*·30	...	*·06	·60	·40
Sarah Meads, æt. 27, chronic laryngitis	·10	·20	·10	·11	·12	*·04	*·01 †·02	*·01 †·02	*·01 †·04	·05	·05
In healthy male .	·09	·25 to ·30	·09	·10	·10	·02 to ·06	·03 to ·06	·02 to ·05	·03 to ·06	·03 to ·07	·03 to ·07
In healthy female .	...	·10 to ·20	...	...	...	·03 to ·06	·02 to ·06	·02 to ·05	·06 to ·10	·05 to ·10	·05 to ·10

[The sign * prefixed, signifies a falling to that extent. Where no mark is prefixed, and also where the † is prefixed, a *rise* is indicated.]

In each of these cases the first line of figures indicates the movements during ordinary respiration ; the second line when added shows the movement on deep inspiration.

In all the cases the thorax was flattened, narrowed or elongated, the abdomen relatively full, and the lower boundary of the thoracic viscera unusually low.

The great inspiratory action was diaphragmatic ; the motion of the sternum and of many of the ribs being reversed. It was not that the costal muscles were inactive, but the contrary : for in Chester the second ribs advanced ·30 and ·25 in. ; and in Maltby they fell back on tranquil respiration, but on deep inspiration they advanced ·70 in.

they swell out. So with the lungs ; if they be lengthened when the air can neither escape from nor enter them, their sides will collapse ; if they be shortened, their sides will swell out.

In the extreme cases, in which no air can enter the lung during the inspiratory efforts, the diaphragm descends with power, and drags down the yielding, spongy lung. The lung is considerably lengthened, and, as no air can get into it, it necessarily collapses at the side and in front, owing to atmospheric pressure. Under these circumstances, the walls of the chest are forced backwards.[1]

The force of the muscular expansion of the chest is overpowered by the superior force of atmospheric pressure. According to the degree of diaphragmatic descent and of closure or narrowing of the air-passages, is the falling back of the thoracic walls partial or universal. The falling-in of the lower end of the sternum, and of the contiguous sixth costal cartilages, is, in these cases, almost invariable, unless, as in old age, the costal cartilages be ossified, when the lower end of the sternum may be protruded by the upward and forward movement of the ribs ; but in this case there is usually falling in of the sixth and eighth ribs to the side.

The second ribs almost always advance, and they, in consequence, often push forward the upper end of the sternum ;

[1] "The passage of the air into and from the lung has an important effect upon the muscular respiratory movements. When a lung, or a considerable portion of it, is prevented from expanding by disease or any other cause, the pressure of the air on the inner surface of that portion of the chest covering the unexpansible lung is not now exercised during its dilatation ; in other words, this portion of the chest, in expanding, must do so in opposition to the whole of the atmospheric pressure on its outer surface, amounting to 15 lbs. on the square inch. This pressure appears to be too great for the muscles of inspiration, acting upon that part of the chest, to overcome, for the ribs are there motionless, or nearly so, and if the lung is in a state of collapse, the walls of the thorax covering it fall in."—Dr. Reid, art. Respiration, *Cycl. of Anat. and Phys.*, August 1848, p. 337.

but, in the extreme cases, that also falls back, as in Piner, Maltby, Mann, and Slater (Table III., Cases 89, 90, 93). The following is the order in which different parts of the chest fall in, according to the extent of the diaphragmatic descent and the obstruction in the air-passages :—

When the obstruction to the entrance of air is slight, as in Scattergood, from enlarged tonsils, (Table III., Case 91,) only the lower end of the sternum falls in.

If the obstruction be a little greater, the sixth costal cartilages, in addition, fall in.

If it be still greater, as in Slater, from laceration of the larynx or trachea, (Table III., Case 93,) the upper end of the sternum, in addition, falls in.

If still greater, as in Mann, from bronchocele, (Table III., Case 90,) the fourth costal cartilages, in addition, fall in.

If still greater, as in Maltby, from bronchocele, (Table III., Case 89,) and in Piner, from obstruction in the fauces, the second costal cartilages, in addition, fall in.

While, in the extreme cases, all the thoracic and the intermediate ribs may collapse during inspiration, in every case the lower or diaphragmatic ribs move outwards to the normal or to an exaggerated extent. Thus in Chester, an extreme case, the diaphragmatic ribs moved outwards from ·12 in. to ·15 in., instead of ·09 in. or ·10 in. This is a striking corroboration of the purely diaphragmatic auxiliary action of those ribs.

In a patient with consolidation of the lower lobe of the left lung, and in whom there was very slight laryngeal narrowing, the whole of the thoracic expansion was diminished, but it was nowhere reversed.

It will be observed in all the cases, that, at certain parts, the same rib that falls in at the beginning of an inspiration moves forwards toward the end of it. In such instances, the first action of the diaphragm, the descent of which is sudden, is to draw down the lung more rapidly than air can rush in to supply the displaced portion of it, and the walls over the lung necessarily collapse. The diaphragm acquires almost at once its complete descent, and the lung its complete elongation and collapse; the action, however, of the thoracic ribs, at first overpowered, continues, and the lung becomes thereby gradually expanded; the reversed motion consequently speedily ceases and gives place to the usual expanding motion.

Effect of Narrowing of the Air-passages on the Respiratory Movements during a DEEP *Inspiration.*—In the cases of Scattergood, Maltby, Mann, and Slater, it may be noticed that certain ribs that fell in during an ordinary, moved outwards to a considerable extent during a deep, inspiration; the ribs in question usually but not always fell in just at the beginning of the deep inspiration.

Mrs. Slater, before she coughed, inspired quickly and deeply, and then the falling in of the lower end of the sternum was greatly increased, and the upper end of the sternum that previously advanced then fell backwards. In all cases, if the inspiration increased in rapidity, the falling-in increased in extent, although the whole inspiration was deeper; the increased rapidity of the diaphragmatic descent causing a greater lateral and anterior collapse of the lungs and chest. When the deep inspiration is performed slowly, the ribs that recede in ordinary inspiration may advance during the whole act.

Whatever cause impedes the entrance of the air through the air-passages—whether obstruction in the nostrils and palate; enlarged tonsils; narrowed fauces, obstructed larynx (as in laryngitis), or trachea (as in croup and bronchocele);—may produce restrained and reversed motion of the thoracic walls during inspiration, owing to the excessive action of the diaphragm and the diaphragmatic ribs, and the consequent elongation and collapse of the lung.

Obstruction in the Right or Left Bronchus.—I have not met with a case in which the right or left bronchus alone was obstructed by a foreign body, or by narrowing of the bronchus, either from disease in its walls or external pressure; but it is very evident that in such a case the motion of the ribs over the affected side will be reversed, while that of the opposite ribs and of the diaphragm will be exaggerated: indeed, this sign will indicate into which bronchus a foreign body may have fallen.

Effect of Obstruction of the Air-passages on the EXPIRATORY *Movements.*—In cases of obstruction in the air-passages, the expiratory motions are usually the exact reverse of the inspiratory; that is to say, when a rib falls back in inspiration it advances in expiration; and when it first falls in and then moves forward during inspiration, it first moves forward and then falls in during expiration.

Effect of Narrowing of the Air-passages on the Rhythm of RESPIRATION.—In Robinson, (obstruction in the nostrils,) the duration of the inspiration was to that of the expiration as 6 to 10.

In Maltby, (thyroid body enlarged,) it was as 5 to 8.

In Scattergood, (disease of larynx,) expiration was slower than inspiration.

In these cases the expiration was slower than the inspiration; but in that of J. Chester, a boy with enlarged tonsils, the inspiration was slow and followed by a pause, after which the expiration was performed with a gush; here the inspiration and pause seem to have been longer than the expiration.

In all the cases I have seen of obstruction to respiration arising from laryngitis, the expiration has been longer than the inspiration. The greater length of the expiration is due, I conceive, to widening of the laryngeal inlet by muscular control during inspiration, while, during expiration, the vocal chords not being drawn asunder, the outlet is narrower, and the obstruction greater. It is difficult to account for the lengthening of expiration in Robinson's case, from interruption in the nostrils, and in Maltby's, from bronchocele.

In Robinson, during expiration the abdomen fell back, quickly at first and then slowly, while the thoracic ribs moved forwards, their advance being equally slow throughout. Here the diaphragm returned suddenly at the beginning of expiration, pushing the lungs into the thoracic space more quickly than the air could escape from them. The walls of the chest were forced outwards to give increased lateral space for the shortened and thickened lung ; the action, in fact, of inspiration was reversed.

The falling-back during expiration of the thoracic walls at the second ribs was equally slow throughout : this was noticed both in Scattergood's case and that of a patient with condensed left lower lobe, as well as in Robinson; and this equal slowness of thoracic expiration is characteristic of obstruction in the outer air-passages. The rhythm, then, in these cases is disturbed, the expiration, which is equally slow throughout, being usually longer than the inspiration, especially in laryngitis.

In the case of enlarged tonsils, the expiration was not prolonged.

Summary.—Obstruction to respiration in the outer air-passages may arise from clogged and narrowed nostrils and palate, enlarged tonsils and narrowed fauces, larynx or trachea (pp. 47—52) ; obstruction to respiration in one lung, from narrowed or clogged right or left bronchus. (P. 54.)

In cases where the air-passages are materially obstructed, owing to the elongation and collapse of the lungs, the chest is flattened, narrowed and elongated, the lower margins of the lungs are unusually low; from the presence of the liver, the right side is fuller than the left, and, from the collapse of the left lung in front, the heart is in great part in contact with the walls of the chest, its impulse being extensive.

The diaphragmatic descent and abdominal protrusion are very rapid and sometimes extensive, but generally the abdominal protrusion is diminished; the lungs, admitting air with difficulty, are lengthened, and, owing to atmospheric pressure, they collapse, and the sterno-costal walls, especially at the lower end of the sternum, fall backwards. (Pp. 47—54.) The thoracic walls, in some places, often recede at first and then advance during inspiration. (P. 55.)

The extent of the reversed thoracic motion is in proportion to the narrowing of the air-passages and to the extent and rapidity of the diaphragmatic descent. (P. 54.)

During a deep inspiration, many parts of the thoracic walls, that fall in at the beginning of the act or during tranquil breathing, advance considerably as the expiration is prolonged. (P. 54, 55.)

The inspiration is shorter than the expiration, especially in laryngitis: the expiratory falling-back of the abdomen is often quick at first and then slow, but the expiratory falling-back of the thoracic ribs is always equally slow throughout. (P. 55.)

SECT. II.—*Effect of Obstruction in the smaller Bronchial Tubes, Bronchitis and Vesicular Emphysema, on the Movements of Respiration.*

In the cases considered in the last section, the air found its way into the lungs with difficulty, owing to obstruction to respiration in the outer passages; the lungs and chest were consequently elongated, narrowed and flattened, and they contained little air.

In *bronchitis* and *vesicular emphysema*, the outer passages are free, but there is obstruction to respiration in the smaller bronchi; and while the air enters the cells with difficulty, there is much greater difficulty to the exit of the air from the cells. The air gradually accumulates in the air-cells, which are distended, and in emphysema very greatly dilated, the whole lungs being necessarily greatly enlarged.

The chest of course partakes of the increased size of the lungs and heart. It is rounded, broad and deep, being expanded to the utmost. The dorsal curve is unusually great, and the diaphragm is also very much lowered.

Effects of Bronchitis and Emphysema on the Respiratory Movements during ordinary Respiration.—The chest and its contents are throughout amplified to an extent greater in extreme cases than they can be in health during the deepest possible inspiration.

The heart is enlarged and lowered. The enlarged lungs spread forwards and downwards in front of the heart, occupying a great portion of the space previously occupied by that organ; they in great part cover the heart and interpose themselves between it and the sternum, ribs, and intercostal spaces. A small portion of the right ventricle is in contact with the thoracic walls, immediately behind and to the left of the xiphoid cartilage. The impulse is no longer perceptible over the intercostal spaces, but is felt over, below, and to the left of the xiphoid cartilage.

The diaphragm is everywhere flattened, and is a full inch lower than it is in health.

Owing to the obstruction in the smaller bronchi, and to the chest being already almost expanded to its greatest possible extent, the efforts of inspiration, though energetic and laborious, cannot inflate the lungs to anything like the healthy degree.

The Lower End of the Sternum and adjoining Cartilages recede during Inspiration.—During inspiration, the diaphragm descends with great force, drawing down and elongating the inferior portion of the lungs, while the upper part of the chest moves forwards and upwards, expanding the superior portion of the lungs. While the abdomen and the upper part of the chest protrude, the lower end of the sternum and the adjoining costal cartilages collapse during inspiration. The same remarkable phenomena occur that take place in extreme narrowing of the larynx ; the chest falls backwards during inspiration : but, whereas in extreme cases of laryngeal obstruction the whole chest may be flattened and narrowed during inspiration, in emphysema and bronchitis the upper part of the chest always moves forward during inspiration, and it is only the lower part of the chest that recedes.

The chest collapses in bronchitis and emphysema, for the same reason that it does so in extreme laryngeal obstruction ; the lungs are enlarged above and lengthened below more rapidly than air can enter them, and, owing to atmospheric pressure, they necessarily collapse below, and the walls of the chest there fall backwards. The walls of the chest at the lower end of the sternum and the adjoining cartilages recede in bronchitis and emphysema, for the same reason that they recede (though more extensively) in extreme narrowing of the larynx. The falling-back during inspiration of the lower end of the sternum, and the adjoining costal cartilages, and the protrusion of the abdomen and of the upper part of the chest, is shown in the accompanying daguerreotype views of W. Rawson, a boy aged 13, suffering from bronchitis and emphysema. In relation to this subject, I beg to refer to the explanation given in the last section, p. 47—52.

The inspiratory efforts of the diaphragm and the upper part of the chest are very great and laborious, but the inspiratory movements of these parts are far from being augmented to a corresponding extent. The abdominal movement is often lessened, and but seldom augmented, in emphysema; and although the motion of the second ribs is often somewhat exaggerated, in some cases it is not so. In every case, the inspiratory muscular efforts are much more exaggerated than the respiratory movements of the upper part of the chest. The movement of the diaphragm, during the deepest possible inspiration, is never so great as in health, its extreme descent being in the worst cases only the third of an inch, and in milder cases two-thirds (as will be seen in the Table and analyses of cases given below);[1]

[1] Table referred to above:—

Cases.	Upper portion of sternum.	Second rib.		Abdomen.
		right.	left.	
	inch.	inch.	inch.	inch.
In W. Redmill, age 46, emphysema, bronchitis—Table III., Case 101	·05	·07	·04	·30
John Hart, 32, bronchitis, some emphysema, dyspnœa—Table III., Case 99	·02 to ·06	·02 to ·09	·03 to ·12	·18
John Worth, 30, bronchitis, emphysema—Table III., Case 102	·03 to ·05	·02 to ·05	·02 to ·10	·25 to ·35
C. O'Donnell, 46, bronchitis, emphysema	·07	·05	·05	·40
W. Galloway, 46, diseased heart, emphysema, bronchitis—Second observation.—Table III., Case 98*b*	·06	·12	·14	·20
George Simpson, 50, bronchitis—Table III., Case 97	·04	·09 to ·12	·09 to ·08	·25
W. Rawson, 13, bronchitis, emphysema—Table III., 96*a* 96*b*.—See Daguerreotypes	·04 to ·10	·06 to ·11	·12	·12 to ·18
Second observation	·03 to ·10	·03 to ·12	·15	·35
W. Shaw, 30, emphysema, bronchitis—Table III., Case 108	·08	·10 to ·15	·08 to ·15	·45
J. Shaw, 45, chronic bronchitis, slightly obstructed larynx—Table III., Case 104	·12 to ·20	·10 to ·15	·10 to ·15	*5 †·23
J. Linthwaite, 50, chronic bronchitis—Table III., Case 100	·09 to ·24	·10 to ·25	·10 to ·25	·10 to ·40
J. Squire, 30, chronic bronchitis, emphysema—Table III., Case 95	20 to ·30	·25 to ·26	·22 to ·25	·31 to ·50
Healthy male from 10 to 45 or 50	·03 to ·06	·03 to ·07	·03 to ·07	·25 to ·30

[The ordinary figures, and those with † prefixed, denote a forward motion during inspiration; those with * prefixed a backward motion.]

while the inspiratory muscular efforts of the diaphragm are unusually energetic. (With a much slighter effort, I have

In Linthwaite, J. Shaw, and Galloway, the upward movement of the upper end of the sternum was a little more than its forward movement.

Cases.	Linthwaite.		J. Shaw.		Galloway.
	Ordinary inspiration.	Deep inspiration.	Ordinary inspiration.	Deep inspiration.	Ordinary inspiration.
	inch.	inch.	inch.	inch.	inch.
The upper portion of the sternum advanced	·09 to ·24	·40	·25	·90	·04 to ·05
The upper portion of the sternum moved upwards	·09 to ·24	·55	·30	·90	·06

In many of the cases, the inspiratory muscular efforts were very powerful, the supplementary muscles being called into action. The amount of motion was far from being equal to the muscular force. The resistance to the muscular effort is unusual, and resides in the costal walls, (which have already, even at the end of expiration, the dimensions produced in health by the deepest possible inspiration, their minimum being the maximum of health,) and in the minute tissue of the whole lungs.

The abdominal protrusion was above the average in :—

Cases.	Abdomen.			Diaphragmatic rib (10th).	
	right.	centre.	left.	right.	left.
	inch.	inch.	inch.	inch.	inch.
W. Shaw	·12	·45	·10	·01 *·03	·03
J. Worth	...	·25 to ·35	...	·03	·03 to ·10
J. Squire	·12	·31 to ·50	·12	·20	...
C. O'Donnell	·06	·40	·11	*·01 †·10	·11
J. Linthwaite	·07 to ·15	·10 to ·40	·07 to ·15	·10 to ·20	·10 to ·20
W. Rawson, second observation . .	·10	·35	...	...	...

It was normal in—

Redmill	·10	·30	·10	·10	·10
Simpson	·10	·25	·10	·10	·06

And was lessened in—

W. Galloway, first observation . . .	·08	·20	·12	·03	·08
,, second observation . .	·06	·20	·05	·015	·015
J. Hart	·08	·18	·09	·04 to ·06	·04
John Shaw	·02 to ·03	*·05 †·23	·02 to ·03	·08 to ·10	·08 to ·10
W. Rawson, first observation—worst .	...	·12 to ·18	...	·10	·12
Health	·09	·25 to ·30	·09	·10	·10

[The ordinary figures, as also those with † prefixed, denote a forward movement to that extent; those with * prefixed, a backward movement, during inspiration.]

PLATE VI

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seen the diaphragm descend in health from one to two inches.) The muscular efforts are more powerful in proportion to their inefficiency and to the severity of the disease.

In all the cases the diaphragmatic action was exaggerated, but especially in those where the abdominal motion was diminished. This is well illustrated by the case of Rawson, detailed below. When first examined, he suffered from a severe attack of bronchitis, with emphysema; the diaphragmatic efforts were very laborious, but the abdominal

In all these cases the muscular action was much exaggerated, but especially in those where the abdominal motion was diminished.

Rawson, an interesting boy of 13, (whose daguerreotypes were taken first in the tranquil state and then during a deep inspiration,) illustrates this point well. When he was first observed, he had, in addition to habitual enlargement of the lungs, a severe attack of bronchitis; the dyspnœa was extreme: at this stage when the respiratory muscles were strained to the utmost, the abdominal protrusion was only ·12 to ·18 in., while during the second observation, made a month later, when the bronchitis had nearly ceased, the abdominal protrusion was above the average, being ·35 in.

In John Shaw, in whom respiration was very difficult, it will be seen that the abdomen fell back at the beginning of the inspiration, and then moved forward. In this man the entrance of air had a double difficulty in the smaller bronchial tubes and in the obstructed larynx. The falling-in of the abdomen at the beginning was due, I conceive, to the lateral expansion caused by the excessive action of the diaphragmatic ribs, the outward movement of which was ·08 to ·1 in., while that of the abdomen at the sides was only ·02 to ·03 in.

It will be observed that in John Shaw, whose muscular efforts were very powerful, and whose abdominal protrusion was the greatest, being ·45 in., the lateral motion of the abdomen was only ·02 to ·03.

This diminution of abdominal protrusion with manifest increase of diaphragmatic effort allies the cases now under review to those in which the outer air-passages were obstructed. By referring to the table of those cases, it will be seen that in most of them the abdominal protrusion was lessened,—in Slater, it was only ·06, while the diaphragmatic action was rapid and exaggerated. In Piner, in whom the obstruction was the greatest, the abdominal protrusion, judging by the eye, was considerable.

movement was only half the healthy amount, being ·12 to ·18 in.; when observed a second time, after the disappearance of bronchitis, the abdominal movement was ·35 in., while the diaphragmatic effort was inconsiderable. This diminution of abdominal protrusion with manifestly increased diaphragmatic effort, allies in this respect emphysema and bronchitis with cases of extreme laryngeal obstruction, in which the same phenomena present themselves.

The falling back of the lower end of the sternum and the adjoining part of the chest is more extensive and greater in amount, in proportion to the amount of obstruction in the smaller bronchi, the energy and inefficiency of the inspiratory muscular efforts, and the flexibility of the costal cartilages.[1]

[1] The amount of falling back will be seen in the individual cases :—

Cases.	Lower end of sternum.	Sixth costal cartilage.		Fourth costal cartilage.		Eighth rib.	Central abdomen.	Second rib.	
		right.	left.	right.	left.			right.	left.
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
Jos. Squire, æt. 30.	*·12	*·6 †·24	*·10 †·33	·22 to ·25	·22 to ·25	...	·31 to ·50	·25 to ·26	·22 to ·25
Rawson, æt. 13 (See Daguerreotypes).	*·3 to *·06	*·07	*·05	*·02 †·05	*·01 †·03	...	·12 to ·18	·06 to ·11	·12
Second observation	*·08	*·10	*·03 †·02	·03 to ·09	·11	...	·35	·03 to ·12	·15
G. Simpson, æt. 50, bronchitis . . .	*·05	*·02 †·03	*·04	*·03	*·03	...	·25	·09 to ·12	·08 to ·09
W. Galloway, æt. 40, emphysema, diseased heart, bronchitis . . .	*·03	*·03	*·03	*·03	*·01 †·04	...	·20	·12	·14
Last observation .	*·04 to *·15	*·02 †·04	*·04 †·04	*·02 †·02	*·03 †·02	...	·20	·08	·12
J. Hart, æt. 32 . .	*·01 to *·04	·05	·05	·01 to ·03	·03 to ·09	...	·18	·02 to ·09	·03 to ·12
J. Linthwaite, æt. 50	*·02 † ·08	*·01 †·10	*·02 †·08	·08 to ·12	·06 to ·10	...	·10 to ·50	·10 to ·25	·10 to ·25
W. Redmill. æt. 46	*·02	·02	·03	·03	0	...	·30	·07	·04
J. Worth, æt. 30 .	*·01 †·03	·03	·04 to ·12	·01	·0 to ·05	...	·25	·02 to 0·5	·02 to ·10
J. Shaw, æt. 45 . .	*·005 †·03								
W. Shaw, æt. 30 .	·10 to ·12	·15	·12	·12	*·03 †·07	...	*·05 †·23	·10 to ·15	·10 to ·15
	...	...	...	...	...	...	...	·10 to ·15	·08 to ·15
						r. l.	r. c. l.	Tenth rib.	
C. O'Donnell, æt. 44	' ·04	*·01	*·01 †·01	*·03	*·01 †·02	*·08 *·07	·12 ·45 ·10	·01 *·03	·03
	·06	*·03 †·03	*·01, †·06	*·01 †·03	*·01 †·04	...	·06 ·40 ·11		

[The ordinary figures, and those with † prefixed, denote a forward movement to that extent; those with * prefixed, a backward movement, during inspiration.]

We see, from the actual observation, that, excepting the two Shaws and O'Donnell, the lower end of the sternum fell back either during the whole inspiration or at the beginning of it, and that the sixth cartilages fell in, especially on the left side in the neighbourhood of the heart, in nearly all

In the slighter cases the lower end of the sternum recedes only at the beginning of inspiration. The descent of the diaphragm is very rapid at first, a portion of lung is displaced downwards, and, as air cannot enter with sufficient rapidity, the lower parts of the lungs collapse, and the lower end of the sternum is forced back by atmospheric pressure just at the beginning of the inspiration. As the inspiration proceeds, the portion of lung which at first collapses, gradually expands, and towards the end of inspiration the lower end of the sternum moves forward in common with the rest of the anterior thoracic walls.

1st stage.—If the case be slight, the lower end of the sternum falls back only at the beginning of inspiration and then advances.

2nd.—If the case be somewhat more severe, the lower end of the sternum alone falls back through the whole of the inspiration.

those cases ; the amount of retraction of the sixth cartilages bearing a proportion to that of the lower end of the sternum.

During inspiration—

In Worth and Linthwaite	The lower end of the sternum fell back at the beginning and advanced towards the end of the act.
In Worth, Redmill and Hart	The lower end of the sternum alone fell back.
In Galloway (1st observation), Squire, Rawson (2nd observation), and Linthwaite.	In addition, the sixth costal cartilage fell back.
In Rawson (1st observation), Galloway (2nd observation), (they were then worse,) and Simpson.	In addition, the fourth costal cartilage fell back.

These observations show that a greater number of cartilages fall back in the same case when the patient gets worse, as in Galloway, and a less number when he improves, as in Rawson ; thus we are afforded a test of the progress of the case.

3rd.—If the case be still more severe, the sixth costal cartilages fall back in addition to the lower end of the sternum.

4th.—And in the most severe cases, in addition the fourth costal cartilages fall back.

If the case under observation grows worse, the amount and extent of the falling back increases, according to the stages just given; while, if the case improves, the extent of the collapse of the chest diminishes, as in the boy Rawson, in whom, at the first observation, the lower end of the sternum and the sixth and fourth costal cartilages receded; and at the second observation, when he was improving, the fourth costal cartilage no longer fell in, while the sixth did so. We are thus afforded a test of the favourable or unfavourable progress of the case.

In some cases, the lower end of the sternum, instead of falling backwards, *protrudes during inspiration;* and in these cases *the lower part of the chest*, instead of being flattened, *is narrowed during inspiration.*[1]

[1] Cases in which the lower end of the sternum protrudes during inspiration:—

In William Shaw and O'Donnell the lower end of the sternum did not fall in, but moved forwards, during inspiration. In Shaw the whole of the lower part of the chest, from the sixth rib down to the eighth, became narrowed during inspiration, the sixth ribs falling in ·01 in., but the eighth ribs as much as ·08 and ·07 in. In Shaw the dorsal curvature, which always exists to a greater or less extent, in the emphysematous, was unusually great, the lower end of the sternum unusually prominent: the sixth and seventh costal cartilages and ribs advanced somewhat after a boat-shape, and as the rib and cartilage yielded inwards during inspiration, when they were raised they pushed forward the lower end of the sternum, as we have already observed to be the case in rachitic children (pp. 25, 26).

The great dorsal curvature would also tend to throw forward the lower end of the sternum, as has been already remarked (pp. 29, 30).

O'Donnell, aged 46, is a less marked illustration of the same thing; in

In these persons the sixth, seventh, and eighth ribs (the intermediate set), from acquired deformity, are hollow at the side, at the place of junction of those ribs with their cartilages; the sternum is prominent, and the lower part of the chest is deep and narrow. The sixth, seventh, and eighth ribs fall in at the sides during inspiration close to their costal cartilages, and the lower end of the sternum, in consequence, projects considerably.

In certain cases no part of the Thoracic Walls falls in during Inspiration.—In some persons, rather advanced in life, the costal cartilages are stiff and unyielding; and in them the chest, instead of receding anywhere, may advance throughout, as in health. In one such case, the abdomen, instead of the lower end of the sternum, was retracted at the

him the fourth and sixth cartilages fell in slightly while the lower end of the sternum protruded. In this case the cause resided in the firmness of the costal cartilages.

In John Shaw, aged 46—the other man in whom the lower end of the sternum advanced, but who differed from O'Donnell and William Shaw in that except the left fourth costal cartilage, none of the cartilages or ribs receded—the firmness of the ribs and costal cartilages was the manifest cause of the want of falling in. In John Shaw alone did the abdomen fall back at the beginning of inspiration; and in him the centre of the diaphragm evidently yielded in the struggle: in the other cases the abdomen advanced and the sternum or ribs fell in; in him the ribs advanced and the abdomen fell in.

Linthwaite, aged 50, connects the cases in which, during inspiration, the lower end of the sternum receded with those in which it protruded; in him the lower end of the sternum and the sixth cartilage only receded ·02 in., and then advanced ·08 in. With the exception of this trifling retraction at first, Linthwaite's case exactly tallied with John Shaw's; and this difference disappeared in John Shaw after a prolonged examination, when the dyspnœa increased; for then the lower end of the sternum fell back ·03 in. before advancing. In Linthwaite the movements, like those of John Shaw, were modified by the stiffness of the costal cartilages. This point will be further illustrated in considering the influence of old age in modifying the respiratory movements in those affected with emphysema.

beginning of inspiration. The abdominal retraction was evidently caused by the thoracic expansion, in the same way that the usual thoracic retraction is caused by the abdominal protrusion.

In some cases of this class the lower end of the sternum and the adjoining cartilages fall back slightly, just at the beginning of inspiration, and then advance ; and in other cases, although the thoracic walls may not fall back, yet they stand still just at the beginning of the inspiration. This standing still of the thoracic walls is, if I may so speak, the first stage of their falling back.

In those cases of emphysema and bronchitis in which the thoracic walls recede over the lower end of the sternum and the adjoining costal cartilages, the costal walls at the upper part of the chest usually stand still just at the beginning of inspiration, and then advance. This pause at the beginning of the inspiratory movement of the upper part of the chest is due to the same cause as the collapse of the lower part of the chest, namely, the obstruction to inspiration, which is indeed greatest at the beginning of the act.

The Intercostal Spaces fall in during Inspiration.—In applying the chest-measurer in the examination of persons affected with emphysema, care must be taken to place the instrument, not over the intercostal spaces, but over the rib. In emphysema the intercostal spaces fall in very notably during inspiration, as Dr. Stokes, Dr. C. J. B. Williams, and others, have noticed ; so much so, that in Galloway, while the sixth rib moved outwards ·04 to ·09 in., the fifth intercostal space retracted ·08 in. This retraction of the intercostal spaces is present where they are over lung, but not where they are over liver. Thus the exact inspiratory descent of the lung can be observed by the eye; the intercostal retraction stops short at the liver, and, in a less marked manner, at the stomach; as the lungs, during inspiration, replace those organs, the intercostal retraction extends *pari passu.*

The intercostal retraction over the lung is seen in health during a deep inspiration in all persons not overloaded with fat.

The head is lowered during an ordinary inspiration in emphysema and bronchitis, as well as in all other cases of dyspnœa, whether the person be standing, recumbent, or lying on the side, in which last attitude the motion is usually greatest; in each of the Shaws and in Linthwaite the head was lowered from ·02 in. to ·03 in., and in one case ·05 in.

The Expiratory Movements in Bronchitis and Emphysema.— The expiration, except that it is so prolonged, is usually the exact reverse of inspiration. While during inspiration the lower part of the chest first recedes and then advances, during expiration that part first advances and then recedes: but sometimes the advance of expiration is much greater than the falling-back of inspiration. Thus in one case, J. Shaw, towards the end of the examination, when the lower end of the sternum, during inspiration, fell back ·03 in. and advanced ·04 in., it advanced ·1 in. and fell back ·08 in. during expiration.

The advance of the lower end of the sternum during expiration is due to the quick ascent of the diaphragm, which pushes the lungs suddenly upwards.

As the air in the lungs can only escape with difficulty, their lateral diameter is increased and the lower end of the sternum is driven forwards during expiration as much as, or even more than, it falls back during inspiration. As a pause over the upper part of the chest often takes place at the beginning of inspiration, so a like pause, as in Hart's case, often occurs at the beginning of expiration.

Effect of Obstruction in the Smaller Bronchial Tubes on the RHYTHM *of Respiration.*—The duration of expiration is invariably longer, and in many cases much longer, than that of inspiration. The greater the obstruction, the more prolonged is the expiration. The prolongation of expiration is a long recognised and important sign in bronchitis and emphysema. To estimate the exact relative duration of inspiration and expiration, I beat time very rapidly with the finger and count the beats, first during inspiration, and then during expiration; this plan, or simply counting, tells with accuracy the relative duration of the acts.

The duration of inspiration to that of expiration was, in

J. Shaw		4 to 13
W. Galloway,	1st examination	4 to 8
Do.	2nd examination, when the obstruction was greater	4 to 12
W. Rawson,	1st examination	3 to 8
Do.	2nd examination, when the obstruction was less	6 to 9
W. Shaw		4 to 9
J. Linthwaite		4 to 9
J. Hart		4 to 8
J. Worth		5 to 9
J. Squire		4 to 6
G. Simpson		4 to 4 or 5

The prolongation of expiration is invariable, and it is a measure of the amount of obstruction to respiration—in Rawson, as the obstruction diminished, the expiration shortened; and in Galloway, as the obstruction increased, the expiration lengthened. The act of expiration is always prolonged, and, which is the important feature in obstruction in the bronchial tubes, it becomes gradually slower towards the end. After abdominal expiration has ceased, thoracic expiration continues for a short time. The cause of the prolonged expiration is apparent.

During inspiration the beginning of the act is spent in enlarging the larger tubes, which expand readily; and in dilating the lesser ones, which, being then smaller, offer greater obstruction to respiration at the beginning than the end of inspiration. This is one reason for thoracic respiration being slower at the beginning of inspiration. Afterwards, as inspiration progresses, the tubes become wider and admit air more freely. The mucous or sonorous rhonchus, if slight, is often present only at the beginning of inspiration, when the entrance through the smaller air-tubes is most obstructed. If the rhonchi be continuous, they are less grave at the beginning than the end of the inspiration.

During expiration the physical conditions are reversed, the air-tubes being all at their largest at the beginning of the act. At first the air rushes out easily from the larger bronchi; as the expiration advances the smaller tubes diminish, and the mucus they contain fills them more completely. The difficulty to the exit of air from the air-cells is necessarily increased. If sonorous rhonchi be present, they are often, at first, grave; but they gradually rise in pitch towards the end of the act. In such cases the expiration is prolonged, and becomes slower in exact proportion to the increased obstruction in the finer air-tubes. In some cases interrupted rhonchi are accompanied by interrupted expiratory movements.

Whenever, and from whatever cause, the air-tubes, large or small, are clogged with fluid, they obstruct both inspiration and expiration; but the obstruction tells most on the expiration, which is, under these circumstances, at first rapid and then slow, becoming always progressively slower towards the end. The rapid movement at the beginning is chiefly manifested on the abdomen, the slow movement towards the end, on the walls of the chest.

The rapidity of the expiration at first, and its increasing slowness towards the end, characterises obstruction in the bronchi from obstruction in the larynx, as in the latter case: the prolonged expiration is equally slow throughout.

While examining a case of bronchitis, I have observed the expiration, previously of increasing slowness, to become suddenly equally slow throughout. This was traceable to the rapid accumulation of sputa between the vocal chords obstructing the larynx. As soon as the larynx was cleared by coughing, the increasing slowness of the expiration towards the end returned.

In simple bronchitis and simple emphysema, the expiration is not so much prolonged as it is when they are combined. In Rawson's case this was well illustrated—as the bronchitis lessened, the emphysema alone acted, and the expiration was not so much prolonged.

The duration of the expiration varies, in these compound cases, with the varying obstruction in the smaller bronchial tubes.

The expiration is, I conceive, not so much prolonged when the obstruction is seated in the larger bronchial tubes, as it is when in the smaller. The cases of Simpson and Eaton, in whom the expiration was not materially lengthened, are examples of this.

In emphysema and bronchitis, owing to the protrusion, during inspiration, of the abdomen and of the upper part of the chest, and the collapse of the lower end of the sternum and the adjoining cartilages, the rhythm of the movements of respiration is different over the abdomen, the upper part of the thorax, and the lower end of the sternum.

Over the *abdomen*, the *inspiratory* protrusion is quick, and equal throughout. During *expiration*, the abdomen retracts very rapidly and extensively just at first, and then falls back very slowly. Sometimes there is a short pause after the first expiratory movement. After this pause, the abdomen again recedes, though very slowly, and often with two or three interruptions. Abdominal expiration often ceases before thoracic expiration.

Over the *upper part of the thorax*, during *inspiration*, there is, at first, often a pause, or the ribs and sternum move forward slowly at first, and then advance more rapidly and at an equal rate. During *expiration* the upper part of the chest generally pauses just at first; it then moves rather quickly, and afterwards very slowly, becoming gradually slower towards the end. Sometimes there is interrupted thoracic expiration. The thoracic expiration is often prolonged after the abdominal expiration ceases.

The *lower end of the sternum* and the contiguous cartilages, during *inspiration*, either recede throughout, as has been already stated, or fall in at the beginning and then move forward, or only pause at the beginning and then advance. During expiration the movements of the lower end of the sternum are the reverse of those during inspiration. Sometimes when the sternum stands still during inspiration, its motion is reversed at the beginning of expiration.

The characteristic feature of the rhythm of respiration in emphysema is this, that the expiration is quick at first, then slow, becoming gradually slower towards the end.

Effects of Obstruction of the Smaller Bronchial Tubes on the Movements of Respiration during a DEEP *Inspiration.*—I have only observed the extreme inspiratory movements in a few of the cases, and at a few points, the condition of many of the cases precluding the inquiry.

As a general rule, the extreme inspiratory movements were much restrained, and sometimes in part reversed where they were reversed in ordinary breathing.

	Extreme breathing capacity.	Inspiration.	Upper portion of sternum.	Second rib.		Abdomen	Lower end of sternum.	Sixth cartilage.		Eighth rib.	
				right.	left.			right.	left.	right.	left.
	inches.		inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
W. Shaw . .	90	ordinary	·08	·10 to ·15	·08 to ·15	...	·04				
		deep	...	·25	·25	...	·23				
W. Rawson .	...	ordinary	·04 to ·10								
		deep	·30								
Second observation (better) .	...	ordinary	·03 to ·10	...	...	·35	*·08				
		deep	·50	...	...	·50	*·08 †·20				
Redmill . . .	...	ordinary	·05	·07	·04	·30	*·02				
		deep	·25	·35	·30	·50	*·03 †·30				
Simpson . .	...	ordinary	·04	·09 to ·12	·09 to ·08	·25					
		deep	·50	·30	·30	·35					
Linthwaite . .	155	ordinary	·09 to ·24	·10 to ·25	·10 to ·25	·10 to ·40	*·02 †·08	*·01 †·10	*·02 †·08		
	140	deep	·40	·50	·40	·70	*·02 †·20 *·02 †·35	*·01 †·20	*·02 †·17		
John Shaw .	120	ordinary	·12 to ·20	·10 to ·15	·10 to ·15	*·005†·23	·10 to ·12	...	...	·10	·10
	190	deep	·55	·90	·80	·80	·50	...	...	·45	·40
J. Worth . .	230	ordinary	·03 to ·05	·02 to ·05	·02 to ·10	·25	*·005†·03				
		deep	·70	1·10	1·10	·70	*·02 †·60				
Health . . .	...	ordinary	·03 to ·06	·03 to ·07	·03 to ·07	·25 to ·30	·02 to ·06	02· to ·06	·02 to ·05	·08	·08
		deep	1·0	1·10	1·10	1·0	·90	·80	·70	·65	·65

[The ordinary figures, and those with † prefixed, denote a forward motion ; those with * prefixed, a backward motion of the costal walls during inspiration.]

From these scanty materials we may conclude that the extreme motion is, in many cases, very materially diminished : thus in Shaw it was only ·25 and ·35 in. at the second rib, instead of being from ·80 to 1·00 in.

That as the obstruction diminishes the extreme motion increases. Thus, in Rawson, during the first examination, the extreme motion of the upper end of the sternum was ·3 in. ; during the second, when there was less obstruction, ·5 in.

That the extreme motion is a test of the extreme breathing-capacity. Thus, in William Shaw, whose capacity was only ·90 cub. in., the extreme movement of the second ribs was only ·25 in.; while in Worth, whose capacity was ·230 cub. in., the extreme movement was 1·00 in.

That where the breathing-capacity of the lung is considerable, but the obstruction great, the deep inspiration and expiration are slow. In Shaw, although the capacity and motion were considerable, the deep inspiration and expiration were very slow. Shaw's case was complicated by obstruction in the larynx.

That when the lower end of the sternum or a costal cartilage falls back and then rises during an ordinary inspiration, it also does so during a deep inspiration; as—

	The lower end of the sternunm	
	inch.	inch.
In Linthwaite, during an ordinary inspiration . .	receded ·02	and advanced ·08
In Linthwaite, during a deep inspiration . . .	„ ·02 to ·05	„ ·20 to ·35
In Worth, during an ordinary inspiration . . .	„ ·005	„ ·03
In Worth, during a deep inspiration . . .	„ ·02	„ ·60

That when the lower end of the sternum recedes throughout during an ordinary inspiration, it recedes at the beginning of a deep inspiration, and then advances, in proportion to the breathing-capacity: thus—

					inch.		inch.
In Rawson,	the sternum	in ordinary	inspiration	receded	·08	and advanced	0
„	„	full	„	„	·08	„	·20
In Redmill,	„	ordinary	„	„	·02	„	0
„	„	full	„	„	·03	„	·30

That when the lower end of the sternum advances, while the ribs fall in to the side, during an ordinary inspiration, it also advances, and to an increased degree, during a deep inspiration: thus—

In William Shaw, the lower end of the sternum during	ordinary inspiration,	advanced .	·04 in.
„ „	deep „	„ .	·23 „

That when the lower end of the sternum advances, from stiffening of the cartilages, during an ordinary inspiration, it also advances during a deep inspiration, and to a greater degree; and that in such a case the increased lateral expansion of the lower ribs is not proportioned to that of the lower end of the sternum: thus—

		inch.		inch.	
In John Shaw, while the second rib advanced . .	from ·1	to ·15	in ordinary and	·9	on a deep insp.
the eighth rib moved outwards	„	·1	„	·45	„

That when the deep inspiration is involuntary and almost convulsive, as it is when preceding a cough, it is very rapid; and from the rapid descent of the diaphragm, those parts of the chest may recede much that only recede a little during an ordinary inspiration: thus—

In Galloway, the lower end of the sternum fell back during an ordinary inspiration	·04 in. to ·15 in
And it fell back during the rapid deep inspiration preceding a cough	·2 in.

Effects of Obstruction in the Smaller Bronchial Tubes on the Respiratory Movements in OLD AGE.—In old age, the cartilages, being ossified, form with the rib one unyielding piece: and, in consequence, the lower end of the sternum, instead of falling in, moves forward during inspiration, as we see in—

	Upper end of sternum.	Second rib.		Lower end of sternum.	Sixth cartilage.		Eighth rib.		Abdominal protrusion.	Rhythm. Insp. to Exp.
		right.	left.		right.	left.	right.	left.		
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	insp. to exp.
T. Eyre, æt. 75	*·02 †·03	*·05 †·05	*·01 †·02	·06	·07	·06	·04	·04	·35	4 : 8
W. Flinders, æt. 69 . . .	·08	·04	·07 to ·10	·09	·07	·06	·06	·12	·60	6 : 9
T. Thompson, æt. 60 . . .	·06	·07 to ·08	·10	*·01 to †·06	*·04 †·02	*·02 †·06	*·02 †·06	*·03 †·06	·10	4 : 8
Deep inspiration . . .	...	...	...	·13	...	...	*·10	*12		
Health in old age, about the average . .	·02 to ·06	·02 to ·06	·02 to 0·6	·03 to ·07	·03 to ·07	·03 to ·07	·05 to ·10	·05 to ·10	·25 to ·35	4 : 5 or 6

[The ordinary figures, and those with † prefixed, denote a forward motion; those with * prefixed, a backward motion of the costal walls during inspiration.]

In Eyre (Table III., Case 109), and Flinders (Table III., Case 110), the deviation from the normal state was not material (I do not know the cause of the slight falling back of the upper portion of the sternum at the beginning of the inspiration in Eyre). The lower end of the sternum moved forwards somewhat more than the average, and the sixth rib moved outwards somewhat less. In both of these, but especially in Flinders, the abdominal movement was excessive.

In Thompson (Table III., Case 111) alone, of the three, was there the slightest recession of the lower end of the sternum and its adjoining cartilages, and in him they only receded at the beginning of the inspiration, while on a deep inspiration they did not recede at all. It will also be observed that the eighth rib fell inwards at the beginning only of an ordinary, but during the whole time of a deep, inspiration. In this respect his case may be compared with that of W. Shaw (p. 64), in whom, while the lower end of the sternum advanced, the eighth ribs fell inwards during each inspiration.

The rhythm of respiration is changed in old age as it is in the adult.

Effects of Obstruction in the Smaller Bronchial Tubes on the Movements of Respiration in THE FEMALE.—The great development of the superior thoracic, and the restraint on the intermediate and diaphragmatic ribs, due to the wearing of stays, causes in the female a considerable variety in the effects of emphysema on the position of the viscera, the form of the chest and abdomen, and the movements of respiration.

The point in which the respiratory movements of the male and female when affected with obstruction in the smaller air-tubes principally differ is the greatly exaggerated motion of the thoracic ribs.

M. Cross (Table III., Case 113), a young person recovering from a severe attack of fever and bronchitis, is the only exception; and in her, if the examination had been made a few days earlier, if my eye and recollection do not deceive me, the movements would have been exaggerated also. The above cases illustrate all the principal varieties met with in man.

In Cross, Chamberlain (Table III., Case 114), and Elliott (Table III., Case 115), the lower end of the sternum receded, as in the majority of adult males.

	Sternum, upper end.	Second rib.		Sternum, lower end.	Sixth costal cartilage		Eighth rib.		Abdomen	Rhythm. Insp. to Exp.
		right.	left.		right.	left.	right.	left.		
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
Mary Cross, 14, recovering from bronchitis, fever . .	·05	·03 to ·05	·03 to ·05	*·02	*·01	*·02	·03	·02	·15	4 : 6
Deep inspiration	·06	·14	·12	*·02 †·05	...	...	...	...	·50	
S. Chamberlain, 20, acute bronchitis, fever .	·25	·12	·12	*·02 †·08	·07	·08	...	...	·50	
M. Elliott, 50, emphysema, bronchitis .	·15	·12	·15	*·06	*·02 †·06	*·02 †·05	...	...	·02 to ·06	4 : 7
Mrs. Cooper, 30, bronchitis .	·12	·20	·20	·20	*·08	*·10 †·08	*·06 †·08	*·12	·40	3 : 9
S. Henson, 70 .	·15	·25	·20	·09	·06	18	·15	·18	·15	4 : 6
Health, stays off	·06 to ·10	·06 to ·10	·05 to ·10	·03 to ·06	·02 to ·05	·02 to ·05	...	...	·10 to ·20	4 : 5

[The ordinary figures and those with † prefixed, denote a forward movement; those with * prefixed, a backward movement of the costal walls during inspiration.]

In Cooper (Table III., Case 116), the lower end of the sternum advanced considerably, and the sixth and eighth ribs fell in on each side, as in the case of Wm. Shaw (p. 64).

In Mrs. Henson (Table III., Case 119), aged 70, the ribs did not yield anywhere, as in John Shaw (p. 65), and the males arrived at old age (p. 74).

The rhythm of respiration is changed in females exactly as it is in males.

Effects of Obstructed Bronchial Tubes on the Respiratory Movements in CHILDREN.—In children affected with bronchitis, or hooping-cough, the chest is usually very full and rounded above and in front, the sternum arched, and the dorsum much curved; the lungs are usually elongated, the diaphragm being low; the lower end of the sternum and the lower costal cartilages are depressed. The abdomen is usually full.

In healthy children, unless the abdomen be small and the respiratory movements slight, as has been already stated, the lower part of the thorax retracts during inspiration; the retraction taking place in *healthy* children at the lower end of the sternum and the lower costal cartilages in front; but in *rickety* children the whole sternum advances, while the lower ribs at the side fall in (p. 26).

This is indeed the counterpart of the effects of obstruction in the bronchial tubes on the respiratory movements of the adult.

In children affected with bronchitis and hooping-cough the same phenomena of both classes are present, only the respiratory movements of the upper part of the thorax and of the abdomen are exaggerated; and the receding of the sternum in well-formed children, and the lateral falling in of the lower ribs, with advance of the sternum, in rickety children, are increased.

It is very difficult to observe the respiratory movements in children; but I have succeeded in examining, in more or fewer points, the respiratory movements in seven children affected with bronchitis, and in five with hooping-cough. I beg to refer to the Table containing them for the particular movements.

It will be observed that the lower end of the sternum protruded, and the lower ribs fell in at the sides, in Lowe (Table III., Case 125), Garner (Table III., Case 127), and a child with hooping-cough (Table III., Case 129), that the ribs did not fall in anywhere in Garton (Table III., Case 126), and that the lower end of the sternum and the adjoining cartilages fell back in the remaining eight children. In hooping-cough the form of the chest, position of viscera, and movements of respiration, are the same as in bronchitis. During the hooping inspiration previous to the cough, the vocal chords come in contact and separate repeatedly, giving rise to the inspiratory vocal noise. During the hooping inspiration the whole chest falls in much more than it does in the ordinary inspiration; in fact, obstructed larynx is joined to obstructed smaller bronchi to modify the inspiratory movements.

None of the cases referred to in this section died; but I believe the diagnosis is correct in all the cases. To one point, the enlargement of the lungs, I can speak with absolute certainty.[1]

Summary.—In emphysema, and, to a less extent, in bronchitis, the form of the chest and abdomen and the position of the viscera are the same that they are during the deepest possible healthy inspiration.

The chest is full and prominent, the shoulders raised, the spine curved, the sternum forward, the costal cartilages at each side of it full, but not so prominent as usual. The diameter of the chest is everywhere increased, the opposite seventh costal cartilages below the sternum are stretched far apart.

The abdomen just below the prominent xiphoid cartilage is unusually hollow; the diaphragm is low and flat; the lower boundaries of the lungs and heart are a full inch lower than in the normal state. The heart is nearly covered with lung,

[1] Since writing the above passage, W. Galloway (Table III., Case 98*a*, 98*b*), died. The autopsy evidenced emphysema (with bronchitis) and great enlargement of the heart.—August, 1848.

the exposed portion of it, and consequently its impulse, being below the sternum, behind and to the left of the xiphoid cartilage.

During inspiration the diaphragm descends only from one-third to two-thirds of an inch, and the lower boundaries of the lungs and heart, and the upper boundaries of the abdominal organs, necessarily descend to the same extent. The cardiac region is lowered and lessened, the impulse becoming stronger and lower. The respiratory muscular actions are much exaggerated, while the movements are not proportionally, often not at all, increased (p. 60).

The diaphragm descends, the abdomen protrudes, and the superior thoracic (first, second, third, and fourth) ribs ascend and advance with energy ; at the same time the lower end of the sternum and the sixth cartilages fall backwards in the greater number of cases, from childhood to the age of 50 (p. 59).

The lower end of the sternum falls back because the exaggerated action of the diaphragm and of the upper thoracic ribs expands the lungs above, and elongates them below, more rapidly than air can rush in to fill them up ; consequently they collapse intermediately, and the lower end of the sternum and the intermediate ribs (sixth, seventh, and eighth) are forced backwards by atmospheric pressure (pp. 48, 59).

In some the lower end of the sternum is prominent, and the lower part of the chest narrow and deep ; in these, whatever their age and sex, the lower end of the sternum advances and the sixth and eighth ribs and cartilages fall in at the side.

In general the lower part of the chest is flattened, but in these it is narrowed and deepened during a deep inspiration (p. 64).

In old age and in adults with stiff and ossified cartilages, the lower end of the sternum advances, and the ribs move outwards; the outward movement of the eighth ribs being somewhat restrained during a deep inspiration. In some the lower end of the sternum falls back slightly, and then advances during an inspiration (pp. 65, 73).

As both the superior thoracic and the diaphragmatic muscular efforts are always, and the movements usually, exaggerated, the head is lowered at each inspiration, indicating excess of costal motion, while the larynx descends considerably, indicating excess of diaphragmatic action (p. 67).

The movement of the ribs and diaphragm during a deep inspiration is restrained. The smaller the breathing-capacity of the lungs, the less the increase of motion on a deep inspiration (p. 72).

Those parts of the chest that fall back during *ordinary* inspiration, only fall back at the beginning of a *deep* inspiration, after which, as the inspiration proceeds, they advance in proportion to its depth (p. 75).

The expiratory movements are the reverse of the inspiratory: in some, when the ribs fall back slightly during inspiration, they advance considerably during expiration; and in others, where the ribs do not advance during inspiration, but only stand still at the beginning of it, they move forward at the beginning of expiration and then fall backwards (p. 71).

The extent of the reversed inspiratory movement over the lower end of the sternum and the intermediate set of ribs is in proportion to the extent of the obstruction and the mobility of the chest (p. 63).

The rhythm of respiration is materially and characteristically affected in emphysema and bronchitis. The inspiration is short, the expiration is prolonged. During inspiration the air enters rapidly during the whole act, but the facility for inspiration increases towards the end. During expiration the air rushes out easily and quickly at first, but with increasing slowness and difficulty towards the end. During inspiration the air-tubes become larger towards the end, therefore inspiration is then easier; during expiration the air-tubes become smaller towards the end and more clogged with fluid, and therefore expiration is then more prolonged and difficult (p. 73).

The expiration is more prolonged in proportion to the obstruction in the smaller air-tubes; it is longer in emphysema when combined with bronchitis, than in either emphysema or bronchitis simply. It is more prolonged when the obstruction is in the smaller, than when it is in the larger bronchial tubes (pp. 69, 70).

During inspiration the abdomen advances very rapidly; the upper part of the sternum and thoracic ribs stand still just at first, and then advance rapidly; the lower end of the sternum and the adjoining cartilages fall back usually during the whole act, sometimes only at the beginning of it, unless there be malformation of the chest or stiffness of the cartilages (p. 70).

During expiration the abdomen recedes very rapidly at first, then stands still, and again falls back interruptedly and with increasing slowness; the upper part of the chest stands still just at first, then falls back rapidly, and becomes progressively slower towards the end of the act; the lower end of the sternum advances during the whole time, or it advances at first and then falls back (p. 71).

The increasing slowness towards the end of expiration distinguishes obstruction of the smaller bronchi from obstruction in the larynx, in which latter case it is also prolonged, but it is equally slow throughout (pp. 54, 69).

SECT. III.—*Effect of Diseases confined to one Lung or one Side of the Chest, on the Movements of Respiration.*

A.—*Effect of Pleuritis on the Respiratory Movements.*—I have not observed with the chest-measurer any case of pleuritis affecting the whole lung. In the two following cases the pleuritis was partial.

	Sternum.		Second rib.		Sixth cartilage.		Sixth rib.		Eighth rib.		Tenth rib.		Abdomen.		
	up.	lower.	right.	left.	right.	left.	right	left.	right	left.	right	left.	right	cent.	left.
	in.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch	inch.	inch.	inch	inch.
Simpkin, (Table III.) Case 133.	·10	·11	·11	·08	·07	*·07	·03	*·005	·08	·10	·13	·10	·17	·10	·13
Shepherd, (Table III.) Case 134. First observation	·05	*·03	·10	·10	*·03 to *·04	*·03	·03	·03	·08	·08	·08	·03	·06	·15	·08
Second observation	·03	*·02 †·02	·10 to ·20	·10 to ·20	*·01 †·03	*·02	·01	·*01	·05	·03	·05	·04	·05	·08	·07

[The ordinary figures, and those with † prefixed, denote a forward movement; those with * prefixed, a backward movement of the costal walls during inspiration.]

Sarah Simpkin, a woman of 40, had a rustling friction-sound over the anterior and lateral portion of the lower lobe of the left lung and the adjoining portion of the diaphragm. When she attempted to breathe deeply, her breath was caught by a severe pain over the cardiac region. In her the respiratory movements were everywhere normal, excepting just over the seat of the friction-sound, the left sixth costal cartilages moving ·07 in. and the right ·07 in.; the left eighth rib moving outwards ·1 in. and the right ·08 in.; but the left sixth rib fell in ·005 in., while the right sixth moved outwards ·03. In Simpkin's case the pleuritis locally restrained the breathing movement, at the seat of the pleuritis,—the sixth rib, and not at the seat of the catching pain,—the sixth costal cartilage.

Shepherd, a little girl of 7, suffering much from dyspnœa, presented comparative dulness on percussion over the lower lobe of the right lung, and over the upper lobe of the left. The inspiratory breath-sound was diminished, and the expiratory increased, over the lower lobe of the right lung; in the opposite lobe the inspiration was coarse, the expiration unchanged; next day there was a loud smooth to and fro friction-sound. The expiratory-sound, whispering, as it were, under the ear, was audible when she whispered; and, when she spoke, ægophony was caused by the whispering expiratory friction-sound, accompanying and following the vocal resonance. In this girl, unequivocally suffering from pleuritis, the respiratory costal movements on the first day were perfectly normal. The sixth, eighth, and tenth ribs of each side respectively ·03 in., ·08 in., ·08 in.; the right side of the abdomen presented a slight diminution.

Next day, when the dyspnœa was much lessened, the friction-sound being audible over the right lower lobe, the expansion of that lobe was somewhat greater than that of the left.

During the first examination, when the rapidity of breathing was excessive, and the costal and diaphragmatic breathing were both exaggerated, the lower end of the sternum and the sixth cartilage fell back ·03 in., owing to the rapid expansion of lung above and elongation of it below, causing intermediate collapse from atmospheric pressure, as was observed in emphysema and obstructed larynx (pp. 47, 58).

These two cases show that pleuritis without effusion may either cause diminished motion or not.

As a general principle, pleuritis undoubtedly does lessen the movements. Andral (*Clinique Medicale*, ii. 598) says, "Dans la pleurésie costo-pulmonaire la respiration est surtout diaphragmatique; au contraire, dans l'inflammation de la plèvre qui tapisse le diaphragme, ce muscle devient immobile, et la dilatation du thorax est surtout le résultat du mouvement d'ascension des côtes." Dr. C. J. B. Williams (*Library of Medicine*, iii. 110) considers the sign equivocal, and due to pain. Dr. Walshe (*Diseases of the Chest*, p. 219) states, that after pain has abated, the motions have acquired greater freedom until they were again obstructed by the accumulating fluid. M. Collin (Dr. Forbes' translation, in his *Original Cases*, p. 294) says, that in the earliest stage the motions of the affected side are enfeebled or almost extinguished, the ribs over the diseased part being fixed and the remainder moveable.

M. Collin's view is certainly too decided: indeed, non-motion in pleuritis would have a very injurious result; the fibrous adhesions, so usually met with, would be short, and confine the lung if there were no motion; as it is, they are long, and admit great freedom of movement; and this elongation of them is due to the to and fro movement of the lungs and ribs during respiration, drawing upon and lengthening the new and plastic adhesions.

The existence of friction-sound is itself a proof of respiratory motion in simple pleuritis, and Dr. Stokes justly attributes the frequent silence of pneumonic pleuritis to the want of pulmonic motion.

Summary.—Pleuritis, it may be justly said, usually restrains the respiratory movements sometimes because of pain, but sometimes although there be no pain. In some cases the movements are not at all lessened, and I believe, in simple or dry pleuritis, they are seldom, if ever, entirely destroyed. The respiratory movements of the opposite lung and of the unaffected portions of the same lung, are, from compensation, exaggerated.

B.—*Effect of Effusions into the Cavity of the Pleura on the Respiratory Movements.*—This is one of the two cases allowed by Laennec to influence the breathing movements :—" Je n'ai jamais pu constater d'inégalité manifeste et constante dans les movemens des deux côtés du thorax, que dans des cas d'empyème très abondant ou de déformation de la poitrine." (*De l'Auscultation Mediate*, i. 24.)

Avenbrugger noticed deficient respiratory movement from pleuritic effusion nearly a century ago; M. Collin, Dr. Hodgkin, Dr. Williams, Dr. Walshe, Dr. Hughes, and others, have given to the sign its value ; Dr. Stokes and Dr. Townshend, in their admirable descriptions of the disease in question, do not dwell on the symptom.

No disease has been more thoroughly illustrated than this, as to the effect of the collection, in increasing the size of the affected side, on the position of the ribs and the intercostal spaces, and the displacement of the heart, the opposite lung, and the abdominal organs.

I have examined with the chest-measurer two cases of effusion into the right cavity of the pleura and three into the left.

In the cases of Webb (Table III., Case 137), Roach (Table III., Case 138), (for whose case I am indebted to Dr. Walshe,) and Davis (Table III., Case 136), the effusion was considerable. In Webb, the left, in Davis, the right, side was much distended. The heart was, in Webb, displaced, and its impulse felt to the right of the sternum, while the impulse of the apex in Davis was felt considerably to the left of the nipple. In Webb, the diameter over the nipples was, on the left side, 7·4 in. ; on the right 6·5 in.—nearly an inch of difference.

The effusion was not considerable in Cook. The left side was, however, an inch larger than the right. The heart beat to the right of the xiphoid cartilage. The effusion was disappearing from Brown (Table III., Case 135), (Dr. Bence Jones favoured me with the examination of Brown and Webb,) the heart having returned to its normal position, and the tape measurements of the two sides being about equal. The diameter over the nipples was, on the right side, 7·8 in.; and, on the left side, 7·4 in.—not quite half an inch of difference.

	Sternum.		Second rib.		Fourth rib.		Sixth costal cartilage.		Tenth rib.		Abdomen.		
	upper.	lower.	right.	left.	right.	left.	right.	left.	right	left.	right	cent.	left.
LEFT CAVITY.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
Walter Webb, æt. 16 . . .	·08	*·01 †·04	·12	·05	·08	0	·06	*·02 † 02	·10	·02	·10	·12	·06
J. Roach . .	·12	*·02 †·04	·05	0	·12	0	·08	* 03 †·02	·12	·02 to ·03			
Deep inspiration . . .	...	...	·20	·12									
T. Cook, æt. 6.	·02	·03	·08 to ·12	0	·05 to ·08	*·01	*·01 †·04	0	·05	·01	·06	·15	·03
Second observation . . .	*·02	*·04	·08 to ·12	0	·08	0	·08	*·02	·08	0	·12	·22	·03
RIGHT CAVITY.													
Lydia Davis, æt. 18 . . .	·10	*·04	·18	·17	*·01 †·02	*·01 †·01	* 01	*·02 †·02	·06	·12	·12	*·03	·06
James Brown, æt. 21 . . .	·03	·04	·05	·10	·02	·03	·03	·04	·05	·10	·10	·30	·16
Deep inspiration . . .	...	...	...	...	·40	·70							
Health . . .	·03 to ·06	·02 to ·06	·03 to ·07	·03 to ·07	...	...	·02 to ·06	·02 to ·05	·10	·10	·09	·25 to ·30	·09

[The ordinary figures, and those with † prefixed, denote a forward movement; those with * prefixed, a backward movement of the costal walls.]

In all the cases, the motion of the affected side was diminished, while that of the healthy side was exaggerated; the diminution extending, in W. Webb and T. Cook, to all the respiratory movements. In all the cases excepting Cook and Davis the movements of the superior thoracic ribs—the second—were less affected than those of the intermediate and diaphragmatic ribs. This corresponds exactly to the principal seat of the effusion and consequent obstruction to respiration,—namely, the lower part of the chest.

The abdominal movements in Webb were restrained on the affected side and at the centre, but not on the other side. In Brown and Cook, the recovering cases, the abdominal movement was slightly exaggerated on the unaffected side, and normal at the centre and on the affected side. In Davis, the abdominal movements were, it is stated, reversed. My notes state that the motion was greater on the most affected side. Davis's case, which was obligingly shown to me by Dr. Ormerod, was complicated. The effusion into the right pleural cavity followed pneumonia, which still existed, of the lower lobe of the right lung, and there were indications of disease in the lower lobe of the left lung. As the abdominal movements are stated to be the reverse of what they are in the other cases—namely, greatly increased on the side of effusion—one is inclined to suspect an error in the note; otherwise, the complication must have modified the movements. The movements, both of the diaphragm and of the affected side, being diminished, the respiration by the thoracic ribs is exaggerated.

As the lung, when free from adhesions, is floated forwards at the upper part of the chest, and comes there, if anywhere, in contact with the ribs, so it is there that the respiratory movements are modified to the least extent. Thus, in Davis, Brown, Webb, and Roach—

	Davis.	Brown.	Webb.	Roach.		Roach.
The second rib on the affected side moved during an ordinary inspiration . .	inch. ·18	inch. ·05	inch. ·05	inch. 0	and, on a deep inspiration	inch. ·12
Second rib on unaffected side . .	·17	·10	·12	·05	„ „	·20

In Davis, the unusual exaggeration of the motion over the upper lobes, both sound and affected, was evidently due to the existing pneumonia, more than to the effusion. In

Webb and Roach, the lower end of the sternum, and the sixth costal cartilages of the affected side, receded at the beginning of inspiration, and, towards the end of it, advanced. This partially-reversed motion is evidently due to the displacement, downwards, by the diaphragm, of a portion of the fluid, the chamber holding it being elongated below by the diaphragm, and widened above by the thoracic ribs. The lower part of the chest during inspiration at first collapses over the fluid, from atmospheric pressure. After a time, the increasing amount of air in the lung more than replaces the displaced quantity of fluid, and the walls of the chest again move forward. In Davis, the lower end of the sternum fell back throughout the inspiration, and the fourth and sixth cartilages of both sides receded either partially or entirely. In her, the expansion of both lungs, but especially the right, was impeded by the accompanying pneumonia, and hence I conceive the non-motion of the lower end of the sternum, and of the right sixth costal cartilage, towards the end of the act. (For an explanation of the falling back of certain parts of the chest in disease, see pp. 47, 58.)

In James Brown, the case in which the effusion had diminished, the lower end of the sternum and the sixth costal cartilage advanced during the whole inspiration. In him, the respiratory movement was throughout more nearly normal. The diminution, however, of the movements on the affected side were marked and universal.

	Second rib.	Fourth rib.	Sixth cartilage.	Tenth rib.	Abdomen.
The ordinary inspiratory movements of the right,	inch.	inch.	inch.	inch.	inch.
the affected, side being	·05	·02	·03	·05	·10
Deep inspiration .	—	·40	—	—	—
Of the left side . .	·10	·03	·04	·10	·16
Deep inspiration .	—	·70	—	—	—

In a case of extensive effusion, in which paracentesis was performed, I observed that the lower ribs fell in partially on the affected side, while they moved outwards on the healthy side.

I have had no opportunity of observing the diaphragmatic action in those cases where, from the extent of the effusion, the diaphragm is so displaced as to become concave instead of convex.

Deep Inspiration.—In the worst cases, the extreme voluntary inspirations were not—indeed, could not be—observed. In Roach, they were very much restrained, the increase being from 0 in. and ·05 in. to ·12 in. and ·2 in. In Brown, the restraint was slight on the healthy side, and considerable on the affected side, the increase being from ·02 in. and ·03 in. to ·4 in. and ·7 in.

Summary.—When fluid is extensively effused into either cavity of the pleura, the affected side is throughout enlarged; the lungs are compressed, and float forwards and upwards, so as to be in contact with the superior ribs; the surrounding organs—namely, the heart, the opposite lung, and the abdominal organs—are all encroached upon and displaced. The motion of the whole affected side, both costal and diaphragmatic, is restrained, while the motion of the whole opposite side, excepting perhaps the diaphragm, is exaggerated. The exaggeration is more marked over the superior thoracic ribs, and the motion of those ribs is less diminished on the affected side, than over the lower ribs.

Owing to the displacement, downwards, of a portion of the fluid, the lower end of the sternum and the adjoining cartilages on the affected side fall back during inspiration, from atmospheric pressure. In extreme cases, the lower ribs fall in at the side during inspiration.

Pneumothorax excites nearly the same displacement in the walls of the affected side, and in the adjoining viscera, that effusion of fluid does, the difference being that, while in the latter the lungs are floated forward, in the former they lie upon the dorsum.

I have not observed any case of pneumothorax with the chest-measurer, but I have minute notes of the motion of the chest in the interesting case of Murden—an old man of 70, over whose chest the wheel of a waggon had passed. No rib was broken, but the left lung was ruptured at the lower anterior angle of the superior lobe: the lungs were affected with Laennec's emphysema. The left side was an inch wider than the right, "the respirations irregular, forty-two in the minute, chiefly abdominal; though all the thoracic muscles are employed, the right side of the chest expands considerably, whereas the left side, an inch wider than the right, does not expand." On the next day it is noticed that "the abdominal muscles contract suddenly and with rigidity at the commencement of expiration, the expiration sometimes commencing with a vocal noise."

I was summoned one day suddenly to a poor woman, dying, the nurse said, in one of the wards. She had phthisis, with cavities chiefly affecting the right side, the left side, as Mr. Martyn observed, having the greatest range of motion. "On the right side the upper lobe is consolidated, and contains a large vomica, with gurgling heard over the whole lobe and cavernous respiration." When I saw her the respiratory movement of the left side, which was very prominent, was absent, while that of the right side was considerable. She was moribund, and I made no further examination. On post-mortem inspection, pneumothorax in the left cavity was discovered, the air coming from a ruptured abscess seated in the lower margin of the upper lobe. This case, though only partially observed, is interesting, in that first one side, then the opposite had the greatest amount of motion, just as one or the other had the greatest amount of disease to restrain the motion.

C.—*Effect of Condensation of the Lung on the Movements of Respiration.*—Condensation of the lung follows the absorption of pleuritic effusion, when the lung does not recover its expansion, and is owing usually to firm semi-cartilaginous adhesions. The contracted side is in all its dimensions smaller than the sound side; the anterior inner margin of the sound lung encroaches on the contracted side, passing over to that side of the edge of the sternum; the sternum is drawn and the spine curved to the affected side. The diaphragm is high, and the abdominal organs consequently encroach on the chest. The heart, if the left side be contracted, is unusually to the left; if the right side, often greatly to the right, of the sternum; the whole lung, on the affected side, is contracted, the surrounding organs encroaching on that side—in fact, there is the exact reverse of what the same case presented at the stage of extensive effusion, when the affected side was enlarged, and the fluid, which had condensed the lung, encroached on the surrounding organs, displacing the opposite lung, the heart, and the contiguous abdominal viscera.

In these cases the sound lung is enlarged and its respiration exaggerated.

The case of the boy Cook, already mentioned among those affected with effusion into the pleura, became, after some months, an interesting example of the effect of condensation of the lung on the respiratory movements (p. 86).

Cases of Condensation of One Lung from Effusion into the Pleura.

	Sternum.		Second rib.		Fourth rib.		Sixth costal cartilage.		Sixth rib.		Tenth rib.		Abdomen.			Tape measurements. Above nipple.		Tape measurements. Lower end of sternum.	
	upper.	lower.	right.	left.	right.	left.	right.	left.	right.	left.	right	left.	right	cent.	left.	right.	left.	right.	left.
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
T. Cook, first observation, effusion into the pleura .	·02	·03	·08 to ·12	·0	·05 to ·08	·01	*·01 †·04	·0	...	...	·05	·01	·06	·15	·03	...	...	10·7	11·2
Ditto, second observation .	*·02	*·04	·08 to ·12	·0	·08 to ·12	·0	·08	*·02	...	...	·08	·0	·12	·22	·03				
Expiration .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	11·5	11·1
Third observation, condensation of lung	·02	*·03	·10	·0	·05	*·01	*·02 †·02	*·03	·02 to ·05	*·01 to *·03	·06	·01	·15	·20	·07	...	...	12·3	11·2
Deep inspiration	·45	·20	·60	·20	·30	·12	·40	·30	·40	·13	·20	·05	...	·30	...	...	...	12·7	11·3
Antero-posterior diameter at the level of the junction, the fourth rib with its cartilage . . .	...	...	...	...	7·3	6·2													
Barbara Beasley, æt. 7, fluid almost gone from left pleural cavity.	·0	·12 ?	·10	*·02 †·02	·05	·0	·07	·0	...	...	·05	·0	·08	·15	·0	10·7	9·5		

[The ordinary figures, and those with † prefixed, denote a forward movement; those with * prefixed, a backward movement of the costal walls during ordinary inspiration.]

When the first observations were made upon Cook (Table, p. 92, and Table III., Case 139), the left side, on which was the effusion, was by half an inch larger than the right; the amount of effusion not being great; and the heart was displaced so as to beat to the right of the xiphoid cartilage.

At the time of the second observation, the dimensions of the sides were reversed, the right side being nearly an inch larger than the left, and the diameter of it above an inch greater. The right lung had expanded considerably, that side being an inch and half larger than on the former occasion, while the left side was less. There was, indeed, some little respiration returning in the left lung, manifested by some resonance on percussion below the left clavicle. The heart's impulse was now unusually to the left of the nipple. It will be observed that the difference of motion was throughout very nearly the same during the first observation, when fluid was effused and doubtless being absorbed, and in the second, when the fluid had been absorbed and the lung was condensed.

During tranquil inspiration the whole condensed side was motionless, the abdominal movement was less by one half on the condensed than on the sound side, and the lower end of the sternum and the sixth left costal cartilage receded, owing to collapse of the elongated lung (p. 86).

During a deep inspiration every part of the chest expanded, but the forward movement of the left side was only a third of that of the right side. The sixth, eighth, and tenth ribs of the affected side moved outwards less in proportion than the superior ribs moved forwards; indeed, the dilatation from the thoracic ribs was markedly greater than that from the diaphragmatic, owing to the lung being more condensed below, and also to its being more elongated by the descent of the diaphragm. The expansion of the left thoracic ribs acts also to expand the left margin of the right lung, which moves during a deep inspiration about half an inch further to the left of the sternum.

The case of Beasley (Table III., Case 140) resembles that of Cook in the recent, scarcely complete disappearance of pleuritic effusion, and in the diminution of measurement; that of the condensed or left lung being 1·2 in. less than that of the right. In Beasley the whole movements of the left side, both costal and diaphragmatic, were annihilated, the left second rib alone moving, and the motion of that rib was exactly balanced, as it first retracted and then advanced ·02 in. The lower end of the sternum advanced in Beasley, whose case differs from that of Shaw in this circumstance, and in the annihilation of the diaphragmatic movement.

The influence of the diaphragmatic descent in Smith caused, as has been seen, elongation and collapse of the lung and consequent falling in of the lower ribs; in Beasley, as the diaphragm did not act, the lung was not elongated, did not collapse, and did not fall in excepting at the second ribs. During a deep inspiration the sixth rib fell in ·05 in., the diaphragm then most probably descended, elongating the lung, and causing it to collapse. In cases such as this of Smith, when the expansion of one side of the chest is exaggerated, of the other diminished, the sternum moves a little towards the exaggerated or healthy side. This was pointed out to me by my pupil, Mr. Martyn; it is a circumstance that readily catches the eye, and is therefore of value in leading the attention to the cause of it.

Summary.—When the whole of one lung is simply condensed, the movements of that side are either much diminished, annihilated or reversed, while those of the opposite side are increased. The motion of the diaphragm on the affected side, though restrained, is not annihilated, the unexpandable lung being lengthened by the diaphragmatic descent, and the diaphragmatic and intermediate ribs consequently often fall in during inspiration, while the superior ribs are motionless, or move outwards but a little. During a deep inspiration the retraction and rest of tranquil breathing give place on the affected side to inspiratory expansion, greater from the motion of the thoracic ribs, and of the diaphragm, than from that of either the diaphragmatic or intermediate ribs.

The cases of consolidation complicated with phthisis will be considered under that subject.

D.—*Effect of Phthisis on the Movements of Respiration.*—The lungs in phthisis present so infinite a variety of conditions, that we must look for a considerable variety in the phenomena presented by the movements of respiration. It so happens that though I have observed a fair number of cases with the chest-measurer in the advanced stages of phthisis, I have not examined any with it in the early stages.

The Whole of One Lung Affected.—Among the advanced cases, there are thirteen in which the whole of the most diseased lung presented unequivocal marks of disease. The wood-cuts at pages 98 and 99, taken from J. Boot, having tuberculous disease of the whole right lung, represent the position of the ribs and lungs and other viscera, before and after the inflation of the lungs. They show the great diminution in the expansibility of the diseased side. In this case very firm tendinous adhesions enveloped the lower lobes, and combined with tuberculous deposit to prevent their free expansion.

In Neale (Table, p. 97, and Table III., Case 141), a communication existed between an abscess in the axilla and a dilated bronchial tube and small tuberculous cavities in the upper lobe of the left lung, through a curious opening in the second rib. The lower lobe contained many tubercles, but was chiefly solidified by the pressure of strong tendinous pleuritic adhesions. In Boot (Table, p. 97, and Table III., Case 150) there were cavities in the upper lobes of both lungs, but that of the right lung was chiefly affected, and the tendinous thickened costal pleura restrained the expansion of, and solidified, the lower lobe.

Those cases of phthisis affecting the whole of one lung are so nearly allied in the physical condition of the diseased part, and in the phenomena of respiratory motion, to the cases of condensed lung from pleural adhesions just considered, that it will be well to examine such cases before those where only the upper portion of the lung is diseased.

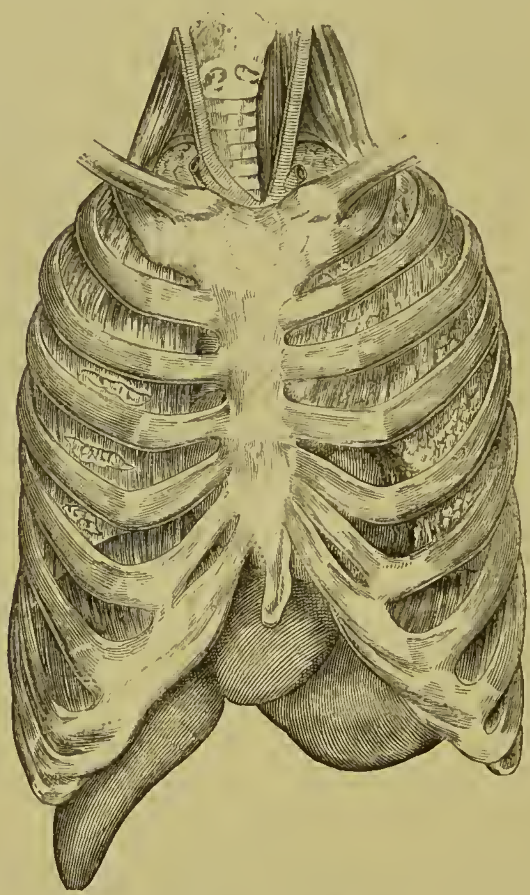
CASES OF PHTHISIS IN WHICH THE WHOLE LUNG IS AFFECTED.

	Sternum.		Second rib.		Fourth costal cartilage.		Sixth costal cartilage.		Sixth rib.		Tenth rib.		Abdomen.		
	upper.	lower.	right.	left.	right.	left.	right.	left.	right.	left	right.	left.	right.	centre.	left.
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
LEFT LUNG.															
W. Neale, age 51, tubercles in both lobes, especially the upper: consolidation of lower lobe	*·03	*·04	·11	*·02	·06	*·02	·08	*·04	...	...	·16	·10	·22	·25	·06
Second observation .	*·02 †·02	*·04	·15	*·01 †·03	·20	*·03	·11	*·03	...	...	·16	·08	·25	·15 to ·20	·14
Daniel Hardy, age 41 .	*·01 †·01	·11	·08	...	*·02 †·05	*·03 †·04	·12	*·01 †·02	...	...	·15	·09	·18	·15	·01
Deep inspiration . .	...	...	·15	·05	...	...	·40	·10	...	...	...	...	...	·60	
RIGHT LUNG.															
Joel Boot, age 39, in articulo mortis, pp. 98, 99	*·01 †·06	*·10	·06	·10	*·04	*·03	*·05	*·05	...	...	·14	·15	·5	·25	·20
Mary Robinson, age 15.	·03 to ·06	·05 to ·06	·02 to ·04	·10 to ·12	·01 to ·03	·07 to ·12	·02 to ·03	·05 to ·06	·01	·10	·02 to ·04	·10 to ·15	·04 to ·07	·10 to ·15	·10 to ·15
Deep inspiration . .	·17	·10	·10	·50	...	...	...	...	·08	·30	·13	·40	...	·50	
Pearson, age 7, in articulo mortis, not quite exact	·13	·10	·15 to ·20	·08 to ·10	·15 to ·20	·06	·15	·08 to ·10	·12 to ·16	·08	·20 to ·15	·15	·10	*·06	·10
Expiration	...	...	·0	·02 †·12	...	·02 *·08	...	...	...	·02 †·10	...	...	...	·10 *·04	

	Above nipple. right.	Above nipple. left.	Xiphoid cartilage. right.	Xiphoid cartilage. left.	Diameter at nipple. right.	Diameter at nipple. left.
Tape measurement in Mary Robinson	11·4	11·8	11·1	12·1	5	6·1
Ditto during deep inspiration	11·6	12·5	11·2	12·4		

[The ordinary figures, and those with † prefixed, denote a forward movement; those with * prefixed, a backward movement of the costal walls during ordinary inspiration.]

There is, in such cases, general lessening of the most affected and general enlargement of the least affected side;



JOEL BOOT, AGE 39.

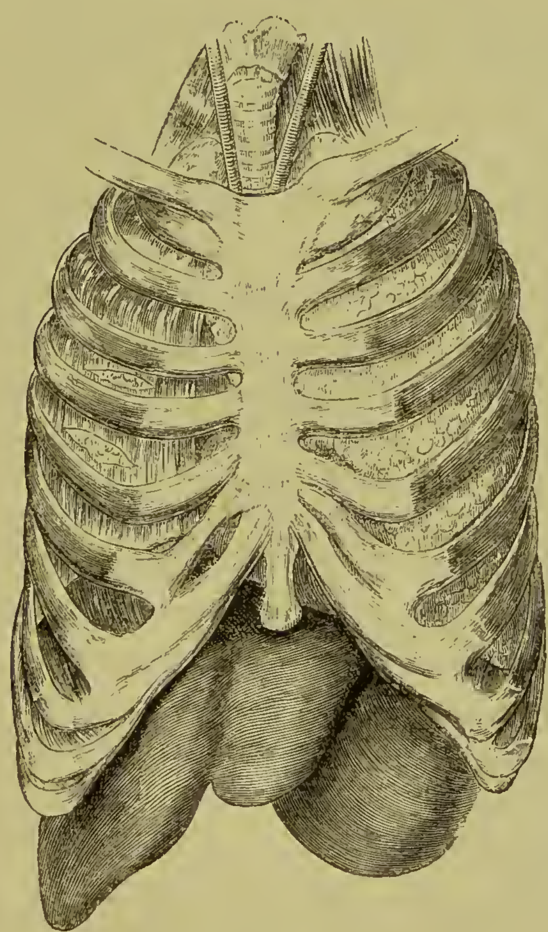
In this figure the lungs are not inflated; it represents *tranquil respiration.*

Tubercles and a cavity in the upper lobe of the right lung; tubercles through the right lower lobe; and universally thickened tendinous-pleura, prevent the expansion of the whole right lung.

A small cavity on the summit of the left lung: this does not prevent the expansion of that lung, which is free and universal. See pp. 95—101, and Table III., Case 150.

the least affected lung descends considerably, and, in most cases, finds its way beyond the margin of the sternum over to the affected side.

In the cases of Neale (Table III., Case 141) and Boot (Table III., Case 150), the expansion of the lower lobe was restrained, not by the tuberculous deposit so much as by the firm, strong adhesions. Those adhesions formed continuous



JOEL BOOT, AGE 39.

In this figure the lungs are fully inflated; it represents a *deep inspiration.*

bands of strong, thick tendons, passing from rib to rib, and enveloping the whole surface of the lung in contact with the costal pleura: they were truly intercostal adhesions. M. Louis (Dr. Walshe's translation, p. 35) found that out of 112 subjects who died of phthisis, one only was entirely free from adhesions ; in twenty-five the adhesions were cellular, easily torn, limited ; in the rest they were either extensive or general, composed, more or less, of cellular tissue ; in these cases large cavities were almost always found ; the more advanced and extensive the disease, the more dense usually were the adhesions. Dr. Hodgkin, in his *Lectures on Morbid Anatomy*, vol. ii. p. 177, says: "The contraction which accompanies the changes which this pleuritic deposit undergoes, in conjunction with alterations in the lung, from the consolidation of texture and contraction of excavations, is, I believe, the principal means which produces the alteration of form which sometimes accompanies the want of resonance at some parts of the chest in phthisical patients." This remark of Dr. Hodgkin with regard to the permanent contraction of the lung in such cases is, I am convinced, to be applied also as the principal cause of the deficient, absent, or reversed motion of those parts of the chest occupied by the diseased lung. I have found that if adhesions be loose, cellular, and long, even though they be universal, the lungs enlarge, when distended, to the normal extent.

When the adhesions are tendinous, very strong, intercostal passing from rib to rib, and embracing the lung in an unyielding tendinous sheath, as in the cases of Neale and Boot, then the lung can be distended but laterally very little, or not at all, although there is usually some descent of the diaphragm, and consequent elongation of the diseased lung, as is shown in the wood-cut, p. 99. In these cases, when the adhesions are cut across, the exposed tissue of the lung is usually in part expansible ; but the adhesions prevent, or impede, the expansion.

In Pearson's case, the observations from whom were taken *in articulo*, the distension of the left lung, especially the upper lobe, was much restrained by intercostal adhesions, but not to the almost absolute extent found in Neale.

The impediment to expansion during life was, in these cases, proportioned to the strength and inexpansibility of the adhesions lining and restraining the ribs, and investing the lungs. It will be observed, that, although all the movements were restrained, those of the thoracic and intermediate ribs were so much more than those of the diaphragm and diaphragmatic ribs.

This will be found to apply to the thirteen cases in which there was, to a greater or less extent, consolidation of the lower lobe, and in all of which, except Neale, there were cavities of considerable size in the upper lobe.

The dimensions and respiratory movements of the opposite, or less diseased lung, were notably exaggerated. This exaggeration extended, in nearly all the cases, through the whole lung, the costal and diaphragmatic motion being alike increased.

The inspiratory elevation, and outward movement of the ribs, draws the sternum very palpably over to the unaffected side, a point to which my pupil, Mr. Martyn, drew my attention. In Neale's case, it was well seen that the sternum is drawn to the right by the right costal expansion ; and in Boot's, to the left, by the expansion of the left side. (See wood-cuts at pp. 98, 99.)

When the right lung is affected, as in Boot, the exaggerated expansion of the left lung covers the heart during inspiration, and often causes the disappearance of its impulse from the intercostal spaces, and its appearance below the xiphoid cartilage.

When the left lung is affected, as in Neale, owing to its deficient expansion, the heart is not further covered by it during inspiration, and its impulse, instead of being lessened in the intercostal spaces, is increased, as the heart is drawn downwards.

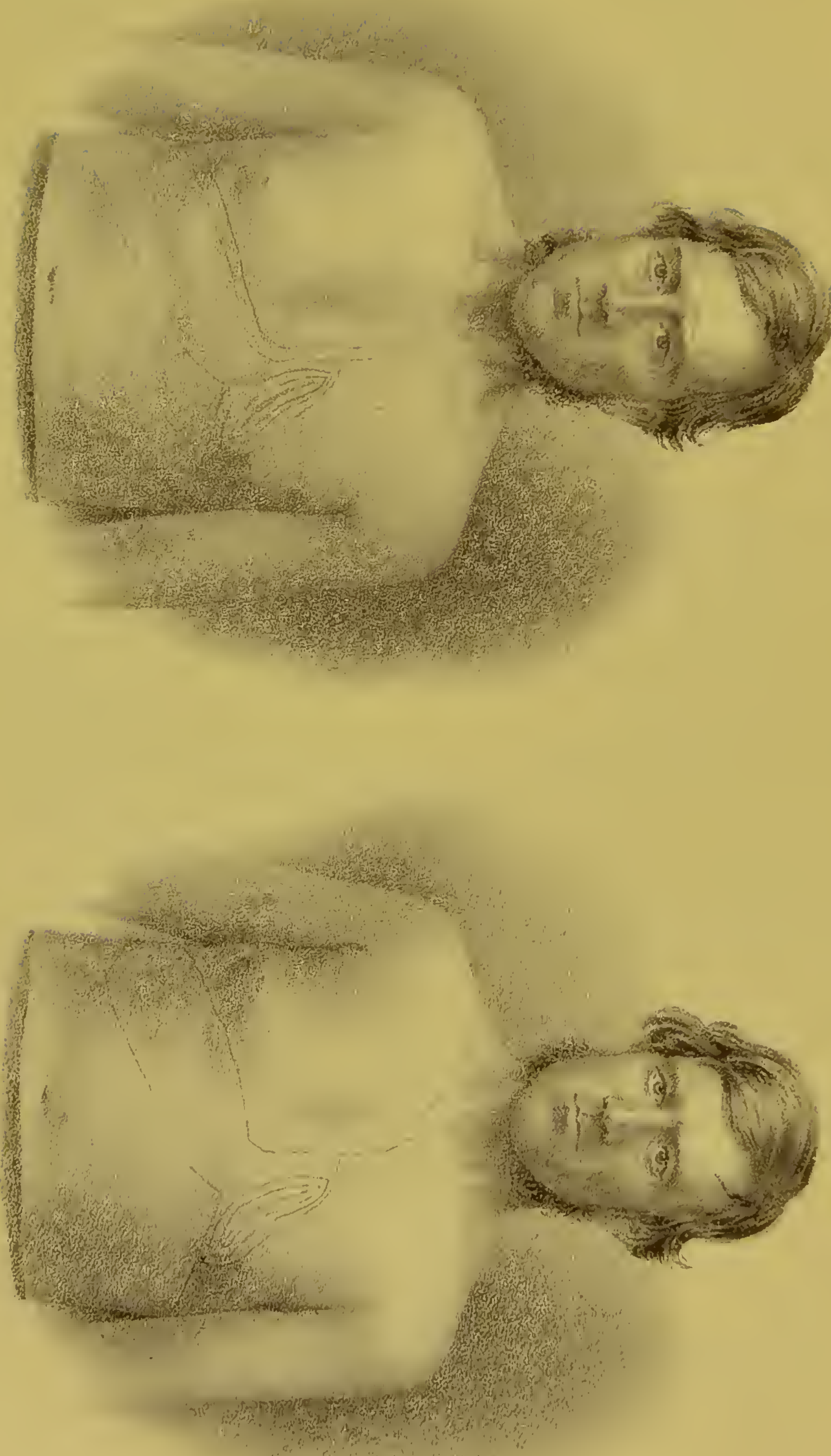
In Neale, the liver is pushed down extensively by the descent of the right side of the diaphragm, the stomach descending but little ; while in Boot, the stomach is pushed extensively downwards, the liver descending but little. Out of thirteen cases, in which the lower lobe was more or less diseased, and in nine of which the left, and four the right, lung was affected, the sixth costal cartilages retracted during inspiration in ten, and the lower end of the sternum in six ; in eight of the cases there was retraction of the sixth cartilage through the whole inspiration ; in the other two, only at the beginning. In one of the excepted cases—Elliott (Table III., Case 143,)—the lower end of the sternum fell back at the beginning of inspiration ; and in the other—Pearson (Table III., Case 148,)—who was observed *in articulo mortis*, the abdomen retracted during inspiration at the centre, the costal action was consequently throughout exaggerated : in her, the ribs over the affected side protruded slightly, and the abdomen considerably, at the beginning of inspiration.

The retraction was, in these instances, as in those where it occurred from condensation, due to the rapid elongation and collapse of the lower portion of the lung, by the descent of the diaphragm (p. 94).

In two of the cases, the upper end of the sternum fell back throughout, and in four, just at the beginning of, inspiration. This partial retraction of the upper end of the sternum might be due, in some of the cases, to obstruction to inspiration, from laryngitis. But we shall have to consider another cause, residing in the non-expansibility of the thickened walls of the cavity.

Cavities in one Upper Lobe.—I have observations of twenty-four cases in which there were cavities in one upper lobe ;

PLATE VII.



the upper lobe of the opposite lung was in all the cases notably less diseased, and the lower lobes of both lungs were not appreciably affected. All those cases in which the whole of one lung was diseased have been already taken out and placed in the previous subsection.

Of the 13 cases in which the whole of one lung was more or less solidified with cavities in the upper lobes	in 9, the left was affected. 4, the right ,,
Of the 24 cases in which there were cavities in the upper lobe only of one lung . .	in 14, the left was affected. 10, the right ,,

The accompanying lithographs from daguerreotypes of Samuel Redgate (Table III., Case 163), the once celebrated fast bowler, illustrate the change in the visible form of the chest, and the position of the viscera during a deep respiration. In the daguerreotype taken during tranquil respiration, the right side is manifestly larger than the left, but not very materially so; the right lung encroaches on the left side, its inner margin coming beyond the left edge of the sternum. Owing to the falling away of the diminished left lung, the heart is in extensive contact with the costal walls, and its impulse is felt from the third to the sixth costal cartilage.

In the daguerreotype taken during a deep inspiration the left shoulder is scarcely elevated, while the right is raised to a very great extent, and the whole right side is strikingly larger than the left side; the right lung encroaches still further on the left side: the lower margin of that lung descends more than the heart, the impulse of which is not lessened above by the expansion of the left lung, but becomes more extensive below owing to its own descent.

When the right upper lobe is consolidated, the exaggerated expansion of the left lung lowers and lessens the extent of the impulse in the intercostal spaces during an ordinary healthy inspiration; and causes its disappearance from the intercostal spaces, and appearance below the xiphoid cartilage, during a deep inspiration: on the contrary, if the left upper lobe be affected, as in Redgate, the left lung falls back from before the heart, exposing it extensively, so that the impulse is felt often from the second to the fifth or sixth costal cartilage; and during a deep inspiration the impulse increases in extent downwards, without being lessened above.

The selected cases in the Table on the opposite page (105) illustrate the movements of respiration when cavities are seated in the right or left upper lobe.

In only one of the twenty-four cases—Green (Table III. Case 154,)—was the most affected side largest. In Astell (Table III., Case 155,) the two sides were equal; and in Stanyon (Table III., Case 162,) nearly so. The increased size of the least diseased lung was not confined to the subclavicular space, but also extended over the whole front of the chest, down to the lower boundary of the heart and lungs, or to the sixth costal cartilages.

I need not say that although the cases are classed as being diseased in the right or left upper lobe, yet the opposite lung is likewise in almost all cases affected with tuberculous disease, though in a less advanced stage. Consequently, although I have observed no case of incipient phthisis with the chest-measurer, yet in most of the cases the lung having cavities is compared with a lung in the earlier stages.

In twenty-three of the twenty-four cases, the respiratory movements were decidedly and considerably less on the most affected side. In the exception, Saywell, there was undoubtedly a cavity on the right side; yet the motion of that side was a shade greater than that of the opposite. In S. Hoffen my notes state that some of the movements were

Cases of Phthisis in which one Upper Lobe is Affected.

	Sternum.		Second rib.		Fourth costal cartilage.		Sixth costal cartilage.		Sixth rib.		Tenth rib.		Abdomen.			Tape measurements. above nipple.		Tape measurements. at xiphoid cartilage.	
	upper.	lower.	right.	left.	right.	left.	right.	left.	right.	left.	right.	left.	right.	centre.	left.	right	left.	right	left.
LEFT SIDE.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
S. Redgate, 37, breathing capacity 150, large vomica, improving . (See Lithographs)	*·01 †·02	*·02 †·05	·06 to ·10	·03 to ·07	·13	*·02 †·02	·08	*·02 †·04	·07 to ·09	·03 to ·05	·09 to ·11	·07	·14	·40 to ·50	·08	18·2	16·9	18·2	17·6
Deep inspiration	*·02 †·20	*·02 †·25	·50	·30	·55	·30	·34	·24	·50	*·05 †·30	·30	·30	·24	·90	·18	18·9	17·3		
R. Stanyon, 36, breathing capacity 246, large vomica, getting worse	·08 to ·10	·07	·08 to ·11	·06 to ·08	·06	*·01 †·01	·09	*·01 †·02	·07	·03	·15	·14	·13 to ·15	·35	·18	13·8	16·4	15·5	15·2
M. Castle, large cavity . . .	·13	·06	·12 to ·16	·08 to ·13	·04 to ·05	*·02 †·03	·05 to ·06	·03 to ·05	·06	·03	·15 to ·20	·10 to ·12	·08 to ·09	·15	·07 to ·08	13·8	12·2		
RIGHT SIDE.																			
S. Fowles, 27 .	·08	*·12	·05 to ·08	· 2 to ·14	*·03	·07	*·05	·0	...	...	·16	·15	·15	·20	·16				
S. Daft, 65 . .	·09	*·02 †·08	*·01 †·03	·09	*·03 †·01	·05	*·02 †·04	·08	...	...	*·03	·10	...	·30					
Deep inspiration . . .	...	·60	...	...	...	...	·40	·60	...	...	·30	·50							
J. C. Searle, 25	06	·05	·06	·12	*·02 †·02	·06	·05	·0 6	...	...	·07	·08	...	·17	...	15·2	15	14·5	14
Saywell . . .	·20	*·02	·20	·20	·03	·03	·04	·03	...	...	·06	·09	·05	·09	·03				
Deep inspiration . . .	...	...	·80	·60															

[The ordinary figures, and those with † prefixed, denote a forward motion; those with * prefixed, a backward motion of the costal walls during ordinary inspiration.]

greater, some less, over the affected side; here I suspect an error.

In only two of the cases was there absolute non-motion over the cavity; these were the cases of Green and Astell, in the first of whom the affected side was the largest, while in the other the two sides were equal; in neither of them was costal respiration exaggerated. The cavity was superficial in Green, but it was not so in Astell; probably in the last case a block of solid tubercle was situated over the cavity: both of these cases had considerable mobility over the opposite second ribs, their extreme inspiratory movements being respectively ·85 in. and 1 in.

In none of the cases was the motion reversed over the cavity through the whole inspiration; though in three of them the rib receded ·01 in. to ·02 in. at the beginning of the inspiration, and then advanced.

If the eye run down the parallel columns of the movements of the second rib, just over the cavity, it will be seen that, in nearly all, the motion of the most affected side was about one half of that of the less affected side. The motion of the opposite lung was considerably exaggerated in fifteen cases; moderately so in four; and not so in five. In the ten cases in which the costal breathing was not notably exaggerated, the abdominal was slightly so. Although the cavity has, over its centre, almost always an inspiratory movement, yet at its margins I have often found the motion abolished, and even reversed. The fourth costal cartilage is often over a consolidated portion of lung, which forms the walls of the cavity. The fourth costal cartilages receded either at the beginning or during the whole of an inspiration in fourteen out of twenty-two cases. The fourth cartilages receded in six out of ten cases on the right side, and in eight out of twelve on the left.

Of the whole thirty-nine cases observed in which there were cavities in one lung, there were eleven in which the upper end of the sternum fell in at the beginning of inspiration. This might be in some cases from laryngitis ; but as the laryngitis of phthisis does not usually obstruct respiration materially, as is manifested in the case of Andrews (Table III., Case 179), I conceive this can seldom have an influence. The falling-back of the upper end of the sternum is, I conceive, due to its being so often in front of the consolidated border of the cavity. The lung outside the consolidated portion expands, and the cavity itself expands also, when acted upon by the costal movement. I conceive that the expansion of the lung to each side of the consolidated wall of the cavity stretches that wall and causes it to collapse, hence it so often recedes just at the beginning of inspiration. In a few cases, especially over the fourth rib, the wall recedes during the whole inspiration. For an explanation of the cause of the falling-back of the costal walls in disease, see pp. 47—52.

In many cases, both around and over the cavity, the thoracic wall stands still just at the beginning of an inspiration. This is, as it were, the first stage of an absolute falling-back. The same phenomenon is observed in emphysema.

The lower end of the sternum, and the adjoining sixth cartilage on the affected side, recede, either at the beginning of inspiration, or throughout, in about one half of the cases. Here the falling-in is due to the elongation of the affected lung through the action of the diaphragm, and its consequent collapse.—See pp. 101, 102.

The elevation of the clavicle and sternum, in the few cases in which I observed it, corresponded with the forward movement of the sternum and second rib. In one half of the cases, the action of the diaphragm is somewhat restrained on the affected side. The movement of the diaphragmatic ribs was diminished

In 6 cases	out of 10	on the right side	when that side was affected.
And in only 4	„	13	on the left side	„

This preponderance of restraint on the right side is probably due to the presence of the liver, which is often enlarged in phthisis.

While examining the movements over a cavity, I have found, at short intervals, a great change in their amount. This could occasionally be traced to the accumulation of the contents of the cavity at intervals, and to the consequent additional obstruction to its expansion and contraction. The gurgling rhonchus is most usually heard at the beginning of an inspiration, and the end of an expiration: the cavity and its tubes are then smallest, and the fluid it contains most nearly fills it; at the end of inspiration and beginning of expiration, when the cavity is expanded to its full extent, the fluid gravitates to the bottom of the cavity, away from the bronchial inlet; but by and by, when the cavity is again lessened by expiration, the fluid again plugs its outlet, and re-produces the cavernous rhonchus.

The prolongation of the expiration, and its increasing slowness towards the end, is often due to the same cause.

During a deep inspiration the difference between the expansion of the two sides is usually very apparent to the eye. The cavernous lung usually expands from one half to two-thirds of the amount that the opposite lung does; the proportional difference between the expansion of the cavernous and that of the opposite lung is somewhat lessened, but the actual difference, from the whole motion being increased, is much greater, and, therefore, much more palpable.

If there be disease in one lung, the restrained motion on that side will, as has just been said, be more palpable during a deep than during an ordinary inspiration ; but if there be diminished motion during tranquil breathing, without any morbid cause, the difference in the motion will usually disappear during a deep inspiration; the movement, for instance, may be ·03 in. on the right side, and ·06 in. on the left, in tranquil breathing ; and on taking a deep breath they may be 1·1 in. on the right, and 1 in. or 1·1 in. on the left. Here we possess an unequivocal sign of the absence of difference in the amount of disease on the two sides.

In many cases, the movements are very much restrained over the cavity during a deep inspiration ; if they be so, the movements over the opposite lung are usually also restrained, and in a like proportion.

	Over the Cavity. inch.	Over the corresponding part of the opposite Lung. inch.	Abdomen. inch.
In Durow, the movement, on a deep inspiration	·15	·35	·30
Harly	·05	·15	
Rutland	·16	·30	
Porter	·00	·30	
Castle	·20	·35	·40
Smith	·26	·35	·40
Emmet	·35	·60	
Redgate	·30	·50	·90
Searle	·40	·60	
Kirk	·40	·70	1·00
Alvey	·40	·85	
Alvey, second observation	·55	·90	·70
Green	·45	·85	·70
Astell	·70	1·00	
Parson	·70	1·00	1·50
Searle, second observation	·80	1·20	

When the cavity is lessening, and the health improving, the restraint on the cavernous side may increase, while the movement on the opposite side may increase. Thus—

In Robinson (a case of this class long watched)	·10	·50	·50

The extreme advance of the abdomen is, also, usually restrained in proportion (within certain limits) to the restraint on the extreme movement over the cavity during a deep inspiration, as is evident in the Table on previous page (109).

If the disease be improving, as in Redgate and Robinson, the abdominal motion is proportionally greater.

Cavities, or Softening Tubercles, in the Upper Lobes of both Lungs in nearly equal degree.—In these cases, the movements of the two sides more nearly balance each other.

The two sides do not usually differ in contour; the whole chest is flat, the sternum being as prominent as, or more so than, the third, fourth, or fifth costal cartilages; the lungs, falling away from the heart, leave it extensively exposed; the mass of the lungs, unless there be universal tuberculous deposit, is diminished; the size of the abdominal, in proportion to that of the thoracic, organs is, therefore, considerably increased, and the hepatic and gastric bulges are high and prominent.

I have examined, with the chest-measurer, four cases of this class.

These cases present slight differences here and there, in perfect keeping with the minor difference in disease on the two sides.

In Flanagan, a patient of Dr. Roupell, at St. Bartholomew's Hospital, (Table III., Case 180,) the difference is trifling on a deep inspiration, and does not exist during ordinary breathing; the solidified, or softened left lung, obstructs the movements nearly as much as the cavernous right lung.

A Cavity in the Middle Lobe of the Right Lung.—I have examined one case of this kind.

In this case, a cavity existed in the middle lobe, and

Cases of Phthisis in which the Upper Lobes of both Lungs were affected.

	Sternum.		Second rib.		Fourth rib		Sixth costal cartilage.		Eighth rib.		Tenth rib.		Abdomen.			Tape measurements. above nipple.		Tape measurements. at xiphoid cartilage.	
	upper.	lower.	right.	left.	right.	left.	right.	left.	right.	left.	right.	left.	right.	centre.	left.	right.	left.	right.	left.
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
T. Andrews, sides equal, numerous cavities in both lungs behind . .	·10	·05	·15 to ·18	·09 to ·15	·06	·05	·05	·05	·12	·12	·10	·10	·14	·20	·20				
J. German, cavities on both sides, more on right . . Second observation	·03 to ·10 ·06	·04 *·05	·06 to ·15 ·08 to ·10	·10 to ·20 ·13	·05 ·06	*·01 †·05 ·06	·03 ·03	·04 ·03	... ...	... ...	·11 ·10	·11 ·10	·12 ·13	*·05 †·15 ·20	·05 ·04				
D. Flanagan, age 39, cavity in right lobe, deposit in left, sides equal. Diameter—right, 5·7; left, 5·9 inch Deep inspiration .	·02 to ·10 ...	*·01 †·02 ...	·04 to ·08 ·15	·04 ·20	·03	·05	·02	·05	...	...	·05	·05	·05	·18	·08	17·2	17·2	17·2	17
S. Vallance, age 15, cavities in both lobes, largest in the left; left side largest . . . . Deep inspiration .	*·02 *·04 †·04	*·09 ...	*·01 †·03 ·25	*·01 †·03 ·35	*·02 †·02 ·30	*·03 *·04 †·04	·03 ·20	*·03 ·12	... ...	... ...	·11 ·30	·10 ·20	·16	·23	·16	13	13	12·5	11·6

[The ordinary figures, and those with † prefixed, denote a forward movement; those with * prefixed, a backward movement of the costal walls during ordinary inspiration.]

occasioned a very marked restraint in the motion of the fourth and sixth cartilages on that side; in fact, their motion was annihilated, as is shown in the annexed Table.

	Sternum.		Second rib.		Fourth rib.		Sixth rib.		Tenth rib.		Abdomen.		
	upper.	lower.	right.	left.	right.	left.	right	left.	right	left.	right	cent.	left.
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
J. Tenuini, 40 .	·05 to ·10	*·05	·08 to ·10	·10 to ·14	·01 to ·02	·02	·0	·12	·10	·10	·12	·20	·10
Deep inspiration	·30	...	...	...	...	...	...	...	·10	·30			

From these observations we may conclude that, wherever and whenever an extensive cavity exists in the lung, the respiratory movements are restrained over that cavity, but not obliterated; that the respiratory movement is greater over the centre than over the circumference of the cavity, and that, immediately over the circumference, the ribs or sternum often recede, either during the whole inspiration or, which is more usual, only at the beginning of it. The firm, tendinous, pleuritic adhesions that surround the lungs in the advanced stage of tuberculous disease have more restraining influence over the movements than the disease itself has.

"*Incipient*" *Phthisis.* — I have no observations to offer made by the chest-measurer, in persons affected with phthisis at this stage. The united testimony of Andral, Sir James Clarke, Dr. Forbes, Dr. C. J. B. Williams, M. Collin, M. Fournet, Dr. Hughes, and other accurate observers, affirms, that even in the early stages the movement of inspiration, especially on a deep inspiration, is restrained over the seat of the disease.

The observations of Andral speak directly to the point of the immobility, or partial mobility, of the chest, over that part where the lung is indurated from agglomeration of tubercles.[1] It follows from the physical nature of the progressive changes in phthisis, that the inspiratory motion over a cavity which has a respiration of its own must be greater than that over the more solid but softening tuberculous mass that immediately precedes the formation of a cavity. On this point I hope to make further special inquiries.[2] Andral has, however, decided it as a matter of direct observation.

Summary of the Effects of Phthisis on the Movements of Respiration.—In the earlier stages, the movements over the diseased portion of lung are restrained. When a mass of lung is solidified by tuberculous disease, the mobility is still further restrained (pp. 110-112).

Where cavities are formed, their inspiratory expansion is

[1] "Dans la phthisie pulmonaire, l'on observe un phénomène encore plus remarquable ; c'est l'immobilité, ou du moins la dilatation moindre d'une partie plus ou moins étendue d'un des côtés du thorax, là où les tubercules sont agglomérés en grand nombre. Cette immobilité plus ou moins complète d'une partie des parois thoraciques, et surtout évidente chez certains phthisiques, au-dessous de l'une des clavicules, entre cet os et le sein. Ce n'est pas avec l'existence de vastes excavations tuberculeuses que coincide le plus souvent ce défaut partiel des mouvemens des côtes, mais bien avec l'existence d'une pneumonie chronique formée, soit autour de tubercules crus et plus ou moins nombreuses, sois autour de petites cavernes. C'est à dire que l'immobilité partielle des côtes coincide le plus ordinairement avec un son mat."—ANDRAL, *Clinique Medicale*, ii. 97.

[2] *Postscript, August* 1848.—Dr. Barlow recently favoured me with the observation of a patient of his, at Guy's Hospital, that illustrates this passage. There was a large cavity at the summit of the right lung, and a consolidated mass of tubercles and a smaller cavity at the summit of the left lung. The second, third, and fourth ribs were more prominent on the left side than the right; and the respiratory motion, as indicated by the chest-measurer, was greater, both during an ordinary and a deep inspiration, over the extensive cavity on the right side than over the half-consolidated, half-cavernous, lung on the left side.

much diminished, chiefly by the firm, tendinous, and pleuritic adhesions that embrace the diseased portion of lung (pp. 99-110).

There is almost invariably some movement of inspiration over the cavity. But although the part in question always advances during inspiration, especially a deep inspiration, yet, at the beginning of the inspiration it sometimes recedes slightly, and frequently stands still just before its inspiratory advance (pp. 107-110).

The respiratory expansion and movements over a cavity are greatest just towards the end of inspiration and the beginning of expiration, when the cavity and the tubes leading to it are the largest, and when the fluid in the cavity lies in its hollow, and does not plug the bronchial tubes. The obstruction to the movement over many cavities, especially those containing liquid, is greatest just at the beginning of inspiration, and towards the end of expiration, when the cavity and tubes are at the smallest, and the fluid, its amount being the same, plugs the bronchial tubes. The obstruction to cavernous respiration varies with the amount of fluid in the cavity and its tubes (p. 108).

The firm walls surrounding a cavity have no inspiratory expansion: the respiratory movements over the region of dulness surrounding a cavity are much smaller than those over the cavity itself; they are often immobile; their motion is often reversed at the beginning or through the whole course of inspiration and expiration (p. 107).

The reversed motion is most frequent over the third and fourth cartilages.

The motion of the lower end of the sternum, and the sixth cartilages, on the affected side, is often reversed by the diaphragmatic lengthening and collapse of the lung (p. 107).

. The descent of the diaphragm is somewhat restrained on the affected side, in about one-half of the cases; the motion of the right diaphragmatic ribs is more frequently diminished than that of the left, when the respective superior lobes are diseased, owing, I believe, to the presence of the enlarged liver (p. 108).

When the whole lung is more or less consolidated, and its expansion obstructed by tendinous adhesions, the lateral expansion of the whole affected side of the chest is lessened (pp. 98-103).

If the diaphragm act freely, the movements of the sixth costal cartilage on the affected side may be reversed. Those of the superior thoracic ribs, over the cavity, are never reversed throughout, seldom even at the beginning of inspiration and expiration, but those of the third, fourth, and fifth cartilages are often prevented and reversed.

The respiratory movement of the opposite lung is, in the great majority of cases, exaggerated.

E.—*Effect of Pneumonia on the Movements of Respiration.* Laennec repeatedly assured himself that the dilatation of the chest was equable in cases of peripneumony, confined to one side.[1] Grisolle invariably found the dilatation equal, unless pleuritic pain of severe character existed. Dr. Walshe, remarking on these statements, is satisfied that the motions of the chest are diminished in simple pneumonia, with extensive consolidation, independently of the influence of pain. Dr. Stokes incidentally remarks, that the absence of frottement in pneumonia is owing to the diminished motion of the inflamed lung. Dr. C. J. B. Williams states that manual examination may often detect a deficiency in the motion of

[1] Dr. Forbes's Translation, p. 13.

the ribs of the affected side. M. Fournet observes that, in chronic pneumonia of the upper lobe, diminution of motion is seen. From these statements one is led, *à priori*, to expect that, in some cases of pneumonia, the movements on the affected side are diminished, and that in others they are not. This is corroborated by the few observations I have yet made with the chest-measurer in pneumonia.

	Sternum.		Second rib.		Fourth rib.		Sixth rib.		Tenth rib.		Abdomen.			Tape measurements	
	upper.	lower.	right.	left.	right	left.	right.	left.	right	left.	right	centre.	left.	right	left
	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch
H. Kitchen, age 35, pneumonia, rapid recovery.	·03	*·01 †·03	·05	·05	·03	·02	·04	·03	·08	·09	·08	·20	·18	17·7	16·
Deep inspiration. . . .	·06	*·02 †·04	·10	·08	·05	·06	·07	·05	·10	·07	·06	·18	·15		
T. Carrington, recovery not very rapid .	·05	·03	·03	·03	·0	·03	*·01 †·03	·04	·04	*·01	...	·28 to ·40			
Second observation . . .	*05to*·08	*·07	·03 to ·05	·15	*·02	*·02	*·05	*·02 †·01	·09	·09	·12	·16	·08		
E. Streeton, 18, pneumonia of right lower lobe, bronchitis . . .	*·02 †·05	*·10	*·03 †·06	·12	*·06	·04	*·02	·08	·12	·19	·12	·25	·17		

[The ordinary figures, and those with † prefixed, denote a forward movement: those with * prefixed, a backward movement of the costal walls during ordinary inspiration.]

In Kitchen, the respiration always went on freely. Crepitation in the right lower lobe soon gave place to a mucous rhonchus, and resonance on percussion returned. Viscid brown sputa were readily parted with. The pneumonic lung was, by an inch, the largest. The respiratory costal movements of the affected side were never less than those of the left side, and during a deep inspiration they were somewhat greater. The deep inspiration was remarkably restrained, on both sides, and over all parts of the lung. The movement, on a deep inspiration, was, over the right and left second rib, only ·10 in. and ·08 in. respectively, and a like proportion was kept throughout, so that the costal motion was not a tenth of its natural amount. This small range of respiration on both sides accounts, in part, for the equal expansion, but this is chiefly, I conceive, due to the expansibility of the diseased lung, the air-tubes being at all times permeable. In fact, consolidation was never established.

Although the *costal* respiration was equal on the two sides, yet the action of the *diaphragm* was considerably less on the affected side, the abdominal movement being ·08 in. on the affected, and ·18 in. on the left side.

The cases of Carrington and Streeton were not purely pneumonia. In Streeton, who died, it was complicated with bronchitis; in Carrington, with the prevailing influenza. In both, pneumonia existed in the right lung, and the movements were restrained over that lung.

Summary.—I am not entitled to infer with confidence, from these scanty materials, what are the characteristic modifications of pneumonia on the respiratory movements.

From what many accurate observers have stated, from the cases here given, and other cases observed without the chest-measurer, and from the nature of the disease and its analogy to condensation of the lower lobe of one lung, one is, I conceive, entitled to say, that when the lower lobe, affected with pneumonia, is consolidated, the costal and diaphragmatic motion over the consolidated portion of lung is restrained.

Pneumonia of the lower lobe may sometimes cause restraint in the movement of the ribs over the corresponding upper lobe. In a case observed by me some years since, my attention was directed to pneumonia in the base of one lung, by the movement over its apex being deficient in comparison with that of the opposite lung.

I believe it will be found that, in all cases of pneumonia of the lower lobe of either lung, the descent of the diaphragm on the affected side is restrained, while that of the opposite side is exaggerated.[1]

That, in those cases where the costal motion is restrained, the restraint will be greatest in the lower ribs—the diaphragmatic and intermediate sets (illustrated by Dr. Barlow's case).

That the expansion of the chest over the unaffected side is exaggerated in all cases, and, in some cases, that also of the thoracic walls over the unaffected lobe of the diseased lung.

In acute pneumonia, the restraint to the increased inspiratory movements, during an attempt at a deep inspiration, is great and universal.

F.—*The Rhythm of Respiration in those Cases where the Disease is confined to one Lung, or one side of the Chest.*—In all the diseases of this class, the rhythm of respiration may be affected. In none of these diseases is the rhythm always deranged. In all of them, when the rhythm is altered, the expiration is prolonged.

The prolongation of the expiration is always, I believe, due to obstruction in the bronchial tubes; and in all these cases the expiration is quick at the commencement of the act, and becomes gradually slower towards the end. In fact, the same class of causes that alters the rhythm in bronchitis and emphysema alters it in the diseases now under review.

In pleuritis and pleuritic effusion, and pneumothorax, the expiration is often retained at first by the involuntary contact

[1] Dr. Barlow favoured me lately with the examination of a female affected with pneumonia of the lower lobe of the right lung. The movement of the diaphragmatic ribs (the ninth) over the affected side was ·1 in.; over the left side, ·3 in. The abdominal parietes, which had but little motion below the left tenth rib, actually fell in from ·06 in. to ·1 in. over the corresponding point of the right side. This case is an additional proof that non-motion, or even reversed motion, of the diaphragm on the affected side is often an indication of pneumonia affecting the base of the lung.—August, 1848.

of the vocal chords. These suddenly separate with a vocal cry or moan, and the expiration then rushes out very quickly at first, owing to the forcible expulsive action of the expiratory muscles. The same disturbance is met with in pleurodynia, pneumonia, peritonitis, and some other ailments, in which an inspiration excites pain, and the involuntary expiratory vocal efforts just described.

In phthisis, the accumulation of fluid in a cavity, or in the bronchial tubes, excites, as in bronchitis, prolonged expiration—quick at first, then slow, and of increasing slowness towards the end, when the narrowing of the air-tubes increases the obstruction from the presence of fluid. The mechanism of the prolonged expiration, slower towards the end, which often exists in phthisis, where there are cavities containing fluid, has been already inquired into (pp. 107-114).

In phthisis, if there be no obstruction to inspiration and expiration from fluid in the bronchial tubes or cavities, the rhythm of respiration is not usually disturbed.

In pneumonia, I conceive that the rhythm will be disturbed in like manner under the like circumstances, although M. Collin states that, in pneumonia, the inspiration is prolonged.

I beg to refer to the remarks on the Rhythm of Respiration in Emphysema and Bronchitis for a more full inquire into that subject (p. 68).

PART IV.

EFFECT OF DISEASES OF THE HEART AND PERICARDIUM ON THE MOVEMENTS OF RESPIRATION.

SECT. I.—*Effects of Pericarditis on the Movements of Respiration.*

In severe cases, when there is pericardial effusion and the free and attached pericardium are both involved, the central tendon of the diaphragm being inflamed, the motion of the abdomen at the centre may be diminished, absent or reversed, during inspiration, and the movements of the left fourth, fifth, and sixth cartilages may be reversed, (either wholly, or only at first,) abolished or diminished.[1]

The movements of the ribs of the right side, and of the left superior thoracic ribs, are at the same time exaggerated.

The retraction of the sternum and of the left costal cartilages is due to the elongation and consequent collapse of the distended pericardial sac by the action of the diaphragm. The exaggerated costal expansion also tends to draw a portion of the fluid away from behind the sternum and the left costal cartilages, and they hence fall back, owing to atmospheric pressure.

If pericarditis be less extensive and acute, the action of

[1] *Postscript, August* 1848.—Dr. Barlow gave me the opportunity of seeing a patient of his with pericarditis, in whom the abdominal movement was only about ·1 in. below, and to the left of the xiphoid cartilage. In a case of pericarditis, attended by Dr. Barlow, the lad finding relief from it, had of himself put a band round his abdomen, so as to restrain the abdominal and diaphragmatic movement.

the diaphragm and the movements of the left costal cartilages are still restrained, but to a less extent in proportion as the disease is slight or partial.[1]

[1] The effect of diseases of the heart and pericardium on the movements of respiration :—

That the inspiratory descent of the heart may exist in *pericarditis*, even with extensive effusion, was proved by the cases of Redgate and Cummins; diagrams from whom, in life, are given at pp. 532, 534 of my paper in the *Provincial Medical Transactions.*

In both of these, the seat of the impulse was lowered during a deep inspiration,—in Redgate, from the first, second, and third intercostal spaces in the tranquil state, to the third and fourth spaces ; and in Cummins, from the third and fourth spaces, to the fourth and fifth. We have here an absolute proof that the heart may descend during inspiration, in a case of pericarditis with effusion. The case of Cummins proves, however, that though the descent of the diaphragm is not prevented, yet the expansion of the chest on the affected side is restrained, as in him the axillary and sub-mammillary measurements of the right side increased, during a deep inspiration, from 12·4 in. to 12·6 in., and from 13 in. to 13·4 in., while the left side was stationary at 12·6 and 13 in. The diaphragm, Redgate's case showed, may be also restrained ; the descent of it on the right side being greater than on the left.

In only one of the cases of pericarditis that I have examined with the chest-measurer, Weldon (Table IV., Case 181), was the pericarditis uncomplicated with endocardial noises. His case was, in other respects, more complicated than the rest, as he suffered habitually from Laennec's emphysema, to which rheumatic pericarditis was superadded. I have grouped all the cases of pericarditis, endocarditis, valvular disease, and pericardial adhesions, into one table, to which I refer. By thus grouping them, cases of the same kind are kept together, and the influence of various modifications can be readily compared.

In Weldon, the exposed portion of the heart (the cardiac region) was small, and low down, being behind and to the left of the xiphoid cartilage. This was owing to the emphysematous lungs occupying the space normally occupied by the heart. The chief modifications in the movements of respiration were those of emphysema. The lower end of the sternum at first retracted and then advanced during an inspiration. The peculiarity in the movements, manifestly introduced by the pericarditis, was an additional falling back of the left sixth cartilages compared with the right. While the right retracted ·03 in., the left fell back ·05 in. ; and while the right fourth cartilage advanced ·05 in., the left receded ·02 in. at

SECT. II.—*Effects of enlarged Heart on the Movements of Respiration.*

When the heart is materially enlarged, the expansion of the lower end of the sternum and of the cartilages and ribs in front and to the side of the cardiac region is restrained.

first, and then advanced ·02 in. The retraction was here in part due to the emphysema ; and, over the left side, in part to the pericarditis. In Hibbert and William Shaw, aged 15, (Table IV., Cases 182-3,) there was rheumatic pericarditis, without effusion, with faint endocardial murmur—aortic in Hibbert, mitral in Shaw. In both of these, the sternum, and the left fourth and sixth cartilages, receded during inspiration, either at the beginning only, or during the whole time, while the motion on the right side was nearly normal. In Lee, Thorley, and Benson, (Table IV., Cases 185, 186, 188,) the heart was enlarged, with some little pericardial effusion; and there were pericardial friction-sounds, with exocardial murmurs. In these, as in the others, the motion of the left sixth and fourth costal cartilages was either less than that of the right, or was absent or reversed, during inspiration. In all the cases, there was more or less restraint in movement of the abdomen at the centre, while, at the sides, it was scarcely affected.

In Thorley, the abdomen advanced at the centre, on the first examination, ·07 in. At a later examination, when he suffered much from pain and dyspnœa, the abdomen, at the centre, fell back ·1 in. during inspiration ; at the side, it scarcely moved. Here the motion of the diaphragm was paralysed at the centre, and almost at the sides. The action of the diaphragmatic ribs was very slight, while the advance of the whole right ribs, and of the upper thoracic left ribs, was much exaggerated.

In the interesting case of a girl, with the examination of which I was favoured by Dr. Gill, suffering from pericarditis, with extensive effusion, the abdomen fell back at the centre during inspiration.

According to Dr. Stokes, muscles, when inflamed, are paralysed. This is borne out in these cases, where the central tendon of the diaphragm was inflamed, and the action of the diaphragm arrested. The diaphragm fell back, in Thorley's case, on the same principle that the sternum fell back when the diaphragm was active, in hiccough, narrowed larynx, and emphysema. In the latter cases atmospheric pressure forced back the ribs over the lengthened and collapsed lung; in the former case, the

The size of the heart does not permit the usual extensive forward expansion of the left lung.

If the heart be very large, the lower end of the sternum and the adjoining left cartilages may sometimes recede slightly during inspiration. The descent of the diaphragm is freely permitted both in front and to the sides.[1]

SECT. III.—*Effects of enlarged Heart with Pericardial Adhesions on the Movements of Respiration.*

If there be pericardial adhesions with valvular disease and enlargement of the heart, the costal expansion in front of the heart is restrained, the lung cannot pass in front of the heart, the descent of the diaphragm is restrained, and the heart's impulse is little or not at all lowered at its upper part.

abdomen over the widened and shortened lung. In Thorley's case the heart's impulse was scarcely lessened above during inspiration, on the second examination, when the diaphragm was inactive ; and friction-sounds were heard just over the heart. Partial adhesions were probably being formed.

The case of Clark is almost an exception. In reality, the active pericarditis had ceased before its existence was discovered. All the general signs of illness had disappeared. Health was returning, but there was a loud to and fro friction-sound, like the rubbing of fine emery-paper over the cardiac region. It was evident that active disease had disappeared, and that there was left merely the roughness of the membranes no longer inflamed ; in a fortnight the friction-sound disappeared.

[1] Effect of enlargement of the heart with valvular disease on the movements of respiration :—

In the cases of John Illston and Mary Tomlinson, of whom diagrams are given in my paper on the Position of the Viscera, pp. 218-22, the heart and the left lung descended, as well as the right, to the normal extent during a deep inspiration ; the heart's impulse descending in Tomlinson from the third, fourth, and fifth intercostal spaces, to the sixth intercostal space, and behind, below, and to the left of the xiphoid cartilage.

In the cases of Simmonds, Roe, Soar, and Leavers, (Table IV., Cases

While the movements of the centre of the chest and abdomen are restrained, the lateral superior movements of the former and the lateral movements of the latter are not restrained.

In cases where the pericardial adhesions are firm and the heart enlarged, the advance of the sternum during inspiration is restrained by the adhesions. The action of the diaphragm from below, and of the costal expansion from the sides, withdraws a portion of the heart from behind the sternum; the heart collapses, and as the expanding lungs cannot interpose themselves between the heart and the ribs and sternum, the sternum, especially at its lower end, and the adjoining costal cartilages, especially the left, fall backwards during inspiration.

Owing to the adhesions and the consequent non-intervention of the lungs during inspiration, the extent of the impulse is not lessened above during inspiration. The intercostal spaces which may sometimes be seen to fall in over the lungs during inspiration do not fall in over the heart.

These signs will sometimes enable us to distinguish whether, when the heart is enlarged, there be adhesions or not.[1]

194, 192, 195, 193,) affected with valvular disease and enlargement of the heart, the movements of the left costal cartilages over the cardiac region and of the lower end of the sternum were restrained, while, excepting in Simmonds, the expansion of the superior thoracic ribs and of the whole right side was exaggerated.

In Simmonds, there was mitral regurgitation, but the heart was scarcely enlarged, and the respiratory movements were but little restrained.

[1] Effect of pericardial adhesions on the movements of respiration :—

When the adhesions are loose, the heart free from valvular disease and normal in size, I do not suppose that pericardial adhesions will materially influence the breathing movements.

It is otherwise when they follow a severe attack of rheumatic pericar-

PART V.

THE VARIOUS CAUSES THAT MAY EFFECT ANY PARTICULAR ABNORMAL MODIFICATION OF THE RESPIRATORY MOVEMENTS.

In the progress of this inquiry into the movements of respiration in disease, I have taken the various diseases in their classes, and singly, and endeavoured to ascertain what effect each has in modifying the breathing movements.

ditis, are firm, and are accompanied by valvular disease and enlargement of the heart.

W. Shaw, (Table IV., Case 197,) aged 14, was just such a case. In him the lower end of the sternum and the adjoining cartilages protruded. The heart's impulse, which was visible in the epigastrium, threw the whole cardiac region violently forwards, with a rapid fall after the systole. The whole sternum fell back during inspiration. The abdominal movement at the centre was restrained, while at the sides it was exaggerated. He died. The pericardium was universally adherent. The mitral valves were diseased.

In other cases of adherent pericardium with enlarged heart, I have observed that the impulse was not lowered or lessened above during a deep inspiration.

In Bower, (Table IV., Case 199,) I infer that the pericardium was adherent—the heart being enlarged, the aorta regurgitant—because the impulse, which was very extensive, did not lessen in extent during inspiration. The intercostal spaces fell in over the lungs at each inspiration; their retraction stopped short suddenly at the margin of the cardiac region, just as it did at the upper boundary of the liver. In Bower, as in Shaw, the impulse was strong and heaving—returning suddenly. The region of the cardiac dulness extended considerably to the right of the sternum. In him the sternum at its lower end and the adjoining cartilages, especially the left, retracted during each inspiration; at the same time the sixth and eight ribs fell in to the side, the left more than the right; while the diaphragmatic ribs and the abdomen to each side moved very freely outwards. The motion of the abdomen at the centre was very much restrained, being only ·15 in., one half its usual amount; while that

I purpose here, in concluding the inquiry, to view rapidly, in their aggregate, the various morbid causes that may effect each particular deviation from the healthy movements of respiration.

Causes that arrest or restrain the Diaphragmatic Movements, and exaggerate the Costal Expansion, during Inspiration. Arranged as the effect is greater or less.

Peritonitis, especially of the diaphragm.
Pericarditis, especially of the central tendon of the diaphragm.
Pleuritis affecting the diaphragm.
Pericardial adhesions, with enlarged heart.
Aneurism of the abdominal aorta, close to the diaphragm.
Tumours attached to the diaphragm.

Ascites, Flatus, Ovarian tumours,	When they distend the abdomen so as materially to push up the diaphragm.

Paraplegia (?) if the phrenic nerves be involved in disease.

Causes that restrain the Costal Movements symmetrically, and exaggerate the Diaphragmatic.

1. Injuries to the spinal marrow, just below the fourth cervical vertebra.
2. Obstructions in the breathing-passages, either the nostrils, fauces, larynx, or trachea.

In hanging, or suffocation, hiccough at the beginning of the act; and

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of the sides was ·18 and ·2 in., right and left, being double the normal amount of motion.

The restraint of the diaphragm at the centre and in front is evidently due to the physical obstacle to its descent in the large and adherent heart, while the posterior portion of lung is, for compensation, called more freely into play, and is not interfered with in its descent.

In Bower, and also in Ellis, (Table IV., Case 198,) an old man who died with pericardial adhesions following pericarditis, the head was markedly lowered (in Bower ·02, in Ellis ·03 to ·05 in.) during each inspiration.

In pericardial adhesions with enlargement, the advance of the sternum is restrained by the adhesions. The action of the diaphragm from below, and of the costal expansion from the sides, withdraws a portion of the heart from behind the sternum, the heart collapses, and the sternum falls back.

in the fits of hysteria, during the violent struggles, when the vocal chords come together, during an attempt at inspiration,—the diaphragm acts with its whole force, draws down and elongates the yielding lungs, which collapse because air cannot enter them, and the chest retracting, is flattened and narrowed by the pressure of the atmosphere.

In croup, the hoop of hooping-cough, the crowing inspiration in children, in hysteria, and in the return noise made during inspiration by exhausted public speakers, described by Mr. Bishop,—the diaphragm acts forcibly, but with less power; the air is not absolutely excluded, but so little is admitted, that the sternum, especially the lower end of it, and the adjoining cartilages, fall back during inspiration.

In œdema glottidis, laryngitis, swollen palate, and obstructed nostrils, according to the degree of the obstruction is the like result obtained.

In these cases expiration is usually prolonged, and is in general equally slow through the whole act.

Causes that restrain the Movements of the lower end of the Sternum, and the Intermediate Sets of Ribs, and exaggerate those of the Diaphragm, and the superior Thoracic Ribs.

Obstructions in the smaller air-tubes.

In emphysema and bronchitis, respiration is impeded,—inspiration most at the beginning, expiration at the end, when the small tubes are the narrowest, and the obstruction they offer is greatest.

In these cases, the diaphragm draws down and elongates the lungs, at the same time that the superior thoracic ribs amplify them upwards. These actions are performed more rapidly than air can enter; consequently, the lungs collapse, and the chest falls in at the lower end of the sternum and the sixth, fifth, and fourth costal cartilages—that is to say, between the two expanded portions.

In healthy infants, the lower end of the sternum falls in during inspiration, especially if the abdomen be large, and the inspiration quick.

In rickety children, the ribs and cartilages, and the sixth, seventh, eighth and ninth ribs, bend in at their articulation during inspiration, and the sternum protrudes.

In emphysema and bronchitis, if the lower end of the sternum be prominent, and the adjoining sides of the chest sloping, the sixth, seventh and eighth ribs fall in at the side, and the lower end of the sternum protrudes during inspiration.

Cause that restrains the Thoracic Ribs of both sides.

Posterior spinal curvature.

Causes that may arrest or restrain the Costal and Diaphragmatic Respiratory Movements of the whole of one side, those of the opposite side being exaggerated.

Obstruction in the right or left bronchus.

Emphysema and bronchitis of the whole of only one lung.

Pleuritic effusion and pneumothorax distending the whole of one side.

Condensation of the whole of one lung, usually from strong pleuritic adhesions, following empyema.

Consolidation from phthisis, combined with cavities and tendinous adhesions of the whole of one lung.

Pneumonia, especially if both lobes be involved.

Extensive external injury to the whole of one side (fractured ribs).

Extensive pleurodynia.

Lateral curvature of the spine.

Hemiplegia (?).

Causes that may restrain the Respiratory Movements of the five superior or Thoracic Set of Ribs, in whole or part, of either side, all the other Movements being exaggerated.

Phthisis in all its stages, affecting one upper lobe.

Pneumonia of one upper lobe.

Pleuritis of one upper lobe.

Obstruction in the bronchial tube leading to either upper lobe.

Injuries or diseases of the ribs, or of the parts contiguous, if the movements of the ribs in question cause pain or mischief.

Causes that may restrain the Respiratory Movements of the sixth, seventh, and eighth Ribs, or Intermediate Set.

Pneumonia of the lower lobe.

Pleuritis of the lower lobe.

Partial pleuritic effusion.

Condensation of the lower lobe; dense pleuritic adhesions.

Peritonitis.

Local injuries.

The motion of the sixth rib may be restrained by disease of the upper part of the lower lobe, and lower part of the upper lobe.

Causes that may restrain the Diaphragmatic Ribs of one side during Inspiration.

Inflammation of one side of the diaphragm (pleuritic or peritoneal).

Pneumonia of the lower lobe—its lower part.

Any cause that may restrain the movement of one side of the diaphragm.

Causes that may produce Retraction of the whole Sternum, and, more or less, the adjoining Cartilages, during Inspiration.

Obstruction to respiration in the outer air-passages.

Pericardial effusion—extensive.

Pericardial adhesions—universal, with enlarged heart.

Pleuritic effusion—universal.

Phthisis affecting the whole of one lobe.

Extensive injuries to the ribs.

Causes that may produce Retraction of the lower end of the Sternum.

The same causes that may produce retraction of the whole sternum, when less severe.

Emphysema and bronchitis.

Condensation of the whole of one lung.

Causes that may restrain the Motion of the left superior Thoracic Ribs.

Pericardial effusion ; pericardial adhesions.

Excessive distension of the stomach.

Causes that may restrain the Motion of the Intermediate Set of Ribs (sixth and seventh) on the left side.

Pericarditis—pericardial effusion.

Enlarged heart—pericardial adhesions.

Distension of the stomach—enlargement of the spleen.

Causes that may restrain the Motion of the left Diaphragmatic Ribs (ninth, tenth, eleventh, and twelfth), and the left side of the Diaphragm.

Distension of the stomach.

Enlargement of the spleen.

Causes that may restrain the Movements of the right Thoracic Ribs.

Enlarged liver from adventitious deposits ; adherent liver.

These causes may also restrain the movements of the right intermediate and diaphragmatic ribs and the right side of the diaphragm.

Causes arresting the right fourth, fifth, and sixth Cartilages and Ribs.

Pneumonia of the middle lobe.

Cavities in the middle lobe.

The motion of any rib, or set of ribs, may be restrained or arrested by various modifying causes, while all the rest of the respiratory movements are exaggerated.

The following admirable remarks, made by M. Andral, in his *Clinique Medicale* (tom. ii. p. 98), comprise everything that has been said, or need be said, on this subject :—" Cette immobilité partielle de quelques côtes n'est pas sans interêt sous le simple rapport physiologique. Ce fait ne prouve-t-il pas que dans l'inspiration les côtes peuvent se mouvoir indépendamment les unes des autres, et qu'elles n'ont pas seulement un mouvement commun ? Si, comme nous l'avons vu souvent sur les phthisiques, les côtes inferieures peuvent se mouvoir encore lorsque les supérieures restent immobiles cela prouve qu'indépendamment de l'action des scalènes que nous ne nions point dans l'état ordinaire, les muscles intercostaux sont susceptibles à prendre une part active dans l'acte de l'inspiration."

The independence of each intercostal muscle of the action of the scalenus, and the muscles above it, is here affirmed and proved.

PART VI.

ON THE DIAGNOSTIC VALUE OF THE OBSERVATION OF THE MOVEMENTS OF RESPIRATION.

From the many diseases that derange the movements of respiration, from the multifarious varieties of those disturbed movements, and from the same disturbance being produced by different diseases, it is manifest that we cannot form a diagnosis by observing the arrest, restraint, or exaggeration of any particular respiratory movement. While we cannot, however, be thus directed to a final diagnosis, we have made a first good step towards it. We have shut out a number of diseases, of which the existence is disproved by a modification in the respiratory movements, opposite to that which they produce. We have narrowed our inquiry, and isolated it to a certain small class, one or other of which must be the cause of the deranged movement. The seat of the disease is made out by the inquiry. If we see the movements arrested or restrained over the left upper lobe, we examine that lobe; if that be healthy, we inquire successively whether the heart be diseased, the lower lobe of the lung inflamed, the stomach distended, the intercostal muscles, the ribs, or the neighbouring parts, be injured, or diseased, or in pain. If we find that the part of the organ of which the function is arrested be not diseased, we look, in a widening inquiry, for those diseases, or injuries, or malformations, to which the movements of the parts in question would be adverse. Each of these disturbing causes must of course be distinguished by its individual diagnostic signs.

In the *ordinary Involuntary Respiratory Movements* there are two points to be inquired into—what movements are restrained, and what exaggerated? If respiration be arrested, or restrained, in one part, the exaggeration elsewhere usually more than compensates for the local diminution. The degree of the local exaggeration is usually in proportion to the activity of the disease. If the descent of the diaphragm is restrained by a chronic cause, as in ovarian dropsy, the movements of the thoracic ribs are somewhat exaggerated, but if it is arrested, or restrained, by peritonitis, the exaggeration is much greater, both in effort, frequency, and movement.

The arrest, or restraint, of the involuntary respiratory motion in one part of the chest produces exaggerated motion in all the other parts.

If the motion of any part of the chest be reversed,—as it is in Laennec's emphysema, and laryngeal obstruction over the lower part of the sternum,—we have an almost certain indication that there is some thoracic disease.

Deep Voluntary Inspiratory Movements.—While the derangement of the involuntary breathing-movements gives us certain information, including the possibility of several diseases, and excluding that of all others, the knowledge of the extreme movements during a deep inspiration gives us reasons for setting aside other diseases previously considered possible.

If the movements of any part be restrained during an ordinary inspiration, and yet normal during a deep inspiration, the restraining cause can only be slight.

If the movements, during a deep inspiration, be restrained at one part, and free everywhere else, we may exclude certain acute diseases, as peritonitis and pericarditis, which, while they exaggerate ordinary breathing, are incompatible with a greatly increased deep inspiration.

The extreme movement during a deep inspiration corresponds to the extreme breathing-capacity as ascertained by the spirometer. In fact, in ascertaining this circumstance, the chest-measurer is an imperfect pocket-spirometer which, while it cannot tell the exact capacity, has the additional faculty of localising the diminished movement, if it be local, or of showing it to be diffused over the whole breathing apparatus.

In inquiring into the extreme respiratory movements, we must not overlook the want of control which some persons have over their respiratory movements, who sometimes breathe solely by the ribs, at other times solely by the diaphragm. The best plan with such persons is to direct them by example.

The Rhythm of Respiration.—If the rhythm of respiration be disturbed, we gain positive information that the disease belongs to a certain small class.

If the inspiration be laborious, the expiration slow, and equally slow throughout, we know that there is obstruction in the breathing-passages, as the larynx or fauces.

If the inspiration be laborious and rather quick, and the expiration prolonged, quick at first and then slow, and gradually slower towards the end, we know that there is obstruction to respiration in the smaller bronchi, as in emphysema bronchitis and phthisis. In emphysema the obstruction is constant ; in bronchitis it is sometimes absent during a short interval, after getting rid of the sputa ; and in phthisis it is only present when there is fluid in the bronchi or the cavity.

In many painful diseases, the expiration is at first interrupted, the glottis being closed by the vocal chords ; these part with a moan, and the expiration gushes out quickly at first, becoming gradually slow.

In peritonitis the expiration may be quicker than the inspiration.

The information given by the rhythm of respiration is a valuable assistant to that given by its motion. If the motion be anywhere restrained and the rhythm invariably normal, there is good reason for anticipating that the lungs are free from disease ; on the other hand, if the expiration be materially prolonged, we know that the respiratory organs are in fault.

The knowledge furnished by the deranged movements and rhythm of respiration defines the seat of the disease, but not its nature. To ascertain this, the other aids to diagnosis must be employed. This knowledge is the first step in the inquiry, which it does not prolong, but, on the contrary, shortens, as it directs the attention to the affected part.

In this inquiry I have found the chest-measurer essential. For ordinary observation, the educated eye-sight and touch will usually furnish all the needful information. It is in the cases of doubt and difficulty, and especially in persons really healthy, though supposed by themselves to be diseased, that the chest-measurer is most serviceable.

In conclusion, I beg to thank the various medical men here and in London who have very kindly permitted me to avail myself of their cases; and my pupil, Mr. Martyn, who has with patient intelligence assisted me throughout in this inquiry.

The figures in the Tables in the body of the paper indicate the respiratory movements during an ordinary inspiration, unless otherwise specified.

EXPLANATION OF THE TABLES.

The figures on a line with each name, denote the respiratory movement during an ordinary (involuntary) inspiration.

The figures below those of ordinary inspiration, denote the extent of movement during an extreme inspiration.

The movements are given in hundredths of inches.

The tape measurements in inches and tenths of inches.

Figures separated by a line thus 2/5, denote an extent of motion varying from the one to the other.

The sign * prefixed, denotes a falling in of the costal walls.

The sign † prefixed, denotes a rising of the costal walls.

*1 †5 denotes a backward inspiratory movement of ·01 inch, followed by a forward movement of ·05 inch.

The figures under the head of Rhythm, show the relative duration of inspiration and expiration (ascertained by counting, see p. 68).

The figures above the ordinary tape measurements are those during expiration ; those below, during inspiration.

N.B. The heading "Sixth costal cartilage" in the Tables in the body of the paper correspond with the heading "Sixth rib, anterior" in these Tables.

For the method in which the measurements were taken, see pp. 2-15.

The Author's notes of the cases are accessible to any one interested in them.

TABLE I.—*The Movements of Inspiration in Health,*

Males, pp. 15-18, 27-29.

	Age.		Sternum. upper.	Sternum. lower.	Second rib. right.	Second rib. left.	Fourth and fifth ribs. right.	Fourth and fifth ribs. left.	Sixth rib, anterior. right.	Sixth rib, anterior. left.	Sixth rib, lateral. right.	Sixth rib, lateral. left.
1. J. Whitehead .	17	had ophthalmia, well, robust health, chest healthy.	2 80	2 60	4 100	3 100	3 80	3 80	3	3	3	3
2. G. Withers . .	29	had lumbago, well, robust labourer, chest healthy.	3 80	5 50	6 100	6 100	2½	3	3	3	½	½
3. C. Webster . .	22	ophthalmia, nearly well, robust labourer, chest healthy.	3 100	6 90	3 100	3 100	4 105	4 100	6/7	6	5	4
4. J. Rushworth .	23	healthy, chest healthy.	*1 †2 2/4 120	4 75	2/4 130	2/4 125	3/4 120	3/4 120	4 120	4 120	1	1
5. Charles Cook .	30	dyspepsia, chest healthy.	4/6 35	3 50	5/7 70	5/7 70	3 40	2 45	*2/*1†4 28	*1 †4 28	*1 *5 †35	0/1 *2 †20
6. J. Nettleship .	40	dis. of urethra, robust labourer chest healthy.	5 40	5 40	2/7 50	2/7 50	3/5 22	2/4 30	5/8	3/5 17/20	2/3 20/22	1/2 20/22
7. J Proshaw . .	30	ulcer of leg, nearly well, chest healthy, remarkably well-made man.	5 95	*1 †6/6 *3 †35	8 100	7 100	*1 †2/4	*1 †5	5	5	6	4
8. W. Wainman .	28	lumbago, nearly well, chest healthy.	2 100	5 120	3 115	3 115	3 120	*1 †1 120	6 130	5 130	5 70	*1 †3 70
9. W. Hutchinson .	37	dyspepsia, chest healthy, general health good.	4 130	5 110	7 110	7 100	5 95	3 90	5 80	4 80	2 80	2 80
10. G. Berridge . .	33	affection of knee, well, chest healthy.	4 42	8 100	2/4 70	2/4 70	2/5 60	2/6 60	4/7 50	3/5 50	2 35	1 30
11. James Ward . .	39	lumbago, well, chest healthy.	½/2 50	5/4 50	2/5 60	7/10 60	2 50	1/2 50	2/5 70	2/4 60	2/3 40	1/2 40
12. Westall . .	25 or 26	splendid condition, runner, third best in England.	2½ 180	4 190	5 225	4½	3½	*1 †1	4	1	...	...
13. Seward . .	25 or 26	splendid condition. American runner, best in the world.	3 100	4 100	3 150	4	2	3	4	2	...	...
14. James Pacey . .	17	recovered from fever, chest healthy.	3	5	6	6	3	*2 †3	7	...	...	...
15. George Wardell .	18	recovered from fever, chest healthy.	1½	3	6	4	2	2	5	5	...	...
16. W. Attenburrow	22	healthy, robust, chest healthy.	5 90	2/3 60	8/10 100	8/10 100	5 100	3 100	3/5 50	2/3 40	4 65	3 60
17. J O'Connell . .	45	ulcer of leg, out of health, chest healthy.	4/7	3/4	3/7	3/7	1/3 20	3 20	3 20	3½ 20	1/3 20	3 20

observed by the use of the Chest-measurer, pp. 5–15.

Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.	Breathing capacity.	Height
									Above nipple.		Xiphoid cartilage.		Abdomen.				
right.	left.	right.	left.	right.	centre.	left.	insp.	exp.	right.	left.	right.	left.	right.	left.		c. in.	ft. in
5 70	6 70	5	5	8	25 100	9											
4 40	4 40	3	3	10	25 100	6	4	4	18·2	18·2	17·4	17·4					
7	6 60	8 50	7	13	40 90	11	4	4	17·4	17·4	16·4	16·4					
6	5	7	8	10	20/28 100	10	5	5	16·5	16·2	16·8	16·9	...	...	24		
4 20	4 26	8 28	6 45	6/8	25 70	8/14	6	6	16·3	16·3	16 16·7	15·5 15·8	...	...	20		
8 35	5 35	7 8/12	5 8/12	5/8 12	25 100	3/6 12	5	5	16·2	16·2	16 17·1	16 17·1	...	...	20	190	5 4½
2	2	5	4	8	35	7	4	4	25	22	24	19·7	...	...	17	340	6 0½
10 130	10 130	8 80	8 80	7	25 100	7	...	...	14·2 ... 15	14·2 ... 15·3	13·5	13·5	12·2	11·8	20	185	5 6½
6 95	6 90	8 95	6 80	8 70	25 140	8 70	5	5	15·8 ... 17·3	15·5 ... 17·3	15·5	15·8	13·5	14·5	20	200	5 9
10 50	7 50	9 60	7 65	12/14 54	35 100	12/14 50	7	8	16·6 17 17·8	16·3 16·9 17·6	16·5	16·2	15	15	10	225	5 8½
4/5 32	4/5 18	4/5 22	3/9 25	5 26	20/30 100	11 20	5	5	18·1 17·3 16·7	17·9 19·1 16·4	17·3	16·9	13·8	13·8	22		
...	...	5	5	12	30	12	5	5	...	...	...	...	...	...	...	290	5 9 or 5 8½
...	...	6	6	9	30	8	...	...	...	...	...	...	...	...	25		5 9
...	...	10	10	15	20 120	15											
...	...	6	7	17	24	15											
9/13	8	9	5	12 10	30 10	10/12 15	...	...	17·3	17·5	16·3	16·2					
3 16	8 16	5 30	8 30	3	25 100	9	4	4	17·3	17·3	18	18					

TABLE I.—*Health*—

		Age		Sternum.		Second rib.		Fourth and fifth ribs.		Sixth rib, anterior.		Sixth rib, lateral.	
				upper.	lower.	right.	left.	right.	left.	right.	left.	right.	left.
Males.	18. E. Houghton .	16	disease of knee, robust, chest healthy.	12 50	5 110	3 90	2 70	3 60	1 90	5	4	3 95	1½ 70
	19. J. Curran . . .	44	stricture of rectum, chest healthy, general good health.	4 80	3/4 50	3/5 60	3/5 60	4/7	4/6	4 50	3 50	3 60	3 50
	20. C. Coupe . . .	15	healthy, florid, chest healthy.	7	6 40	9 100	9 95	7 80	5 70	6	5	5 50	2/3 40
	21. T. Plackett . .	14	healthy, chest healthy.	2/3	*1 †2	0/4 50	0/2 60	0/2	0/ *1	2	*2 †1	*1/4 55	*1/4 60
	22. S. Bingham . .	15	broken os humeri, robust.	3/8 60	5/10 70	0/ 3/8 100	0/ 2/6 80	5/10	3/8	10 100	10 95	8/14	8/14
	23. J. Eddishawe .	15	burn, well, perfect health, chest healthy, collier, robust.	4 100	*1 †4 70	4 100	2 90	2/5 50	2/4 50	2/4 50	2/4 50	2 40	1 30
	24. George Smith .	35	perfect health, chest healthy, robust labourer	5	4 100	5 130	3 120	5 120	2 80	6 70	4 70	4 80	3 70
	25. John Coupe .	1	broken arm, nearly well, perfect health, chest healthy.	5 110	4 50	7/6 130	6/5 130	3 90	3 85	3 40	3 35	1 75	1 70
	26 J. Clarke . . .	10	healthy, not strong, chest healthy.	3 70	5 50	5 100	5 100	3 100	*1 †2½ 100	3	2	1½	1
	27. W. Greenfield .	10	disease of knee, pale, chest healthy.	0/3 30	1/2 33	0/3 30	0/3 30	...	...	2	2	1	1
Males.—Cases in which breathing was exaggerated, pp. 17, 19.	28. W. Green. . .	19	dyspnœa, chest healthy.	10 50	5 50	16 80	16 70	10 80	12 60	5	5	5 70	3 60
	29. W. Stennett . .	40	compound fracture of leg, pale, chest healthy.	3 70	8 50	6 150	6 130	9 105	8 105	10	9	6	6
	30. J. Clay. . . .	43	sciatica, chest healthy.	7/10 80	...	10/20 95	10/20 100	15/20 80	12/20 75	15 80	15 80	10/15 50	8/13 50
	31. T. Glossop . .	14	delicate, pale, chest healthy.	12/25	10/25	15/40	10/30	5/30 50	5/30 50	15/26	18/29	16/25	12/20 20
	32. W. Stevenson	adult	lumbar pain, pale. chest healthy.	4/15 50	4/4 60	8/20 70	5/16 70	5/12 80	3/8 75	4 60	4 60	8 80	8 70
	33. J. Beaumont . .	40	ulcer of leg, health good, chest healthy.	8 75	11 50	6 100	10/2 95	8 60	6 50	25	60	2	6
	34. W. Herod . .	19	diseased ankle, chest healthy, delicate.	9 100	7 95	12 100	14 100	3 90	2 65	5 100	4 70	...	...
	35. S. Varney . .	37	chest healthy.	10	8	10 90	12	6	3	6	5	...	...
	36. John Wilson . .	50	ulcer of leg; fair health, fat, chest healthy.	6	8/15 70	4/8 70	5/10 80	*1 †5/15 40	*1 †5/*10 45	10 56	8 50	*1 †3 40	*2 †3 50

continued.

Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.	Breathing capacity.	Height
									Above nipple.		Xiphoid cartilage.		Abdomen.				
right.	left.	right.	left.	right.	centre.	left.	insp.	exp.	right.	left.	right.	left.	right.	left.		c. in.	ft. in.
12 100	8 75	12 60	6 45	14	25 *30†40	8	...	...	16·2	16·2	16·6	16·3					
3 55	3 50	3 55	2 54	7	16/25 40	3/6	...	...	17	17	16	15·3					
6/9	5/8	8	6/7	12 30	28 100	10 20	5	5	13·5	13·2	13·4	13·3					
0/15 60	4/8 60	4/8 60	4/8	8/12	50/60 20	8/12	6	6	14	14	13·8	13·6	...	...	13	136	4 10
10 90	9 75	12 80	10 70	7 30	45 70	5 30	4	4	13·1 ... 14·8	12·8 ... 14·2	13·5 1	13·5	12	11·5	20		
7 40	7 40	4 40	4 40	9 45	25 120	9 45	4	6	14 15	13·3 14·5	14·2	14	12·5	12·5	22	130	4 11½
6 10	6	16 60	6 20	12 70	35 80	8 40	4	4									
5 60	5 60	6 35	6 25	10 25	26 50	8 30	5	6	14·4 13·2	14 13	12·9	12·7	12·1	12·1	20	110	4 7½
5½ 50	5 50	7	6	9	40	7	4	4	12·6	12·6	13	13·2					
7	6	6	6	10/16	20/40 30	8/16	4	4	12	12	11	11½					
10 70	8 70	10 40	8 40	9	18 20	8	...	...	16	17	16	16	...	...	...	185	5 6½
11/9 70	15 70	9	8	9	20	6	4	4	17·2	17·2	17	16·4	...	...	13		
20/30 60	20/30 60/55	30	30	40	90 100 to 150	30/40	9	9	16·5	16·5	16·5	16·5	...	...	9		
10/20 20	10/20	3/7 27	3/7 27	10/15 32	60/90 80	6/12 28	...	...	12·3	12·3	12	12	...	...	23		
10	10 70	10 65	9	4	15 90	4	8	8	15·2	15	16	15·4	...	...	...	208	5 7½
...	...	7	7	25	60 160	25	6	6									
...	...	7 20	4 20	8 30	30 70												
...	...	7	6	14	25 100	13											
10	11	9 42	7 35	11 11/15	45 100	8 8/12	...	...	17	17	18	18					

TABLE I.—*Health*—

		Age.		Sternum.		Second rib.		Fourth and fifth ribs.		Sixth rib, anterior.		Sixth rib, lateral.	
				upper.	lower.	right.	left.	right.	left.	right.	left.	right.	left.
Male.	37. T. Goodrich . .	33	healthy, fat, chest healthy.	7/20	*5/*15	...	...	10	10	*10/*20	*8 *20	...	8
Old Men, pp. 20, 21.	38. William Spick .	53	healthy, chest healthy.	5 50	3	5/8	5/7	4	3	7	7	...	...
	39. W. Beduall . .	61	cataract, health perfect, chest healthy.	8 90	10 90	7/10 75	7/10 70	8/15 80	8/15 80	9 60	7 60	7 60	6 55
	40. J. Wiles . . .	68	sciatica, slight cough, chest healthy.	10/12 100	6/14 80	10 50	10 50	10 75	5 75	10 50	5 50	10 25	5 25
	41. J. Shawcroft . .	65	ulcer of leg, well, health good, heart large, lungs healthy.	10/12 80	12/15 90	6/9 50	6/9 40	9/10 80	7/8 45	10 73	7 35	8 75	4 25 *7
	42. S. Mart . . .	71	ulcer of leg, nearly well, fat, health tolerable chest healthy.	7/10 50	6/9 50	12/13 55	12/13 55	4/6 35	4/7 20	4 20	4 20	3/5 20	*1 †2 15
	43. L. Lane . . .	64	had erysipelas in axilla, nearly well, excellent health, robust, chest healthy.	2/4 25	1/2 10	1½ 21	3 30	0/1½	0/1½	1 15	1 14	3/0	*1 †1
	44. J. Marshall . .	65	hernia, healthy, robust, chest healthy.	10	14	10	10	10	6	13	12	...	...
Females, pp. 22-24.	45. J. Goodall . .	35	cataract, hysterical, healthy chest, stays on	15/20 70	7 15	10/18 70	12/20 70	...	...	...	...	4 10	6 13
			stays off . . .	*2 †7 35	3/4 30	6/8 50	6/8 50	...	...	...	...	2/3 10	2 10
	46. J. Green . . .	20	had fistula, nearly well, perfect health, chest healthy, stays on.	6/10 50	3/4 20	6/8/10	6/8/10	...	...	...	...	3 10	1/2 10
			stays off . . .	3/10	3/10 35	3/10 50	3/10 50	...	...	2/6	2/6	3 10	2/3 10
	47. E. Ball . . .	25	hysterical affection of knee-joint, health good, chest healthy, stays on.	6/10 60	3/5 20	6/12	5/11	...	...	...	...	2 12	1½ 9/10
			stays off . . .	7 70	5 70	8/15	8/15	...	...	...	...	3/4	5 6
	48. M. Daft . . .	17	purpura, improving, chest healthy, stays off.	5 35	4 30	6 45	6 45	...	...	...	...	0/1 26	0/1 28
	49*a*. E. Elsom . .	11	healthy, chest healthy, stays on.	8 50	4 30/40	...	...	...	...	...	...	...	...
	49*b*. [illegible] . .		stays off . . .	6/7 [illegible]	2/5 30	10 60	10 60	...	3 30	*1 †3 25	3/5	*1 †2 *1 †3	...

continued.

Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.	Breathing capacity.	Height
									Above nipple.		Xiphoid cartilage.		Abdomen.				
right.	left.	right.	left.	right.	centre.	left.	insp.	exp.	right.	left.	right.	left.	right.	left.		c. in.	ft. In
...	...	3 *6	3* 6	...	20 30	...	...	...	...	...	10·2	10·2	10·8	10·8			
...	...	6	6	20	40 95												
12 60	11 60	10 22	8 22	8	30 50	6	6/7	10/11	15·2 16 16·7	15·5 16 16·7	15·4	15·6	13·7	14	12		
10 30	5 25	4	3	12	50 90	5	6 6 3	6 9	14·4 15·1 15·7	14·5 15·2 15·8	14·8	14·5	13·8	14	16	150	5 7½
20/22 30 *10	*1 †5 30 *10	8 *10†20	4 *20†15	8 *10†20	35 100	5 *10†15	6	7	15·3 15·6 16·5	15·4 15 7 16	15·5	15·4	14·5	14·5	22		
5/7 5/10	3/4 *8	7 2/4	4 2/2 *2	5/6 20	35 110	5/6 5 *5	6	7	19 19·3	18·7 19	19·2	18·8	16	16·2	18		
4/5 *2 †3	2 *10	4/5	1/2	8	25/40 70	3	8	8	16·9	16·9	17 2	17·2	14·9	15·2	20		
...	...	10	8/9	20	30	20											
...	...	...	...	...	7/8 70	...	7	8	30 30·6	30 30·6	25 25·5	25 25·5	...	...	14		
...	...	...	...	...	15/20 50	...	...	...	30 30·5 31·5	30 30·5 31·5	25 26	25 26					
...	...	...	...	...	8/11 30	...	8	8	33 33·5	33 33·5	26 26·5	26 26·5	...	...	20		
...	...	...	...	...	15/20 50	...	...	...	...	...	14 14·3	13·7 14	14·5 15	14·5 15			
...	...	...	...	...	10 60	...	...	...	34 35·5	34 35·5	29 29·3	29 22·3	...	...	24		
...	...	...	...	...	12/25	...	6	8	33·3 34 35·5	33·3 34 35·5	30 39·5 39·5	30 39·5 39·5					
...	...	...	...	...	15/20 70	...	8	8	13·5 27·8	13·3 27·8	12·5	12	25	25	18		
...	...	...	...	...	10 50	...	5	8									
...	...	...	...	...	20 66	...	...	...	12 12·3 12·6	11·8 12·1 12·3	12	11·8	10·8	10·8			

TABLE I.—*Health*—

		Age		Sternum.		Second rib.		Fourth and fifth ribs.		Sixth rib, anterior.		Sixth rib, lateral.	
				upper.	lower.	right.	left.	right.	left.	right.	left.	right.	left.
Females.	50. H. Barton . .	19	dysmenorrhœa, chest healthy.	20 50	10	28	28	10	7	8	...	...	...
	51. Saıah Bluson .	19	diarrhœa, chest healthy.	18 70	16	25	20	25	16	15	15	...	...
	52. F. A. Winfield .	6	healthy, chest healthy.	5 25	4/5 20	...	...	...	...	...	...	...	...
Children, pp. 25-28.	53. J. Drake . .	2 mo.	healthy child, observed asleep, chest healthy.	2/4	*1/ *5	...	2/4	...	...	...	*1/ *2 *3	...	*½/ *1
	54. F. Williams .	1 mo.	healthy child, chest healthy.	2/4	*3	3/6	4/ 6/10	*1	*1	*4	*3	*3	*4
	55. Child . . .	2¼ y.	healthy child, chest healthy.	2/ 4/5	*2/ *5	3/5	3/5	*1	*1	*3/ *6 *10	*3/ *6 *10	...	*2 *6
	56. M. A. Scott,	2 y. 8 mo.	in epileptic fit, chest healthy.	2/5 5/10	1/2 0?	... 10/12	2/6 9	...	...	2/6	2/6	...	*1/ *2
	57. Mary Wain . .	2	abdomen large, chest healthy.	4/5	15/20 cr. 20	5/7	...	10/12	...	10/15 cr. 20	...	*2/2 *4/1 cr 20/30	...

continued.

Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.	Breathing capacity.	Height
									Above nipple.		Xiphoid cartilage.		Abdomen.				
right.	left.	right.	left.	right.	centre.	left.	insp.	exp.	right.	left.	right.	left.	right.	left.		c. in.	ft. in.
...	...	4	...	...	8 20												
...	...	15	10	10	8/12 60	7/10											
...	...	...	..	...	25 50/60												
...	*1	...	*3/ *4	...	8/10												
*2	*6	*2	*3	...	4/6												
*10 *15	*10 *25	1/2	1/2	...	8/15												
...	5	...	4	...	8/12												
cr. 20/30 cr. †50	...	cr.5/15	...	...	15/20 cr. 20/40												

TABLE II.—*Cases in which the Respiratory Movements were themselves being*

		Age.		Sternum.		Second rib.		Fourth and fifth ribs.		Sixth rib, anterior.	
				upper.	lower.	right.	left.	right.	left.	right.	left.
Motion of the ribs of both sides restrained, p. 29.	58. W. Bulwer . . .	9	posterior spinal curvature at sixth dorsal vertebra	5	15	5	5/8	3	2	6	5
	59. A Youth		ditto ditto . .	2	0	30	2 20	2	8	6	2
	60. Clemens		ditto at the last dorsal vertebra.	4/6 60	9 75	9 70	7 70	3 12	4 40	2 9	5/6 30
Motion of the ribs of one side restrained, p. 30.	61. A Girl.		lateral spinal curvature, convexity to right.	12/20	12	20/25 70	10 60	15/23 *9 *20	3	15 30	8
	62. William Beaton .	15	ditto, lower dorsal vertebra.	6 60	5 40	10 70	9 70	5 30	3/4 30	6 25	6 25
	63. Robert Severn . .	16	injury to left shoulder and cervical vertebræ.	*2 †3	*6	3/6	*6	*1 †5	*6	5	*6
	63*a*. Ditto		second observation . .	2* 2	*2 †3	4/9	*4/5	2	0	9	4
	63*b*. Ditto		third, well	10	11	3/12	3/12	4/8	12	10	4
	64. William Frost, about	45	erysipelas of arm . .	8	...	15 40/70	10 25/50				
	65. John Bingham . .	15	fracture of arm . . .	3/8 60	5/10 70	0/ 3/8 100	0/ 2/6 80	5/10	3/8	10 100	10 95
	66. John Lane . . .	64	erysipelatous abscess in axilla.	2/4 25	1/2 10	1½ 10	3 10	0/1½	0/1½	1 15	1 14
	67. Mrs. Barker . .	42	scirrhous ulcer of left mamma.	6	6	8 35	6 25	...	...	10 38	5 28
	68. James Ward . .	39	old injury to second rib.	½/2 50	4/5 50	3/5 60	7/10 60	2 50	1/2 50	2/5 70	2/4 60
	69. William Parker .	15	abscess between left second and third costal cartilages.	3	*4	8	4 8	4	0	*1	*3
	70. John Sketchley .		fracture of left rib, rupture of lung.	*9 †4	*7	2/9	*5 †7 *5 †3	1	*5	*2 †3	*7/ *9
	71. Moore		pleurodynia, near the sixth costal cartilage.	2/ 5/10	2/6	3/5	2/5	4	½/3	6	5
p. 30.	72. C. Williams .	40 or 50	heart disease, left hemiplegia.	9	0	6	8	1	0	0	0
	73. E. Brooks . . .	4	left hemiplegia . . .	3	2	*1 †1	*1	0	0	*1 †1	0
	74.										
p. 35.	75. W. Glossop . . .	14	exaggerated motion of thoracic ribs from loss of arm.	12/25	10/25	15/40	10/30	5/30	5/30	15/26	18/29
Diaphragm restrained, p. 36.	76. W. Barratt . . .	35	acute peritonitis, more severe on left side, following operation for hernia.	10	5	16/22	16/22	8	6	8	6
	77. William Kew . .	22	acute peritonitis . . .	15	4	20	30	8	12	6	6
	78. Elizabeth Hussey.	55	acute peritonitis . . .	20	5	33	40	10	10	7	8

disturbed, rendered abnormal, or abnormally changed, the Lungs healthy, pp. 29-46.

Sixth rib, lateral.		Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.
											Above nipple.		Xiphoid cartilage.		Abdomen.		
right.	left.	right.	left.	right.	left.	right.	centre.	left.	insp	exp.	right.	left.	right.	left.	right.	left.	
3	4	10	12	15	7	18	20	18									
...	...	...	...	2	1	10	50	7									
...	...	...	...	2	5	4	5	2	...	...	17·5	17·5	15·4	15·2			
...	...	...	...	15	3	15	35	3	...	...	...	...	13·1	13			
6 20	2 20	8 50	8 50	6 35	8 15	7	20 90	4									
...	...	...	...	11	10	16	...	12	...	...	14	14					
...	...	...	...	6	4	...	16 60										
...	...	...	...	15/20	8	20	50	12	...	...	14	14	13·4	13·2			
5/14	8/14	10 90	9 75	12 80	10 70	7 30	45 70	5 30	3	4	16 15·7	16 16·7	15·4	15·6	13·7	14	
3/6 15	*1 †1 15	4/5 *1 †3	2 *10	4/5	1/2	8	25/40 70	3	8	8	16·9 17·2	16·9 17·2	17·2	17·2	14·9	15·2	20
7	1	10	5	11	9	8	18	10	4	4							
2/3 40	1/2 40	4/5 32	4/5 18	4/5 22	3/9 25	5 20/22	23/30 100	11 20/22	5	5	16·7 17·3 18·1	16·4 17·1 17·9	17·3	16·9	13·8	13·8	22
...	...	...	...	9	6	18	25 40	18									
1 †3/5	*8	20	*5	8/11	3/7	22/30	37	*10/15	5	10	...	...	...	...	...	...	22
...	...	...	...	8	10	10	35	8	6	6	17	17	15·6	15·3			
...	...	...	...	5	3	5	25	3	6	7							
...	...	...	...	5	2	5	14										
6/25	12/20	10/20	10/20	3/7	3/7	10/15	60/90	6/12	6	6	12·3	12·3	12	12	...	...	23
...	...	...	...	6	6	2	1/5	0	5	3							
...	...	...	...	5	3	7	6	8									
...	...	...	...	2	2	7	3	6									

TABLE II.—

		Age		Sternum.		Second rib.		Fourth and fifth ribs.		Sixth rib, anterior.	
				upper.	lower.	right.	left.	right.	left.	right.	left.
Diaphragm restrained, p. 36.	79. William Severn	30	chronic peritonitis	13 40	5	10	10	5	3	...	5
	80. Charles Osborne	40	local peritonitis over caput cæcum coli.	10/15	rises very irreg.	12/25	15/25	10	5/10	8	12
	81. George Simpson	43	tumour in abdomen	10 50	5	8	7	6	3	7	5
	82. William St.		enlarged liver, hydatids?	10	2/4	10 40	25 70	1	4	0	*2 †
	83. John Barton	32	adherent liver	10 45	4 80	19 25	30 60	4 15	30 40	6 13	10 30
	84. N. Stones	69	adherent liver?	7/9 30	4 12	5/6 40	5/6 40/50	0/2 *3 †3	0/2 28	0/3 5	1/4 25
	85. J. Clarke	15	intestinal and gastric distension.	6 80	5 50	8/9 110	8/9 100	8 90	4/5 70	10 60	5 45
p. 45.	85. Mrs. Kee	35	pregnant	5 50	3	5	6	...	...	2/4	2
	87. Mrs. Sands	30	pregnant	4 30	3½	5	5	...	...	3	5

continued.

Sixth rib, lateral.		Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.
											Above nipple.		Xiphoid cartilage.		Abdomen.		
right.	left.	right.	left.	right.	left.	right.	centre.	left.	insp.	exp.	right.	left.	right.	left.	right.	left.	
...	...	...	...	5	5	10	13 35	10									
...	...	...	...	12	10	6/8	10/15	15									
...	...	...	...	5	5	10	15 70	10									
...	...	...	...	*2½	5	10	25	10									
6 10	12 20	8 8	20 20	7 20	16 20	18 40	*2 †10 50	25 40	4	5	15 15·2	15 16·3	16·6 16·6	15·5 16	14·2 14·8	14·2 15·2	
0	5	2 6	5 10	4/5 †1 *3	6/7 14	4/7 20	30 70	2/4 10	6	9	14·9 15·8	14·9 15·2	15·6	15·6	15·9	15·1	18
9 60	5 40	13 55	10 45	12 50	10 40	15 30	20 50	10 30	4	6	12·5 13·5	12·4 13·4	12·6	12	12·3	12·5	18
5	4	...	...	6/ 7/8	6	4	8	6/8									
2	½/1	7 30	2 6	4	1	10	10 50	6	4	4	15	15	13	13	...	...	20

TABLE III.—*Cases in which the Respiratory Movements wer[e] ... in the Respirator[y] ...*

Group	Case	Age.	Disease	Sternum. upper.	Sternum. lower	Second rib. right.	Second rib. left.	Fourth and fifth ribs. right.	Fourth and fifth ribs. left.	Sixth rib, anterior. right.	Sixth rib, anterior. left.
Obstruction to respiration in outer air-passages, pp. 48-52.	88. Josiah Chester	13	enlarged tonsils, scarlatina.	20/ *6†10	*14/*20	30	25	15	15	*10	15
	89. T. Maltby	21	bronchocele	*3 †½ *20 †60	*4 *10†30	*3 †1	*2 *10†70	*3	*3	*3	*3
	90. Jeh. Mann	23	bronchocele	*2 †5	*1 †5	5	*1 †6	*3	*2 †3	*3	*3
	91. Alf. Scattergood	16	enlarged tonsils, laryngitis.	8/15	*4 †7 50	10 100	8 70	10	5/8 60	10/15 60	*1 † 60
	92. — Robinson	25	obstructed nostrils and fauces.	*2 †4 30	*6 †10 *4	10	*1 †6	*1 †2	*3	*1 †5	*2
	93. Ann Slater	27	lacerated larynx or trachea.	*6/40	2/*30	6/60	2/40	2/4	4	2/30	2
	94. Mrs. Meads	27	chronic laryngitis	*1 †4	*4	5	5	...	...	*2 †2	*2
Obstruction to respiration in the smaller bronchi, p. 58.	95. Jos. Squire	30	emphysema and bronchitis.	20/30 110	*12 16 *30	25/26	22/25	22/25	22/25	*6 †24	*10†
	96a. W. Rawson	13	emphysema and bronchitis.	4/10 30	*3/*6	6/11	12	*2 †5	*1 †3	*7	*5
Cases of males, in which the lower end of the sternum receded, p. 60.	96b. Ditto, one month afterwards.		emphysema and bronchitis, improving.	3/10 50	*6 *8 †20	3/12	15	3/9	11	*10	*3
	97. George Simpson	50	bronchitis	4 50	*5	9/12 30	9/8 30	*3	*3	*2 †3	*
	98a. W. Galloway	40	emphysema, heart disease &c.	6	*3	12	14	3	*1 †4	*3 †1	* †6
	98b. Ditto, second observation.		worse	4/10	*4/*15 cough *20	8	12	*2 †2	*3 †2 †2 *2	*2 †4	*4
	99. J. Hart	32	emphysema and bronchitis.	2/6	*1/*4 sometimes *1 †5	2/9 70	3/12 60	1/3 20	3/9 30	5	7
	100. J. Linthwaite	50	emphysema and bronchitis.	9/24 40	*2 †8 *2 †20	10/25 50	10/25 40	8/12	6/10	*1 †10 *1 †20	*2 *2
	101. W. Redmill	46	emphysema	5 25	*2 *3 †20	7 35	4 30	3	0	2	
	102. J. Worth	30	emphysema and bronchitis.	3/5 70	*½ †3 *2 †60	2/5 110	2/10 110	1 80	0/5 80	3 60	4/ 8
	103. G. Rogers	41	emphysema and bronchitis.	4/8	*2 †4	*2 †4	6	*2 †2 30	*1 †4 30	*3 †4	*2
	104. J. Shaw	45	bronchitis and emphysema.	12/20 55	10/12 †3 *12 30	10/15 90	10/15 80	12	*3 †7	15	1
	105. Hugh James	25	bronchitis, not severe	8	6	6	9	5	12	6	
	106. J. Clews	30	bronchitis, not severe	4	5	4	4	0	5	3	
	107. J. Eaton	40	bronchitis, not severe	5	5	5/6	4/7	3/5	1/8	6	

isturbed, rendered abnormal, or abnormally changed, by Diseases
rgans, pp. 47-119.

Sixth rib, lateral.		Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.
											Above nipple.		Xiphoid cartilage.		Abdomen.		
right.	left.	right.	left.	right.	left.	right.	centre.	left.	insp.	exp.	right.	left.	right.	left.	right.	left.	
...	...	...	...	12	15	18	0	25									
...	...	...	...	7	6	18	30 100	10	5	8	16	15	14·5	14	...	...	28
...	...	...	...	10	9	...	30 60	3	...	...	11·2	11·2	...	...	...	...	24
...	...	...	...	10/15	10	12	12 100	6									
...	...	...	...	10	9	5	15 20	10	6	10	...	...	...	...	...	...	25
...	...	...	...	...	...	2/20	6/40	2/20									
4	3	7	7	11	12	10	20	10	3	3	14	14	13·6	13·4			
...	...	...	...	20	...	12	30/50	12	4	6							
4/12	5	...	...	...	...	10	12/18	...	3	8							
...	...	...	...	10	12	10	35 50	...	6	9							
...	...	...	...	10	6	10	25	10									
*1 †1	*1 *4	*3	10 *7	3	8	8	20	12	4	8	...	...	15·5	15·5	...	...	28
3/8	4/9	0/ *2/5	*5 †3	1/2	½	6	20	5	4	12	16·5	16·5	16·8	16·8	16·6	16·8	28
3/5	2	10	6	4/6	4	8	18	9	4	8	...	...	...	...	...	...	20
3/16 30	6/14 15	12	10	0/20	10/20	7/15	10/50 70	7/15	4/8	9/16	16·2	16	17	16·4	14·8	14·8	19
...	...	...	...	10	10	18	30 50	15									
...	...	...	...	3 40	3/10 50	...	25/35 70	...	5	9	16	16	14·6 15·6	14·8 15·9	...	...	36
...	...	...	...	6	5	8	40	12	5 abdo	9 minal	18·3	18·6	17 5	17·3			
5 35	4 40	10 45	10 40	8/10 25	8/10 20	2/3	*5 †23 80	2/3	...	...	...	13	15·5 16 5	15 15·5	14·2	14·2	22
..	...	6	6	7	10	10	30	15	5	8	17·6	16·7	17	16·3			
8	...	...	...	8	10/12	3	40/50	35	4	6	17·3	17·5	17·8	16·5	...	...	21
/6	2/5	4	2/5	9	6	8	20/35	15/30	4	4	15·8	15·8	15·8	15 8			

TABLE III.—

Group	Case	Age	Disease	Sternum. upper.	Sternum. lower.	Second rib. right.	Second rib. left.	Fourth and fifth ribs. right.	Fourth and fifth ribs. left.	Sixth rib, anterior. right.	Sixth rib, anterior. left.
Obstruction to respiration in the smaller bronchial tubes. Cases in old men, p. 74.	108. W. Shaw . . .	30	emphysema and bronchitis.	8	4 23	10/15 25	8/15 25	4	6	*3	*1 †
	109. J. Eyre . . .	75	emphysema	*2 †6	6	* †5	*1 †2	*1 †3	*2 †2	7	6
	110. W. Flinders .	69	emphysema	8	9	4	7/10	6/7	5/10	7	6
	111. T. Thompson .	60	emphysema	6	*2/6 13	7/8	10	3	...	*4/2	*2 †
	112. J. Newman . .	58	emphysema	5 *5 †30	1/2 *2 †60	4 40	5 *4 †30	*3 *5 †40	2	*11 *12 †20	*3 *4 †
Cases in females, p. 76.	113. M. Cross . . .	14	bronchitis	5 6	*2 *2 †6	3/5 14	3/5 12	*1/ *½	*1/ *½	*½/ †1 *3/8	*1/ *2 8/15
	114. Sarah Chamberlain	20	bronchitis, left lung . .	25	*2 †8	10/12	10/12	10	10	7	
	115. J. Elliott . . .	52	bronchitis and emphysema	15	*6	12	15	...	...	*2 †6	*2
	116. Mrs. Cooper .	30	bronchitis and emphysema	12	20	20	12/20	*3 †9	*3 †4 *2	*8	*10 *
	117. Mrs. Barker. .	32	bronchitis and emphysema	3/15	*2/ *4	4	4	0	0	1	
	118. Lilly Waud . .	20	bronchitis, left side . .	6/10	*3	10/15	10/15	...	*2 †2	3	
	119. S. Henson . .	70	bronchitis and emphysema	15	9	25	20	...	...	6	
	120. Mary Smith . .		. . . .	5	*6	6	6	...	...	*2	
Cases in children, p. 77.	121. W. Langsdale .	4	bronchitis	3/10	*5/ *10	5/12	5/12	0/3	0/3	*4/ *6	*
	122. E. Brown . .	2	bronchitis	5	*2	7	7	3	1	*3	
	123. M. Miller . .	2	bronchitis	4/12	...	6/13	6/14	0	0	*2/ 4	
	124. T. Smith . .	6 mo.	bronchitis	1/5	*1/ *8	*10/*15	*10/*15	..	...	*1/ *3	
	125. John Lowe . .	4	bronchitis	8/18	6	3/6	5/12	...	...	*1/ *2	
	126. S. Garton .	7 mo.	bronchitis	14/20	10	(?)	6	(?)	0	10	
	127. Geo. Garner .	10 w.	bronchitis	3/20	0/5	...	...	...	..	...	
	128. Eliz. Walker .	3	hooping-cough	9	*1 †4	8/12	8/12	*2	*1	*3	

ontinued.

Sixth rib, lateral.		Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.
											Above nipple.		Xiphoid cartilage.		Abdomen.		
ight.	left.	right.	left.	right.	left.	right.	centre.	left.	insp.	exp.	right.	left.	right.	left.	right.	left.	
*1	*1 †1	*8 *5 †5	*7 *5 †5	1 *3	3	12	45	10	4	9	16	16	15·6	16·5			
0	0	4	4	4	4/5	10	35	12	4	8	17·2	18	18	18·4			
2	4	6	12	16 15	13	20	60	15	6	9	17·4	17·2	16	15·6			
6	*2 †3	†2 †6 *10	*3 †6 *12	*2	*4	...	10	...	4	8	18·5	18·5	18·5	18			
...	...	...	...	4	6	20	60	20									
[illegible]/1	1/2	3	2	3/5	2/5	4	15 50	4	4	6	13·2 13·6	12·6 12·8	12·6	12·5	11·5	11·7	42
...	...	...	...	6	15	20	50	10									
4	4	6	...	10	2	5	2/6	4	4	7	15·5	15·5	13·5	13·5	...	...	32
†2/6	*10	*6 †8	*12	15	8/ *2	30	40	20	...	...	14	13·8	12·8 12·7	12·8 12·6			
...	...	...	...	5	6	4	15	7									
...	...	...	...	8	8	...	6/12										
4	4	15	15	15	18	15	15	12	4	6	14·5	14	12·7	12·5			
10	12	...	...	10	12	4	12	10									
6	*3	*5/ *11	*4/ *6	10	3/6	5	16/20	17	3	2	9·5	9·5	9·1 9·3	9·1 9·3			
..	...	...	...	...	4	...	12										
eg.	...	...	...	...	...	10	10/15	†5/ 15									
3	*1	...	...	...	...	...	10										
1†3	*3	10	*2 †3	7	2/5	7	10	6	...	...	9	9	9·8	9·8			
.	...	...	...	...	6												
.	...	...	*1/ *10	...	...	...	...	2									
	...	...	...	6	6	...	10/20	...	...	...	...	...	...	...	...	...	60

TABLE III.—

Diseases of one lung, or one side of the chest, p. 82.

Group	Case	Age	Disease	Sternum. upper.	Sternum. lower	Second rib. right.	Second rib. left.	Fourth and fifth ribs. right.	Fourth and fifth ribs. left.	Sixth rib, anterior. right.	Sixth rib, anterior. left.
Obstruction in smaller bronchi · children.	129. Child	2	bronchitis	10	*3/ *4	7	10	*2	*2	*2	*4
	130. E. Smith .	18 mo.	hooping-cough	3/10	*2 †4	4/14	3/8	*2	*4	*10	*12
	131. Child , . . .		hooping-cough	15	*5/ *6	...	...	...	...	*15	*15
	132. Child		hooping-cough	10	4	12	12	*2	7	*6	*2
Pleuritis, p. 82.	133. Sarah Simpkin .		pleuritis, lower lobe of left lung.	10	11	11	8	...	...	7	7
	134a. Jane Shepherd, 7, second observation, p. 83 . . .		pleuritis, lower lobe of right lung.	5	*3	10	10	4	3	*3/ *4	*3
	135. James Brown .		effusion into right pleural cavity.	3	4	5	10	2 40	3 70	3	4
Effusion into pleura, p. 85.	136. L. Davis . . .		effusion into right cavity	10	*4	18	17	*1 †2	*1 †1	*1	*2 †2
	137. W. Webb , .	15	effusion into left cavity .	8	*1 †4	12	5	8	0	6	*2 †2
	138. M. Roach, patient of Dr. Walshe . .		effusion into left cavity .	12	*2 †4	5 20	0 12	12	0	8	*3 †
	139a. T. S. Cooke .	8	effusion into left cavity .	2	3	8/12	0	5/8	*1	*1 †4	0
	139b. Ditto, second observation.		condensation of left lung	*2	*4	8/12	0	8/10	0	8	*2
Condensation of one lung, p. 91.	139c. Ditto, third observation.		condensation of left lung	2 45	*2/ *6 20	8/12 60	0 20	5 30	*1 12	*2 †2 40	*3 30
	140. Barb. Beasley patient of Dr. Theo. Thompson.	7	condensation of left lung following effusion.	0	...	1	*2 †2	5	0	7	0
Phthisis affecting the whole of one lung, p. 95.	141a. Th. Neale . .	51	tuberculous disease of the whole of the left lung, cavity in upper lobe .	*3	*4	11	*2	6	*2	8	*4
	141b. Ditto, second observation.		ditto	*12	*12	12	*3	8	*2	12	*12
	141c. Ditto, third observation, in articulo.		ditto	*2 †2	*4	15	*1 †3	20	*3	118	*3
	142. Mrs. Kirk . .	42	ditto	10/20	14	20 70	10/14 40	8	*1 *2 †1	14/1 60	*1 †6 30
	143. M. A. Elliott .	18	ditto	4	*2 †2	5/10 38	4 30	...	...	4	3
	144. Wm. Osborn .	46	ditto	*1 †5	*4	10/12 35	*1 †8 35	6	*1 †3	8	*3 †
	145. D. Harley . .	41	ditto	*1 †1	11	8 15	0 5	*2 †5	*3 †4	12 40	*1 †2 10
	146. J. Wood . . .	37	ditto	*1 †5	7/6	8/14 90	4 40	5	0	12	*1/0
	147. J. W. Porter .	60	ditto	14	10	8 30	5 0	3	*1 †2	8 30	*4 †4

continued.

Sixth rib, lateral		Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.
											Above nipple.		Xiphoid cartilage.		Abdomen.		
right.	left.	right.	left.	right.	left.	right.	centre.	left.	insp.	exp.	right.	left.	right.	left.	right.	left.	
...	...	...	...	...	4												
...	...	...	...	*2	*3	...	25										
...	...	...	...	...	...	...	15										
...	...	...	...	4	3	...	6										
3	*½	8	10	13	10	17	10	13	...	...	...	...	...	...	...	...	24
3	3	8	8	8	8	6	15	8	4	6	...	...	...	...	...	...	52
...	...	...	...	5	10	10	36	16	6	7							
...	...	...	...	3	6	12	*3	6									
...	...	...	...	10	2	10	12	6	5	8							
...	...	...	...	12	2/3												
...	...	...	...	5	1	6	15	3	...	...	10·4	10·1	10·7	11·2	...	...	60
...	...	...	...	8	0	12	22	3									
2/5 40	*1 *3 16	5 35	0/½/1 20	3/6 20	0/½/1 5	10/20	15/20 30	5/10	6	7	11·5 12 12·3	11·1 11·2 11·3	11·5 12·3 12·7	11·1 11·2 11·3	11·3	11·3	20
...	...	...	...	5	0	8	15	0	...	...	10·7	9·5					
...	...	...	...	16	10	22	25	6									
...	...	...	...	25	7	20	12/20	12									
...	...	...	...	16	8	25	15/20	14									
...	...	...	...	7/10 70	6 30	10	25 100	12 10									
6	4	8	10	7	8	7	12	8	4	7	13	12·5					
...	...	...	...	15	10	10	20	4	5	8	$17\frac{4}{8}$	$16\frac{4}{8}$	$17\frac{2}{8}$	$16\frac{2}{8}$			
...	...	...	...	15	9	18	15 60	1	...	...	15·5	14·5	15	13·4			
...	...	...	...	15	5	15	30 70	5	...	...	17·4	16·4	16·9	15			
...	...	...	...	9	4	9	25	4	...	...	...	...	16	16			

TABLE III.—

		Age		Sternum.		Second rib.		Fourth and fifth ribs.		Sixth rib, anterior.	
				upper.	lower.	right.	left.	right.	left.	right.	left.
Diseases confined to one lung. Phthisis of the whole of one lung.	148. Pearson . .	17	tuberculous disease of the whole left lung, cavity in upper lobe.	13	10	17/20	8/10 †4 *12	15/20	6 †2 *8	15	8/10
	149. R. Shitlin . .		ditto	*6	*4	*1 †5	*4 †1 *3 †2	4/*1 †4	*1	*5	*2
	150 Joel Boot . .	39	tuberculous disease of the whole right lung, cavity in the upper lobe.	*1 †6	*10	6	10	*4	*3	*5	*5
	151. M. A. . . .		ditto	5/10	5	2	10/30	3	5/15	2	5
	152. Mary Robinson		ditto	3/6	5/6	2/4 10	10/12 50	1/3	7/12	2/3	5/6
	153. Wm. Warren	19	ditto	3	4/6	2	3	0/4	0	1 2	*1 10
Phthisical cavity in the upper lobe of one lung, p. 102.	154. John Green .	27	phthisical cavity in the left upper lobe, lower lobe not notably affected.	*1 †2	4 *2 †45	3/7 85	0 45	3 80	*2 50	3 85	3 60
	155. T. Astell . .	29	ditto	2	*2	0/1 100	0 70	3 90	*2 75	6 100	3 90
	156. James Meads	55	ditto	5	6 *8 †8	8 30	4 8	8 20	4 6	8 26	6 9
	157. Rd. Alvey .	30	ditto	10	9	12/16 85	5/8 40	12 85	5 40	8	8
	158. Henry Trout.	20	ditto	5	3	7 80	2/5 40	5 70	2/3 50	4	1
	159. John Smith .	48	ditto	*3 †3	*4	12 35	5 20	4	0	5	*2
	160*a*. Ann Durow.	15	ditto	4	*1	6/12	6	*1 †2	*2 †2	3	3/4
	160*b*. Ditto, second observation.		ditto	4/6	1	8/14 35	4/7 15	6	*3	1	*1½
	161. James Parsons	22	ditto	25	*1	27/30 100	12/20 70	10	4/3	10	5/7
	162. Rt. Stanyard	36	ditto	8/10	7	8/11	6/8	6	*1 †1	9	*1 †2
	163. Sam. Redgate	37	ditto	*1 †2/*2 †3 *2 †20	*2 †5 *2 †25	6/10 50	3/7 30	13 55	*2† 2/7 30	8 34	*2 †6 24
	164. Walt. Cavers	18	ditto	*1 †3/15	*3 †4/*1 †13	4/5	*2 †2/3	1/4	*2 †3	*1 †5/6	*3 †4
	165. M. Castle .	12	ditto	13	6	12/16 35	8/13 20	4/5	*2 †3	5/6	3/5
	166. Ts. Rudland .	13	ditto	10	*1 †4	10 30	5 16	0	*1/3	*2 †2	*7
	167. Ts. Coates .		ditto	*1 †4	*3	†8 70	*1 †5 55	0	*8/11	*9	*4

continued.

Sixth rib, lateral.		Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements. Above nipple.		Tape Measurements. Xiphoid cartilage.		Tape Measurements. Abdomen.		No. of respirations per minute.	Breathing capacity.
right.	left.	right.	left.	right.	left.	right.	centre.	left.	insp.	exp.	right	left.	right	left.	right	left.		
12/16	8	25	22	15/20	15 †*10 †10	10	*6 cr. o †10 *4 cr. †8 *8	10										
...	...	...	...	18	12	25	25	18	5	5	15·5	15·6	15·6	15·2				
...	...	...	...	14	15	5	15	20	...	...	...	...	...	4/5				
1	10/18	2	15	4	15	13	10/30	20	3	3								
1/1½	10	2/3	9/10	2/4	10/15	4/7	10/15 50	10/15	...	...	11·6	12·5	11·2	12·4	10·5	11·5		
...	...	...	...	2	4	3/5	30	3	14·6	15·5	15	15						
...	...	...	...	6/7	6	10	30 70	6	...	...	17·5 18·2	17·3 17·7	16·7 17·7	16·9 17·5	...	...	24	
...	...	...	...	9 70	10 50	30	35 150											
3/6 12	3	14 30	9	1	7	15/23	35 40	15	...	...	15	14·2	14·2	14·5	...	...	32	
9	5/6 30	8	10	13	7	10	30	10										
4	2	12	7	13	8	17	34	10	7	9	16·6	15·5	16	15·3				
...	...	...	...	9	8	22	28 40	20										
...	...	...	...	8/14	10	20/25	25/35	10/20	...	...	12·5	12·5						
...	...	...	...	5	9	9	18 30	5	...	...	eq.	eq.						
...	...	...	...	20	15	20	40	12										
7	3	18	8	15	14	13/15	35	8	...	...	16·8	16·4	15·5	15·2	...	...	...	246
7/9 50	3/5 *5 †30	9/12 30	3/4 34	9/11 30	6/7 30	14 24	40/50 90	8 18	7	9	18·2 18·5 18·9	16·9 17·2 17·3	18·2	17·6	17	17	17	150
3/4	*2 †2	6	*1 †3	2/8	1/2	12	25	3/7	3	6	13·7	13·2	13·3	13·3	11·7	11·8	40	
6	3	15/20	10/12	7	6	8/9	15 40	7/8	...	...	13·8 14·1	12·2 12·8	11·6	10·6	11·3	10·6		
...	...	...	...	10	18	7	25	7	5	9	16·6	16	16	17				
...	...	...	...	6 ?	6 ?	...	40											

TABLE III.—

Group	Case	Age		Sternum. upper.	Sternum. lower	Second rib. right.	Second rib. left.	Fourth and fifth ribs. right.	Fourth and fifth ribs. left.	Sixth rib, anterior. right.	Sixth rib, anterior. left.
Diseases confined to one lung. Phthisical cavity in the upper lobe of one lung.	168. L. Fowkes . .	27	phthisical cavity in the right upper lobe, lower lobe not notably affected	8	*12	5/8	12/14	*3	7	*5	0
	169. T. Bailey. . .	33	ditto	5/7	4	2/3 35	8 80	0 30	5 60	*1 †1 50	5 50
	170. M. Summer . .	49	ditto	7	3	8	12	...	...	5	5
	171. Ann Smith . .	59	ditto	6	*8	5/6 †1 *6	15 *1 † ?	*3 6 *3	*2 6 *4	6	7
	172. Sh. Hoffen . .	50	ditto	12	3	18	12	*4	10	5	*6
	173. J. Daft . . .	65	ditto	9	*2 †8 60	*1 †3 65	9 40	*3 †1	5	*2 †4 40	8 60
	174. Sar. Saywell .	20	ditto	20	*2	20 80	20 60	3	2	4	3
	175. J. C. Searles, patient of Dr. Roe		ditto	6	5	4/6 80	12 120	*2 †2	6	5	6
	176. E: Weaver . .		ditto	7	3	5 40	12 60	*1 †2 35	4 50	4	5
	177. Wm. Rossington	35	ditto	10	...	12	15	4	8	*4	4
Cavities in both lungs, p. 111.	178*a*. J. German . .	13	both lungs nearly equally diseased.	3/10	4	6/15	10/20	5	*1 †5	3	4
	178*b*. Ditto, second observation.		ditto	6	*5	8/10	*13	6	6	3	3
	179. Ts. Andrews .	22	ditto	10	5	15/18	9/15	6	5	5	5
	180. Ds. Flanagan .	39	ditto	2/10	*1 †2	4/8] 15	4/8 20	*2 †1/3	5	2	5

continued.

Sixth rib, lateral.		Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements. Above nipple.		Tape Measurements. Xiphoid cartilage.		Tape Measurements. Abdomen.		No. of respirations per minute.
right.	left.	right.	left.	right.	left.	right.	centre.	left.	insp	exp.	right.	left.	right.	left.	right	left.	
16	15	6	4	16	15	15	20	16									
...	...	1	4	...	10	12	30	12									
...	...	...	...	4	6	6	5	8	...	...	11·4	12·4					
...	...	...	...	8	18	24	25	10	...	...	12	11·5					
...	...	...	...	9	*2	...	8	*2									
...	...	...	...	*3 30	10 50	...	30										
...	...	...	...	6	9	5	9	3									
...	...	...	...	7	8	8	17	...	5	5	15·2	15	14·5	14			
...	...	...	...	11	7	8	28	10	9	6	15·3	15·6	14·8	14·8			
...	...	...	...	8	9	20	35	35									
...	...	...	...	11	11	12	*5 †15/25	5									
...	...	...	...	10	10	15	20	4	4	4							
5	5	12	12	10	10	14	20	20	4	4	14·3	14·3	13·3	13·5			
...	...	...	...	5	5	5	18	8	7	5	17·2	17·2	17·2	17			

TABLE IV.—*Cases in which the Movements of Respiration were disturbed, or*

			Sternum.		Second rib.		Fourth and fifth ribs.		Sixth rib, anterior.	
	Age		upper.	lower.	right.	left.	right.	left.	right.	left.
Pericarditis, p. 120.	181. John Weldon . 23	pericarditis, slight effusion, acute rheumatism.	9	*2 †2	10	9	5	*2 †2	*3	*5
	182. Mary Hibbert . 25	ditto	*2 †10	*4 †2	18	7	5	*2 †4	4	*2
	183. William Shaw . 15	pericarditis, endocarditis .	*1 †3	...	7/10	*1 †6	*2 †5	*3 †2	4	*4
	184. Mary Bale . . 20	endocarditis, pericarditis .	6	*4	12	6	4	*2	4	3
	185. Fanny Lee, patient of Dr. Walshe	ditto	2	2	6	8	4	o	3	0
	186. William Thorley 20	ditto	12	2 †2 *4	15/20	15	6/10	3 *4	10	2/4
	187. Geo. Charlesworth 16	ditto	4	*2 †2	8/12	10	2	*1	*1 †2	*1
	188. Emma Benson . 17	ditto	5	*4	5/12	8/12	4	1	*3 †3	*3
Enlarged heart, p. 122.	189. James Hogg . 42	pulmonic valves obstructed, regurgitant heart, large.	7/9	2/3	6/8	4/8	5/6	2	5	2
	190. Thirza Leaf . . 20	aortic regurgitation, heart large, acute rheumatism.	5	5	7	7	...	...	2½	1
	191. C. Walls . . . 52	ditto	4	4	2 20	2 20	2 14	0 25	0 14	6 25
Pericardial adhesions, p. 123.	192. John Roe . . 62	mitral regurgitation, heart large.	11	9	9/12	9	4	3	1½	5
	193. Ann Leavers .	ditto	*1 †5/8	*2	15/20	6	5	*2	*2 †5	*3
	194. Mary Simmonds 25	ditto	5	3	4	6	3	2	3	2
	195. John Soar . . 20	mitral and aortic regurgitation.	6	5	10/12	8/12	2	1	4	3
	196. W. Thorley . . 20 second observation.	endocarditis, pericarditis? and acute rheumatism, partial adhesions?	6/12	*3	15	22	10	5	5/7	3 5
	197*a*. Wm. Shaw . 14	pericardial adhesion, heart large, acute rheumatism.	*4	fell in	8	8	8	rises on expiration.	6	abou[t] 2
	197*b*. Ditto, second observation.	ditto, shortly before death.	10	*2	16	11	7	0	3	*3
	198. William Ellis . 70	pericarditis, pericardial adhesion, heart large.	26/30	26/30	27	25	20/27	*1 †20/20	20	20
	199. Herbert Bower. 35	pericardial adhesion . .	*1 †10	*7	18/25	10/15	*3 †7	*4 †4	*8 †7	*8
	200. John Perry . . 25	aortic and mitral regurgitation, heart large, adhesion ?	*3/7	*3/ *5/	10	10	5/7	6	5	3

rendered abnormal, by Diseases of the Heart and Pericardium, pp. 120-124.

Sixth rib, lateral.		Eighth rib.		Tenth rib.		Abdominal.			Rhythm.		Tape Measurements.						No. of respirations per minute.
											Above nipple.		Xiphoid cartilage.		Abdomen.		
right.	left.	right.	left.	right.	left.	right.	entre.	left.	insp.	exp.	right.	left.	right.	left.	right.	left.	
...	...	...	...	12	...	14/12	20/22	20									
...	...	...	...	10	10	10	10	10									
...	...	...	...	10	8	14	18	12	4	4	12·4	11·8	12	11·4			
...	...	...	...	8	10	8	12	10									
...	...	...	...	4	2	6	8	5									
8/10	3	18/20	10	3	3	2/3	*8 *10 *16	...	4	5	...	...	...	...	...	...	36
...	...	...	...	5	5	15	12	12									
...	...	...	...	5	9	8	15	...	...	...	...	...	...	...	...	...	42
...	...	...	...	5	6	9	16/20	8	4	4	16	15·6	15·8	14·8			
1	1½	6	3	5	5/7	3/10	7/18	6	...	...	15	15·6	13·5	13·5			
...	...	...	...	6/5	3	5	20 100	6									
1½	1	3½	3	6	7	9	15	10	...	...	16·8	16·8	16·5	16·5			
...	...	...	...	8	5	12	25/30	10/12									
3	2	...	...	10	10	13	16	10	5	5	13	14½					
2	2	6	6	12	7		30	13	...	...	16·4	16·3	16	16·2			
10	5	14/15	10	15	7	6	7	6	...	...	15·5	15·2	14·6 14·5	14·7 14·8			
...	...	...	...	12	about 12	15	about 15	15									
...	...	...	...	9	9	...	...	...	...	...	..	...	...	...	...	...	48
5	*3 †7	*1 †3	*5 †2	5	*8	10	35/40	10	4	10	...	...	...	...	...	...	32
*3 †6	*5 †3	*6	*9	12	8	18	15 50	20	4	4							
4	3/5	10	5	9	6	18	25	15	...	...	...	...	...	...	...	...	28

DESCRIPTION OF PLATE VI.

The figures in this plate are copies of daguerreotype views of the chest of William Rawson, the subject of emphysema and bronchitis, during ordinary respiration, and during deep inspiration.—See p. 61.

Fig. 1.—Ordinary respiration. Fig. 2.—Deep inspiration.

DESCRIPTION OF PLATE VII.

The figures in this plate are copies of daguerreotype views of the chest of Samuel Redgate, the subject of phthisis, with a large tuberculous cavity in the upper lobe of the left lung.—See p. 103.

Fig. 1.—Ordinary respiration. Fig. 2.—Deep inspiration.

The lines indicate in both plates the outlines of the internal organs; the concentric lines, the situation of the heart's impulse.

VIII.

ON THE MOVEMENTS AND RHYTHM OF RESPIRATION IN VESICULAR EMPHYSEMA AND BRONCHITIS.

1. *Subjects of the two former Papers and present one.*

MY first paper on Vesicular Emphysema and Bronchitis[1] (*Gazette*, Sept. 8, 1848) contained an account of the size and situation of the internal organs in those diseases, showing that the lungs and heart are increased in size, that the walls of the chest are remarkably developed, and that the diaphragm is permanently and considerably lowered, the abdominal viscera being displaced downwards.

The last paper[2] (*Gazette*, Oct. 27) described the configuration of the chest, and the general aspect in cases of vesicular emphysema: the chest being full, rounded, and prominent, and characterised by certain differences in form, accordingly as the disease attacks persons in youth, manhood, and old age.

In this paper I intend to describe the movements and rhythm of respiration in vesicular emphysema and bronchitis.

2. *Reference to the Author's Paper on "the Movements of Respiration in Disease."*

In a paper on the movements of respiration in disease,[3] published in the last volume of the *Medico-Chirurgical Trans-*

[1] See Paper V. of this collection.
[2] See Paper VI. of this collection.
[3] See Paper VII. of this collection.

actions, I have detailed my observations on the movements of respiration in emphysema. To ascertain those movements with minute accuracy, I employed a chest-measurer. For an account of the mode of using the chest-measurer, and of the details of the observations, I beg leave to refer to the paper in question.

3. *Obstruction to Respiration in Emphysema.*

The respiratory movements in emphysema are directly modified by the physical changes in the lung. The air-cells are enlarged—their walls being stretched and perforated—and the entrance and exit of air to and from them through the smaller bronchi is obstructed.

Owing to the permanent and excessive enlargement of the lungs, and the obstruction in the smaller bronchi, inspiration can only be performed with difficulty, and with laborious efforts; for, as Dr. Williams remarks, "breath is taken as it were on the top of breath." By no amount of exertion can the normal proportion of air be inspired: for instance, the extreme breathing capacity of Shaw was only 90 cubic inches, instead of about 200. Dr. Stokes, in the following passage, describes with admirable force and accuracy certain of the characteristic effects caused by emphysema on the respiratory movements.

4. *Dr. Stokes's Description of the Respiratory Movements in that Disease.*

"When the patients are stripped, and lying on the back, a remarkable character of respiration may be observed. We see the thorax powerfully elevated upwards, and the abdomen as powerfully protruded downwards; but there is this remarkable difference from forced respiration in the healthy state—that the abdominal protrusion does not begin so high; and while the umbilical and hypogastric regions move upwards, the epigastrium and upper portions of both hypochondria remain comparatively motionless; while the corresponding ribs are drawn in. This is explicable by the new position of the diaphragm; it has descended and carried the abdominal viscera before it; and its contraction takes place at a point lower in proportion to its displacement." (*On the Diseases of the Chest*, p. 188.)

5. *Falling in of the Lower Part of the Chest during Inspiration.*

During inspiration some very remarkable phenomena take place; while the abdomen protrudes, and the upper part of the chest advances upwards, the lower part of the chest, especially the lower end of the sternum, actually falls backwards. It is singular to see the respiratory movements, in part, exactly reversed; to observe the lower end of the sternum, and the xiphoid cartilage, and the fourth, fifth, and sixth costal cartilages collapse, instead of protruding during each inspiration. This is well shown in the case of the boy Rawson, affected with bronchitis and emphysema, of whom the admirable engravings of Mr. Linton, taken from daguerreotype and from the original, illustrate this paper. The first daguerreotype was taken when he was breathing tranquilly; the second, during a deep inspiration.

In Rawson, the lower end of the sternum and the adjoining sixth costal cartilages, instead of advancing about $\frac{6}{100}$ths of an inch, fell backwards during inspiration to the same amount, and the fourth cartilage, instead of advancing through the whole inspiration, receded from $\frac{1}{100}$th to $\frac{2}{200}$ths of an inch, and then advanced.

This collapse, during inspiration, of the lower part of the chest, may be observed in the great majority of severe cases of bronchitis and emphysema, where the patients are below the

Ordinary Respiration. Deep Inspiration.

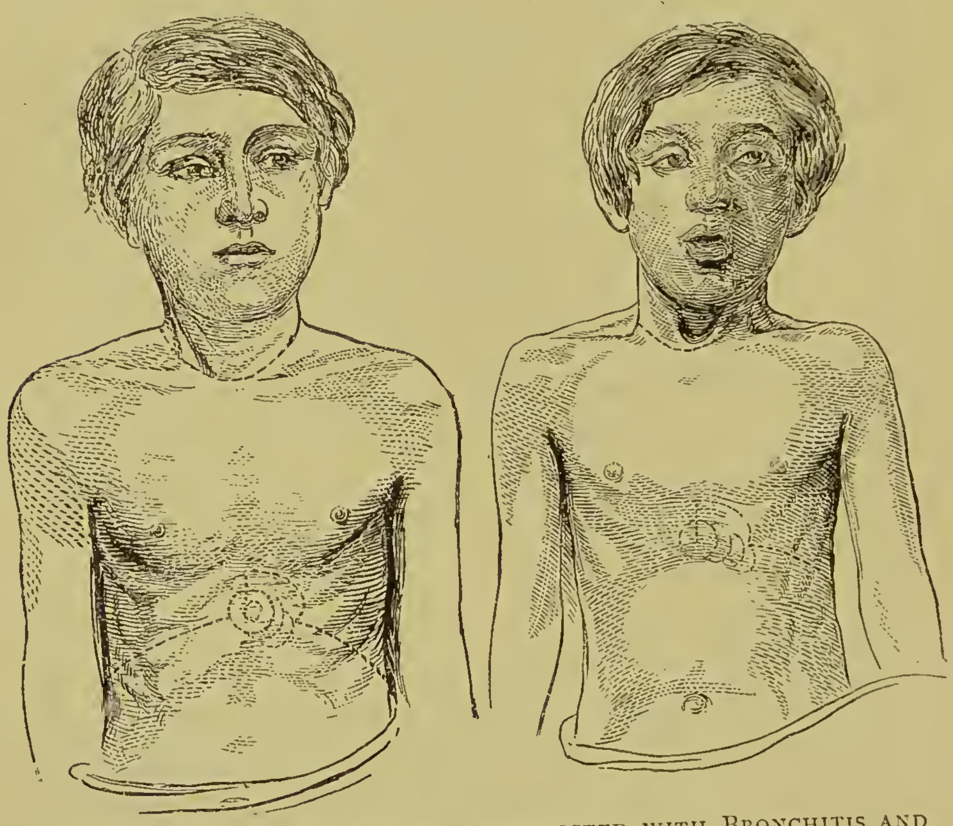

FIG. 1.—WILLIAM RAWSON, ÆT. 13, AFFECTED WITH BRONCHITIS AND EMPHYSEMA.

The dotted lines indicate the outlines of the organs; the concentric lines the position of the heart's impulse.

age of forty or forty-five. Of thirty-eight cases of bronchitis and emphysema, the respiratory movements of which are tabulated in my paper on the Movements of Respiration in Disease, the lower end of the sternum fell back during inspiration, in eight or nine out of the twelve cases of children affected with bronchitis or hooping-cough; in nine out of fourteen cases of males below the age of fifty; and in six out of eight cases of females. The four remaining cases were old men.

6. *Cause of the remarkable Sign in Question.*

The cause of the remarkable sign in question is very apparent. As the air can only enter the air-cells through the obstructed bronchi with difficulty, the lungs are lengthened from below by the powerful descent of the diaphragm, and amplified above by the expansion of the upper part of the chest more rapidly than it is possible for air to rush in to supply the enlarged and lengthened portions of the lungs. The consequence is that the lungs collapse at the lower part of the chest, and the walls of the chest fall in, owing to the pressure of the atmosphere over the collapsed portion of lung. It is not only in emphysema and bronchitis that the phenomenon in question is observed. If we pass a tape round the chest, and voluntarily close the glottis, and attempt to inspire, the diaphragm draws downwards and lengthens the yielding spongy lung, and the abdomen protrudes, notwithstanding that no air is admitted into the lung: the consequence is, that the lungs, being lengthened, collapse, and the costal walls fall inwards. The matter is made plainer by this illustration: "If we lengthen a closed india-rubber bottle containing air, the sides of it collapse; if we compress and shorten it, they swell out. So with the lungs; if they be lengthened when the air can neither escape from nor enter them, their sides will collapse; if they be shortened, their sides will swell out."

The following extract from a paper by Dr. John Reid, on

Respiration, puts this interesting subject in a very clear point of view. "The passage of the air into and from the lung has an important effect upon the muscular respiratory movements. When a lung, or a considerable portion of it, is prevented from expanding by disease or any other cause, the

Deep Inspiration.

FIG. 2.—WILLIAM SHAW, ÆT. 30, AFFECTED WITH EMPHYSEMA AND BRONCHITIS.

pressure of the air on the inner surface of that portion of the chest covering the unexpansible lung is not now exercised during its dilatation,—in other words, this portion of the chest, in expanding, must do so in opposition to the whole of the atmospheric pressure on its outer surface, amounting to 15 lbs. on the square inch. This pressure appears to be too great for the muscles of inspiration acting upon that part of the chest to overcome, for the ribs are there motionless, or nearly so; and, if the lung is in a state of collapse, the walls of the thorax covering it fall in."

7. *In Slight Cases no Falling in: the extent to which the Chest recedes during Inspiration a Test of the Severity, Increase, or Diminution of the Disease.*

In slighter cases of bronchitis or emphysema, when the obstruction to inspiration is inconsiderable, the walls of the chest do not fall in. This was observed in three cases given in the tables referred to above, in which the disease was only slight. In other cases, where the disease was somewhat more severe, the lower end of the sternum only fell in at the beginning of inspiration, and then advanced. In more severe cases, the lower end of the sternum fell in during the whole of the inspiration. As the severity of the case increased, in addition the cartilages to each side of the sternum fell in. The boy Rawson is an interesting illustration of this. When he was first observed, emphysema was conjoined with acute bronchitis, and the lower end of the sternum and the fourth and fifth costal cartilages receded. A month later, the bronchitis was less severe, and the fourth costal cartilage, instead of receding, advanced during inspiration. In another patient, who got gradually worse, and at length died, as the case increased in severity the portion of the lower part of the chest which fell in during inspiration increased in extent.

We are thus, in the increase or diminution of the amount and extent to which the lower part of the chest falls in during inspiration in a case of bronchitis or emphysema, afforded a test of the progressive increase or diminution of the disease.

8. *Cases in which the Lower Part of the Chest is Narrowed instead of being Flattened during Inspiration.*

Although the lower end of the sternum falls in during inspiration in the greater number of cases of emphysema and bronchitis, it does not do so in all cases. William Shaw, the engravings from whose daguerreotypes illustrate this paper, is a case in point. In Shaw, the lower end of the sternum, instead of receding during inspiration, protruded about $\frac{4}{100}$ths of an inch. This protrusion was owing to a remarkable narrowing during inspiration of the lower part of the chest, the sixth and eighth ribs falling in on each side. The inspiratory falling in of those ribs was evidently due to the chest being there unusually narrow and boat-shaped, and the sternum prominent, apparently from malformation acquired in early life. Such malformation frequently occurs in rickety children, owing to the yielding inwards, during inspiration, of the ribs and costal cartilages at their junction. In these children the sternum is unusually prominent, while the chest is narrow : they are, in fact, chicken-breasted. In four out of twelve of the children affected with bronchitis and hooping-cough, the lower part of the chest, instead of being flattened, was narrowed during inspiration.

9. *In Old Age, the Cartilages being Stiff, no Falling-in of the Costal Walls.*

When persons above the age of forty-five or fifty are attacked with emphysema or bronchitis, the cartilages being firm and partially ossified, the walls of the chest do not fall in anywhere during inspiration.

10. *Deepening and Widening of Intercostal Spaces during Inspiration. Dorsal Curvature.*

The daguerreotypes of Rawson and Shaw show very clearly that the lower intercostal spaces become very hollow and deep during inspiration in cases of emphysema. This deepening of the intercostal spaces, which may be observed to a certain extent in all healthy persons not loaded with fat, during a deep inspiration, forms a marked and characteristic feature in cases of emphysema, and is due to atmospheric pressure.

One of the features characteristic of emphysema is the considerable and rounded dorsal curvature, the neck and head being forward and stooping. During inspiration, the dorsal curvature is increased, and the neck and head are further lowered and brought forward. This lowering of the head during inspiration is usually considerable, amounting in some cases to $\frac{1}{20}$th of an inch, and is due to the inspiratory deepening of the dorsal curvature just alluded to, and to the contraction of the sterno-mastoid, which, while it acts with increased purchase, from the mastoid process on the sternum, when the head is well forward, at the same time acts from the sternum on the mastoid processes to draw the head still further downwards and forwards.

11. *Attitude of the Patient during the Attacks of Dyspnœa.*

The attitude of the patient during the attacks of dyspnœa is such as to favour the action of certain supplementary inspiratory muscles. If standing, the patient, bending forward, leans his hands on the table or on his own knees; if sitting, he leans forward, supporting his elbows on the arms of the chair, or his elbows or hands on the knees. The head being well forward, he thus gives purchase for the action of the sterno-mastoid, and, the scapulæ being raised and fixed, he gives solid bearing for that of the pectoral muscles. If the patient be in bed, he either sits forward, leaning his hands on the bed, or his elbows on his knees; or, in some cases, he kneels and leans on his elbows, maintaining a horizontal back; the head at the same time is lowered, resting on the pillow. The sterno-mastoid and scaleni have now a fixed bearing, and, their origins being thrown forwards, those muscles act with every advantage. The pectoral muscles act from the fixed scapulæ, and, the back being horizontal, the costal walls are slung by the serrati from the scapulæ, the respiratory motion of those walls being backwards and forwards as it is in the lower animals, instead of being upwards and downwards as it is in man: in fact, the patient puts himself spontaneously into the attitude in which the mechanical movements of respiration are most easily performed.

12. *Inspiratory Expansion of the Inlets of Respiration.*

The respiratory muscles which act on the inlets of respiration partake of the exaggerated action which characterises those muscles which act to expand the chest. The nostrils, which are always more or less dilated, are, during inspiration, expanded to the full. The whole face is in action: the eyebrows are more than ever corrugated and raised during inspiration; the features are furrowed, and sometimes, when respiration is oral, the mouth is opened or widened, the jaw is lowered, the soft palate is stretched and rendered tense, and the base of the tongue is lowered and brought forward; the inlets and channels of respiration are throughout widened, at the same time—that is, during inspiration—the larynx descends, being drawn downwards chiefly by the action of the diaphragm, which, causing the descent of the trachea at its bifurcation, necessarily also causes the descent of the larynx.

13. *Expiration.*

While inspiration is very difficult in emphysema and bronchitis, owing to the obstruction in the smaller bronchi, and to the lung being enlarged almost to the full, expiration is still more difficult. The muscular actions are not so much exaggerated in expiration as in inspiration, that act not being felt to be so immediately essential to life; but, as will be more particularly seen in considering the rhythm of respiration, expiration is much longer than inspiration. This difficulty of expiration is, in fact, one of the fundamental causes of the enlargement of the air-cells. The action of the expiratory muscles, especially during dyspnœa, is much exaggerated, the abdominal muscles, the latissimus dorsi, and the serratus magnus, being especially active ; the action of the inspiratory muscles are, however, unquestionably more exaggerated than that of the expiratory.

14. *Rhythm of Respiration. The Expiration longer than the Inspiration. The Nature of the Rhonchi, in Relation to the Lengthening of Expiration ; the Expiration quick at first, then slow, and becoming gradually slower towards the end of the act.*

The rhythm of respiration, or the relative duration of expiration and inspiration, is remarkably disturbed in emphysema.

The expiration is considerably longer than the inspiration, instead of being equal to, or but little longer than it. The greater the obstruction in the smaller bronchi in both emphysema and bronchitis, the more prolonged and difficult is the inspiration. If a case affected with emphysema or bronchitis, or both conjointly, improve, the expiration becomes less and less prolonged, until, as the disease becomes trivial, it is scarcely longer than the inspiration. We have thus, in the greater or less increase in the relative length of the expiration, a test not only of the severity of the disease, but of its progress; for if it improves, the expiration shortens; if it becomes worse, it lengthens.

The prolongation of the expiration is in strict relation with the cause and the presence of the existing rhonchi. This is especially manifest in bronchitis, in which disease the rhonchi are developed in proportion to the increased lengthening of the expiration.

In emphysema and bronchitis, not only is expiration lengthened, but it is lengthened in a peculiar manner. The expiration is not equally slow throughout, but it is at first quick and then slow, and it becomes gradually slower towards the end. This quickness of the expiration at first, and increasing slowness towards the end, is owing to the condition of the bronchi. All the bronchial tubes are at their largest at the end of inspiration and the beginning of expiration, and then it is that expiration is easy and quick, as it is then also that the larger and unobstructed bronchi become lessened by the expiratory act. As the lesser bronchi become smaller and smaller during the progress of expiration, the difficulty increases, and the expiration becomes slower and slower. The increasing slowness of the expiration towards the end is in strict relation to the nature of the rhonchi, they being often absent or very coarse and grave at the beginning of expiration, then sharp, and afterwards more sharp and cooing towards the end of the act. In such cases, the inspiratory rhonchus is the reverse of the expiratory, being sharp at first, becoming gradually grave and coarse, and towards the end of the inspiration being often altogether absent.

There are some interesting peculiarities and differences in the motion and rhythm of the abdomen, and of the upper part of the thorax, the expiratory diminution of the abdomen being often sudden and almost complete during the beginning of expiration ; afterwards the abdominal walls either stand still or contract very slowly. The upper costal walls often stand still just at the beginning of expiration, and then recede ; but the costal parietes as well as the abdominal diminish more slowly just towards the end of expiration. For further details on this subject, I beg to refer to the paper quoted above on the movements of respiration in disease.

IX

ON THE MODE OF USING A CHEST-MEASURER, TO ASCERTAIN THE MOVEMENTS OF RESPIRATION IN DISEASE, AND ON THE INDICATIONS IT AFFORDS.[1]

1. *Mode of using the Chest-measurer.*[2]
2. *Indications afforded by it in Health, and*
3. *In Disease.*

SOME years since, with the aid of a patient, and, finally, of Mr. Symmons, I constructed the chest-measurer—an instrument for ascertaining with minute accuracy the modifications of the movements of respiration induced by, and often indicating, disease. In a paper on the Movements of Respiration in Disease, in the last volume of the *Medico-Chirurgical Transactions*, I have given numerous observations made by aid of the chest-measurer, with the view of ascertaining how far different diseases modify the respiratory movements. To that paper I beg to refer.[3] Several of my friends having asked me how to use the chest-measurer, I intend here to state concisely, aided by the graphic delineations of Mr. Linton, the mode of using the instrument, and what indications it affords in health and disease. I may as well state, in

[1] From the *London Medical Gazette*, vol. viii. 1849.

[2] The description of the apparatus used is a repetition of a description given in a former paper; it is retained here for convenience of reference.

[3] Paper VII. of this collection.

the outset, that although the instrument can indicate whether the respiratory movements, and consequently the chest, be healthy or not, and can almost always point to that part of the chest which is diseased, yet it has no pretension to tell the nature of the disease : it does not supersede, but it is a supplement to and assists the other methods of inquiry. It need scarcely be said that, as with the stethoscope, so with the chest-measurer, the method of using the instrument, and the indications afforded by it, can only be known by instruction, close observation, and practice.

1. *Mode of employing the Chest-measurer.*

The instrument must be put together in the manner represented in Fig. 1.

It may be applied to the patient either in the lying, sitting, or standing posture.

The mode of applying the instrument to a patient when *lying* is shown in Fig. 2.

The back of the patient, just behind the lower angle of the scapula, rests upon and steadies the instrument. From this point, as from a centre, all the observations on that side, and some of those on the opposite side, may be made without shifting the base of the instrument or disturbing the patient.

It is very important to hold the instrument steadily : this is easily and perfectly accomplished by bearing the upright rod firmly backwards upon the hinge by the hand at the slide B C, the finger and thumb commanding the rotating rod, C D, which carries the dial and rack, D. The instrument can thus be easily manipulated by the right hand, which can raise or lower the slide, B C, and turn it on the upright rod, so that the rack may be applied first to one part of the chest and

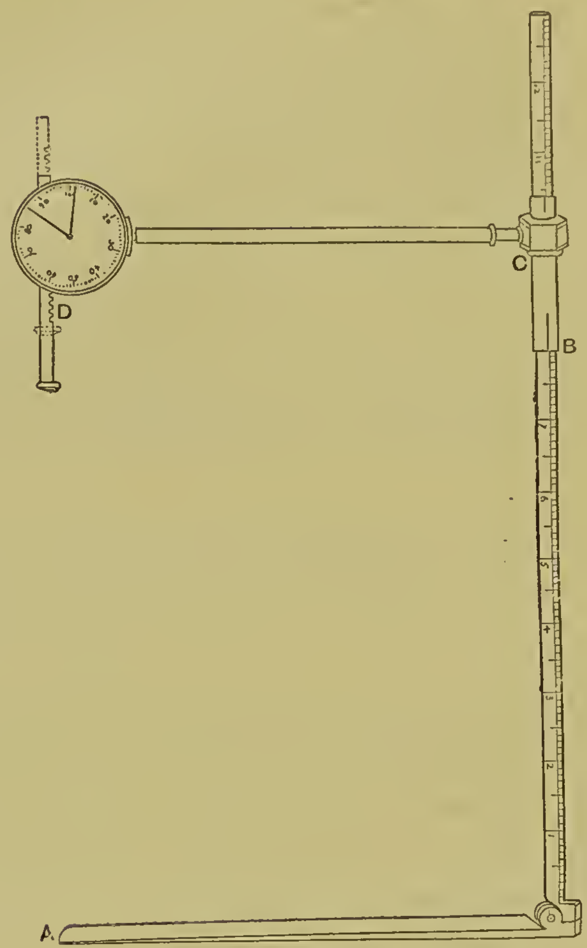

Fig. 1.—The Chest-measurer.

A. Brass plate, covered with silk, on which the patient lies (see Fig. 2).

B. Upright rod, divided into inches and tenths, to indicate, by the slide at B, the diameter of the chest.

C, B. Slide, moving on the vertical rod B, and carrying the horizontal rod and dial C, D.

C, D. Horizontal rod, dial and rack (D). This rod can be drawn out like a telescope from C—an outer rod sliding on an inner; and as the outer rod can be rotated on the inner, the inclination of the rack and dial can be varied at will, by the finger and thumb. This combination of slides forms a universal joint (see Fig. 2).

D. Rack and dial. The rack, when raised by the moving walls of the chest, moves, by means of a pinion, the index on the dial. One revolution of the index indicates an inch of motion in the chest; each division indicates the 100th part of an inch.

The Chest-measurer packs into a pocket case.

abdomen, and then to another. The finger and thumb must so adjust the rotating and elongating rod, C D, that the rack shall always be exactly at right angles to the part of the body the motion of which is being observed. The other hand is at liberty, and can feel for the ribs, so that the rack may be applied exactly over the part to be examined, and at corresponding parts on both sides.

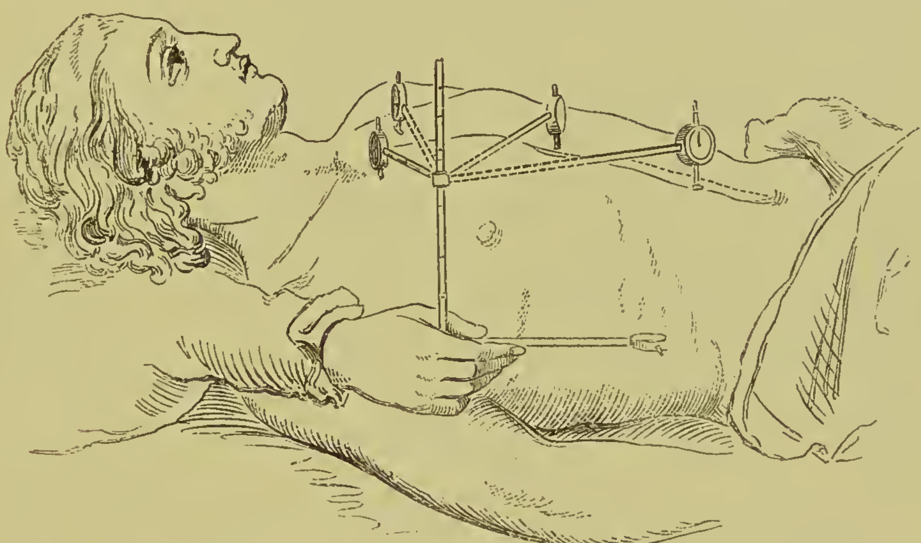

FIG. 2.—MODE OF APPLYING THE CHEST-MEASURER.

By placing the instrument in the manner here represented, the patient lying on the flat plate forming the basis of the instrument (see Fig. 1), the rack and dial, by a little adjustment, can be successively applied over the various parts of the chest and abdomen, without disturbing the patient.

The mind should be clearly made up as to the best positions at which to apply the instrument, so as to make as complete and rapid a survey of the chest as possible. I think the points, the motion at each of which is numbered in Fig. 3, will be found best fitted for ascertaining the amount of the whole respiratory movements; and the following are the order and positions in which I suggest the successive applications of the instrument:—

Before applying the chest-measurer, observe closely and carefully the configuration of the chest, and ascertain the boundaries of the internal organs, and the position of the heart's impulse. Make the successive observations first at the centre, and then at the sides, from above downwards, in the following order:—

First Set of Observations.—At the centre of the sternum, just between the second costal cartilages, and then over the right and left second ribs. (By elongating the rod C D, these observations can be made one immediately after another, the base of the instrument being fixed on one side. It is important to take the symmetrical observations of opposite sides as rapidly as possible one after another, without disturbing the patient, so that the depth of the respirations may be as nearly as possible alike.) By these three observations the amount of expansion of both upper lobes is ascertained, and it is thus at once seen whether the amount of expansion is alike in both upper lobes (thoracic ribs, first to fifth).

Second Set of Observations.—The lower end of the sternum (comparing this with a renewed observation of the upper end of the sternum); the right and left fifth costal cartilages, close to their respective junction with the rib. These observations being made over the heart and the middle lobe of the right lung, indicate the amount of expansion over those parts. I need scarcely here insist on the value of an exact knowledge of the position of the viscera in relation to each other, and to the parietes immediately superficial to them, during both ordinary respiration and a deep inspiration, in the healthy person, and in the patient under observation. Without this information, scientific precision can only be replaced by conjecture.

Third Set of Observations.—(In these and the following observations, the instrument must be applied first on one side and then on the other.) Over the right and left sixth ribs to each side. These are not indicated on the figure, and are not always needful. They show the expansion of the upper part of the lower lobe, and, during a deep inspiration, of the lower part of the upper lobe (intermediate ribs, sixth to eighth).

Fourth Set of Observations.—Over the right and left tenth ribs to each side. These indicate the expansion of the lower portion of the lower lobe, and the descent of the diaphragm (diaphragmatic ribs, ninth to twelfth).

Fifth Set of Observations.—Over the centre of the abdomen and the right and left sides of the abdomen, just below the costal cartilages, and outside the recti muscles. These indicate the descent of the diaphragm—pushing downwards and forwards the abdominal viscera, and lengthening and expanding downwards the thoracic. The motion of the centre of the abdomen indicates the descent of the central tendon; that of the right and left sides, the descent of the right and left crura of the diaphragm.

All these observations should be taken as soon after each other as is consistent with accuracy, when the patient is breathing tranquilly and involuntarily. The patient ought not to be desired to take a deep breath or to speak, or to be otherwise disturbed until they are all taken. It is important that, during these and all subsequent observations, the patient should be desired to look at the ceiling, in order to keep his eye off the dial; if he catches sight of the movements of the index on the dial caused by his own respiration, the respiration is immediately disturbed by the attention being directed to the respiratory movements.

While these observations are being made, the *rhythm of respiration*, the relative duration of inspiration and expiration ought to be observed. An accurate and easy plan of ascertaining the rhythm is to beat time very rapidly with the fore-finger, and to count the number of beats, first during inspiration and then during expiration.

After the whole series of observations of involuntary respiration have been made, the patient ought to be desired to take as deep a breath, and then to breathe out as far as he can without annoyance, the medical man showing him how, (it is so much easier to imitate an example than to follow an instruction; by a little attention to this point, the most nervous patient will do exactly what is wished.) A fresh series of observations must now be made during the forced expiration, over the same points at which the involuntary respirations were noticed. The successive deep inspirations and forced expirations ought as nearly as possible to be of the same extent. Care must be taken not to distress the patient by causing him to inspire too deeply, or to repeat the deep inspirations too rapidly or too frequently.

These observations ought to be taken in a warm room; the shirt or flannel waistcoat ought not to be removed, and only that portion of the chest ought to be exposed which is immediately under observation. It is convenient to cover the neighbouring parts with a piece of flannel. It is well, before commencing the observations, to let the patient see the instrument placed on the medical man's own chest, or to allow him to lift the rack with his finger, so that he (or she) may feel assured of its harmlessness. If the patient is rendered nervous or is excited, the observations cannot be properly made. With a very little precaution no difficulty will be felt on this score.

The mode of applying the instrument to a patient when *sitting and leaning back* in his chair, is exactly the same as when he is lying, only instead of lying upon, he leans against, and so steadies the plate A, which forms the base of the instrument.

When the patient is *sitting upright* or *standing*, the instrument must be entirely steadied by the medical man : this is easily and accurately done by holding the plate A, which forms the base of the instrument, with one hand, while, with the other at the slide B C, he bears the upright rod backwards upon the hinge, and commands with the finger and thumb the rotary rod C D, carrying the dial. This may also be easily accomplished with one hand, by hooking forward the horizontal plate A against the back of the patient, by the hand which commands the slide B C.

We cannot always make the whole of the observations detailed above, and it is, indeed, seldom necessary. If phthisis, for instance, be dreaded, the upper part of the chest ought to be carefully examined; if pneumonia or pleuritis, the lower. It is usually easy to examine the upper part of the chest in females without removing the dress; and the motions of the lower part of the chest and the abdomen can generally be observed by applying the instrument over the dress.

2. *Indications afforded by the Chest-measurer (Movements of Respiration) in Health.*

The numbers here given, indicating the respiratory movements, denote so many 100ths of an inch, or, which is the same thing, so many subdivisions on the dial. A movement, for instance, of $\frac{13}{100}$ths of an inch is marked 13, and one of 1 inch is marked 100.

AVERAGE MOVEMENTS OF RESPIRATION IN THE HEALTHY MALE FROM THE AGE OF TEN TO THAT OF FIFTY. (SEE FIG. 3.)

			Involuntary tranquil respiration	Voluntary forced respiration about
Centre of sternum between second costal cartilage			3 to 6	100
Second rib near the costal cartilage	right		3 „ 6	110
	left		3 „ 7	110
Lower end of sternum			2 „ 6	95
Fifth costal cartilages near the rib	right		3 „ 6	95
	left		2 „ 5	85
Sixth rib at the side	right		5	70
	left		3	60
Tenth rib	right		10	65
	left		9	60
Abdomen	centre	boy	25	90
		man	25 to 30	100
	right		9	
	left		8	

The extent to which the chest can be expanded in health, during the deepest possible inspiration, is very different in different persons. Some, for instance, can cause the second rib to advance two and a quarter inches during forced inspiration, while others can only cause it to advance three-quarters of an inch.

It may be noticed that the movements of the whole front of the chest are pretty nearly equal; of the ribs at the side, somewhat less than equal to those in front; but those of the tenth ribs are, during tranquil respiration, nearly twice as great as those of the anterior part of the chest; while during forced respiration they are considerably less. The motion of the tenth (diaphragmatic) ribs indicates, it will be remembered, the motion of the diaphragm. The motion of the whole left side, excepting the second rib, is somewhat less than that of the right side.

The above is the usual and the most healthy average: but in many persons whose chests are healthy—some of whom are quite well, whilst others are out of health in other respects—the movement over the whole chest, instead of varying

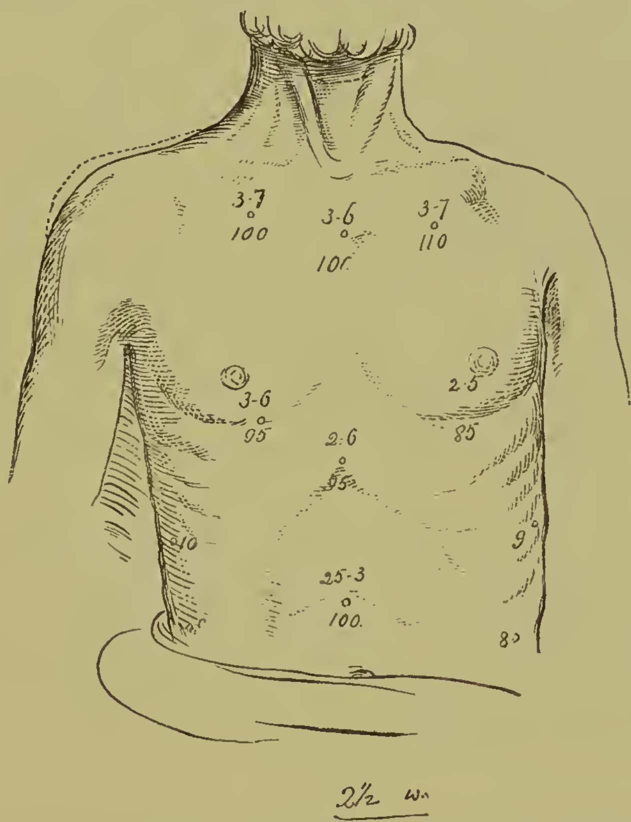

FIG. 3.—HEALTH.

Points to which the chest-measurer may be most advantageously applied, and average amount of motion, in 100ths of an inch, at each of those points, during both ordinary and forced respiration.

from two to six, is about ten. In these persons the motion of the diaphragmatic ribs (tenth) is not increased.

The respiratory movements in the healthy female, at the age of twelve, do not differ materially from those of the healthy male at the same age.

In the adult, the stays, and possibly the natural conformation, modify the respiratory movements. *When the stays are on*, the thoracic movement is exaggerated, while the lower thoracic and the abdominal movement is diminished, the second ribs moving forward from 5 to 20, the abdomen 6 to 11; *but when the stays are off*, the second ribs move forward from 3 to 10, and the abdomen moves forward 8 to 20. During a deep inspiration, the abdomen at the waist moves forward—with the stays on, about 10; off, 15 to 40.

Respiratory Movements in the Infant.—The thoracic movements are considerable, being from 2 to 12; while the abdominal movements are from 8 to 20. The lower end of the sternum, and the adjoining cartilages and ribs, instead of advancing, usually or often fall in during inspiration, especially during quick, sobbing inspirations.

I ought to state that the healthy respiratory movements of both females and children stand in need of additional observations.

The Rhythm of Respiration in Health.—During tranquil breathing in adult males, inspiration and expiration are equal: frequently inspiration is to expiration as 6 to 7; in women and children, 6 to 8 or 9—if breathing be hurried, 6 to 10 or 12; in old age, 6 to 8 or 9.

3. *Indications afforded by the Chest-measurer when the Respiratory Movements are abnormal.*

In nearly all these cases, if the respiratory movements are restrained at one part, they are exaggerated elsewhere.

Cases in which the respiratory movements of both sides are disturbed, the organs of the chest being healthy:—

In *posterior curvature of the spine*, at the sixth dorsal vertebra. The respiratory motion of the ribs above the curvature is restrained, while that of the ribs below it, and of the abdomen (diaphragm), is exaggerated.

In *peritonitis,* the respiratory motion of the abdomen is much restrained,—in severe cases almost annihilated; and, to compensate for the diminished abdominal movement, thoracic respiration is very much exaggerated; great and heaving movements of the upper ribs being one of the marked characteristics of the disease.

In acute peritonitis the patient can scarcely add to the respiratory movement by forced respiration—indeed, every respiration is forced.

The expiration is sometimes shorter than the inspiration.

Cases in which the respiratory movements of both sides are disturbed by diseases of the chest:—

In extreme cases of *laryngitis, croup,* and diseases where there is great obstruction to respiration in the larger air-passages, the abdominal movements are not increased, but the respiratory efforts are laborious, and the costal walls, especially at their lower part, instead of advancing, actually fall in during respiration. The duration of the expiration is increased, it being slow and equally slow throughout.

In *vesicular emphysema* and bronchitis, the obstruction to respiration being in the smaller bronchial tubes, the inspiratory efforts are all excessive and laborious: the abdominal movement is not, though that of the upper part of the chest is, increased, but the motion of the lower part of the chest is actually reversed. (See Fig. 4.)

The expiration is prolonged, being often twice as long as the inspiration: it is quick at first, then slow, and becomes gradually slower towards the end.

Cases in which the motion of the ribs on one side is restrained, the chest being healthy:—

Lateral Curvature of the Spine.—If the convexity be to the right, the ribs on the left side are restrained in movement, while those of the right side are exaggerated.

Injuries or diseases of the ribs, or of the parts contiguous, if the movements of the ribs in question cause pain or mischief.

Cases in which the respiratory movement of the whole of one side is restrained from chest disease, that of the opposite side being exaggerated :—

Universal *pleuritis*—pleuritic effusion.

Pneumonia of the whole lung.

Phthisis of the whole lung. In some of these cases the respiration is not exaggerated anywhere.

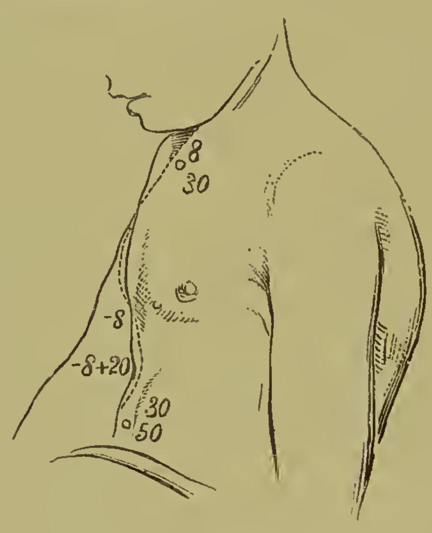

FIG. 4.—VESICULAR EMPHYSEMA AND BRONCHITIS.

The respiratory efforts laborious, the involuntary respiratory motion of the abdomen and upper part of the chest is not materially modified ; while that of the lower end of the sternum, and the adjoining part, is absolutely reversed, falling backwards during inspiration, and protruding during expiration.

Cases of the same class, the motion of the ribs over the upper lobe being restrained :—

Phthisis (see Fig. 5).

Pneumonia of the upper lobe.

Cases of the same class, the motion of the lower ribs and of the diaphragm on one side being restrained :—

Pneumonia, or other disease of the lower lobe.

Cases in which the motion of the central tendon of the diaphragm is restrained, while that of the crura of the diaphragm is not so materially affected.

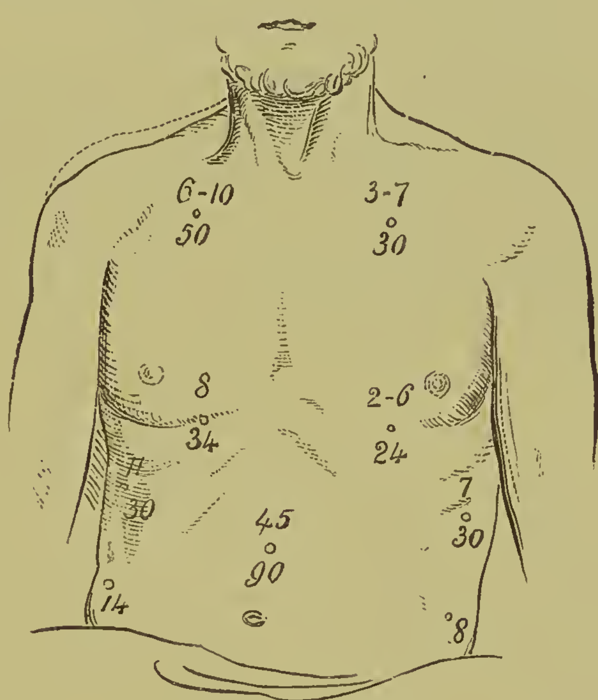

FIG. 5.—PHTHISIS.

Large cavity in the left upper lobe, over which region the respiratory movement is materially restrained.

In cases of *pericarditis*, especially if the pericardium lining the central tendon of the diaphragm be affected, the inspiratory protrusion of the walls of the abdomen at the centre between the xiphoid cartilage and the umbilicus is very much diminished, sometimes, indeed, arrested, but the motion of the abdomen to each side is comparatively only slightly affected.

The above instances will illustrate the principle on which the observation of the movements of respiration (whether with or without the aid of the chest-measurer) operates in aiding the formation of an accurate diagnosis.

If we find the respiratory function of the chest arrested or restrained at any part, to that part our attention is directed, and there we shall almost certainly discover the disease, and by other diagnostic aids detect its nature.

There are many cases in which the respiratory movements can be observed with sufficient accuracy without the aid of the chest-measurer; and there are many practised and able physicians who can almost always detect any disturbance in the respiratory movements by the scientific use of their unaided senses.

X.

ON THE CAUSES WHICH EXCITE AND INFLUENCE RESPIRATION IN HEALTH AND DISEASE.[1]

It is not my object in the following address to investigate either the essential nature of respiration, which consists in the changes which it effects on the organism,—or the channels by which air enters the system, whether through the lungs, the gills, or the skin, with or without the aid of a circulation, —or the mechanism by which respiration is effected. I propose to myself to investigate the various causes which excite and influence the respiratory movements.

But though the essential nature and mechanism of respiration form, as such, no part of the present inquiry, yet it is necessary that the successive stages of the respiratory act should be clearly stated before considering the first stage of that great act, namely, the causes which excite respiration. I shall therefore attempt to sketch the essential nature and the mechanism of respiration, before I proceed to the investigation of the causes by which it is excited.

THE CHANGES EFFECTED BY RESPIRATION ON THE ORGANISM.

Respiration, an essential function of life, lies at the root of physiology. Every living animal must part with the old materials of its fabric whilst it takes up fresh materials.

[1] From the *Transactions of the Provincial Medical and Surgical Association*, vol. xvii. 1856, being an Address in Physiology.

The vegetable assimilates inorganic matter and renders it organic. The animal assimilates the matter rendered organic by the vegetable, and then renders it again inorganic. As the sum of inorganic matter contains more oxygen than that of organic, the surplus oxygen must be parted with when the former is converted into the latter. Consequently the vegetable, in rendering matter organic, must part with the surplus oxygen, while the animal, in restoring the inorganic material, must receive sufficient oxygen to replace that which was lost.

Respiration is the converse to assimilation, the former act abstracting what the latter had deposited; they are both essential to life, but while assimilation may be suspended in all classes of animals, respiration must, in the higher classes, be continuous. Respiration is the combustion of what has been assimilated. It consists more particularly, but not exclusively, in the combustion of the hydro-carbonaceous materials, and their conversion into water and carbonic acid by the oxygen of the respired air, and in the removal from the system of the carbonic acid when formed.

The vigour of life is in direct proportion to the activity with which the organic materials are rendered inorganic. If an animal hybernate, life being latent, the organic materials are almost or quite unchanged; little or no air is supplied; respiration is scarcely performed; the animal functions are almost suspended. If, on the other hand, an animal attack its prey, life is roused to the utmost; the organic materials of the body are rapidly changed; air is supplied plentifully; respiration is vigorous; the animal functions are performed with the utmost power.

Between the two extremes of latent hybernating life coupled with suspended respiration, and energetic life coupled with vigorous respiration, there is every variety and shade of the exercise of life and respiration ; and in every instance the amount of respiration and of the combustion of organic matter exactly corresponds with the degree of vitality exercised.

At the same time that the functions of one organ are vigorous those of another may be suspended; the organic changes go on rapidly in the organ at work, but slowly, or not at all, in that which is inactive. The combustion of each organ varies as the exercise of its function varies.

During the successive stages of life, the exercise of respiration and of the other animal functions are exactly proportioned to each other and to the wants of the particular stage. The restlessness of the child and the activity of the boy correspond to their excited respiration, and the quick repair and waste of their frame. The calmness and power of the man are combined with a usually tranquil respiration, capable of being increased to the utmost as the occasion calls for the higher energies of life. In the old man, deliberate in his movements, respiration is limited and usually slow, being proportioned to the slow change of his organic structures.

The same law that rules the corresponding vitality and respiration of an individual animal during the varied functions of its life also regulates the whole scale of animal life. In the carnivorous mammal, life is energetic, respiration vigorous, and the organic change rapid. In the reptile, life is torpid, respiration feeble, and the organic change slow. The vital energies, the respiration, and the organic change of each animal are in exact proportion to each other, and to the purpose in life for which the animal is fitted.

In the higher grades of animal life respiration must be constantly kept up when the vitality and functions are active; but it may be suspended when they are dormant, as in syncope and hybernation. In the lower grades respiration can be suspended for a time without injury to life; the period of possible suspension being longer or shorter, in proportion as the organic functions are longer or higher.

In all animals, whether they have or have not a circulation,—whether they respire through lungs, gills, the skin, air-tubes, or air-sacs,—whether they have or have not a special respiratory apparatus,—the essential part of respiration is performed throughout the whole organism.

In those beings destitute of a circulation, the air must be diffused by endosmosis through the whole framework. In those animals which possess a circulation the air enters the blood through a special apparatus, or through the skin, and is transmitted by the circulation to the various structures. In these the essential function of respiration is performed around and within the systemic capillaries.

The essential function of respiration consists in the oxygenation of every part of the organism. Respiration is allied to combustion. If we light a candle, the combustion consists neither in the supply of oxygen nor the removal of carbonic acid, but in the chemical union of oxygen and carbon. In like manner, if we breathe, respiration does not essentially consist either in the supply of oxygen or the removal of carbonic acid, but in the chemical union of the oxygen with the hydro-carbons and with the other organic materials. Again, if we light a candle, it is necessary to the continued combustion that the oxygen be supplied as rapidly as it is consumed, and the carbonic acid removed as rapidly as it is formed, else in either case the flame will be quenched. So again, if we breathe, it is necessary to the continued respiration that the oxygen be continuously supplied to the system, and that the carbonic acid, and the other noxious combinations formed, be continuously eliminated from the organism, else in either case those chemical changes in the organism, which constitute the essential function of respiration, will be no longer performed.

There is no difference in the mode of respiration, whether the oxygen enter the organism through the medium of lungs, gills, or any other special breathing apparatus, or through the medium of the skin. In those animals possessing pulmonary respiration, the essential part of respiration is not performed in the lungs. The oxygen is admitted inwards through the lungs to the circulating blood, and is transmitted over the whole organism by the circulation, and the carbonic acid formed throughout the organism is conveyed outwards by the circulation, is rendered free in the lungs, and is expelled thence during expiration. If respiration be cutaneous, oxygen is continuously admitted into the organism, and carbonic acid expelled from it, through the medium of the skin. The frog, which usually respires simultaneously both through the lungs and the skin, may respire through the medium of the lungs alone or of the skin alone. Dr. Edwards kept frogs immersed for months in aerated water, so that they could not breathe through the lungs. They lost their characteristic activity and became sluggish, but they lived for an indefinite period. Pulmonary and cutaneous respiration are essentially alike, but the oxygen is admitted over an infinitely more extensive surface through the lungs than through the skin. The lungs form the most perfect respiratory apparatus, simply because they admit the greatest quantity of oxygen into the system, and are consequently connected with the most rapid oxygenation of the whole organism and the most energetic performance of all the vital functions. The frog, when it breathes through the skin alone, is far lower in vitality, and its organism is less rapidly oxygenated, than when it breathes both through the lungs and the skin.

The circulation in those animals endowed with a circulation, in addition to its proper functions, forms an integral part of the respiratory apparatus; by it the oxygen is diffused over, and the carbonic acid collected from, the whole organism. The circulation is indeed not only the great and diffused channel for the supply of fresh and the elimination of effete material, but it is also the great and diffused respiratory channel for the supply of oxygen and the removal of carbonic acid.

Besides being the great respiratory channel, the circulation is also a seat of the essential function of respiration, the blood being itself oxygenated by the oxygen diffused through it. Indeed, the essential function of respiration is only performed in the lungs, insomuch as the blood circulating through them is being oxygenated, and as the small portion of organic tissue forming the texture of the lung is like every other organic texture, subject to respiratory oxygenation.

The circulation, viewed as a portion of the respiratory apparatus, is inspiratory in those parts of the current which convey the oxygen from the lungs to the left cavities of the heart, and thence over the whole organism; and it is expiratory in those currents which convey the carbonic acid from the whole organism through the veins to the right cavities of the heart, and from those cavities to the lungs, where it is expelled. In the frog, when the respiration is pulmonary, the inspiratory portion of the circulation conveying the oxygenated blood from the lungs is poured into the left auricle; but when the respiration is altogether cutaneous, the inspiratory current is changed, and the oxygenated blood is poured into the right auricle.

When the blood is increasingly charged with carbonic acid, it produces increasing distension of the capillaries, and causes greater and greater impediment to the circulation, in the manner so well illustrated by Dr. Williams. When, on the other hand, the blood is charged with oxygen, it produces tonic contraction of the capillaries, and causes quickening of the circulation. The perpetually renewed supply of oxygen to the blood is therefore necessary, in order that the blood circulating in the capillaries, charged with carbonic acid, may be forced onwards with greater ease by the action of the heart.

We perceive, then, that while respiration thus essentially consists in the combination of oxygen with the effete materials of the organism in order that they may be eliminated, we also see that the supply of oxygen, and the evolution of carbonic acid, are necessary to the continuance of respiration.

Animal heat is the great product of respiration. It is not, however, from the chemical action of respiration alone that animal heat is evolved,—it is, in fact, the common product of all the chemical and electrical, and of many of the mechanical processes, constantly going on throughout the organism. Heat is evolved by the chemistry of the assimilation and formation of the tissues, as well as by the chemistry of the decomposition and elimination of the tissues. The formation of carbonic acid is undoubtedly the chief source of animal heat. The production of animal heat is so much under the control of the nervous influence that I shall consider separately the remarkable effects of that influence.

Effect of the Nervous Influence on the Production of Animal Heat.

Sir Benjamin Brodie found that when he killed an animal, either by pithing or by means of the wourali poison, and kept up artificial respiration, the temperature of the body fell more quickly than it did when the body lay undisturbed, notwithstanding that the venous blood was converted into arterial, and that carbonic acid was evolved almost to the normal amount.

The effect of the nervous influence, and of natural and artificial respiration, on the evolution of animal heat, is well illustrated by the accompanying table, which presents at one view the various tables given by M. Chossat in his remarkable and important Memoir on the influence of the nervous system on the animal heat.

This table demonstrates that the withdrawal of the nervous influence lessens the production of animal heat, whether by removal of the brain, division of the spinal marrow, or the administration of opium, the respiration being in those instances automatic,—or by division of the medulla oblongata, respiration being artificial.

The nerves exercise a local influence on the evolution of animal heat. Elliott and Home observed, that after dividing the nerves of a limb its temperature falls. Mr. Earle noticed that the temperature of the hand of a paralysed limb was 70°, while that of the sound hand was 92°. When the paralysed limb was electrified its temperature rose to 77°.

Throughout the scale of animal life, the lower the nervous energy the lower is the animal heat, and the higher the nervous energy the higher is the animal heat. The sluggish mollusca possess a temperature either the same with, or only a very little higher than, the surrounding medium. Insects, in their perfect state, possess the power of evolving much heat, the larva generates less heat than the perfect insect, while the pupa evolves less heat than the larva. When the bee is excited it has a much higher temperature than when quiescent. Mr. Newport disturbed a hive of bees in winter, when the external temperature was 34½°; the temperature of the

TABLE COMPRISING VARIOUS TABLES GIVEN BY M. CHOSSAT IN HIS MEMOIR ON THE INFLUENCE OF THE NERVOUS SYSTEM ON ANIMAL HEAT.

	Dog. Killed by dividing the spinal marrow in the neck. Body exposed, undisturbed.		Dog. Killed by a blow on the occiput. Circulation kept up by artificial respiration.		Dog. Brain removed above the pons varolii.				Dog. Section of spinal marrow below occiput. Slow artificial respiration. Temperature before operation 103°·8.	
	Rate of Cooling.		*Rate of Cooling.*				*Rate of Cooling.*		*Rate of Cooling.*	
	Actual temperature.	Loss of heat.	Actual temperature.	Loss of temperature.	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature.	Actual temperature.	Loss of temperature.
At the time of death or operation	104°·9	...	103°·46	...	...	...	104°·	...	99°·86	...
End of the 1st hour	101°·66	3°·24	99°·86	3°·6	52	11	99°·5	4°·5	96°·08	3°·78
„ 2nd „	96°·98	7°·92	95°·54	7°·92	131	74	94°·64	9°·36	91°·4	8°·46
„ 3rd „	93°·02	11°·88	91°·76	11°·7	153	101	89°·06	14°·94	87°·26	12°·62
„ 4th „	89°·06	15°·84	88°·34	15°·12	125	91	86°·9	17°·1	Cessation of artificial respiration.	
„ 5th „	85°·46	19°·44	85°·1	18°·36	103	76	85°·46	18°·54	...	...
„ 6th „	82°·94	21°·96	82°·4	21°·06	79	40	84°·2	19°·8	...	...
„ 7th „	81°·32	23°·58	80°·6	22°·86	51	11	81°·86	22°·14	...	...
„ 8th „	...	...	78°·62	24°·84	41	13	80°·6	23°·4	...	...
„ 9th „	78°·26	26°·64	76°·82	26°·64	41	14	79°·34	24°·66	...	...
„ 10th „	...	...	74°·3	29°·16	28	14	77°·72	26°·28	...	...
„ 11th „	75°·02	29°·88	72°·14	31°·32	30	13	76°·46	27°·54	...	...
„ 12th „	...	...	Death, *i.e.*, cessation of circulation.		29	13	75°·2	28°·8	...	...
					Death.				...	...

	Dog. Section of spinal marrow below seventh cervical vertebra. Temperature before operation, 105°·8.				Dog. Section of spinal marrow below third dorsal vertebra.				Dog. Section of spinal marrow below seventh dorsal vertebra.				Dog. Injection of solution of opium into the veins.			
			Rate of Cooling.				*Rate of Cooling.*				*Rate of Cooling.*				*Rate of Cooling.*	
	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature.	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature.	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature.	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature.
At the time of death or operation	...	...	104°·9	...	...	...	104°·9	..	...	...	105°·44	...	102	8	103°·64	...
End of the 1st hour	130	20	98°·96	5°·94	100	32	101°·66	3°·34	128	21	101°·66	3°·78	173	20	97°·88	5°·76
„ 2nd „	106	19	94°·1	10°·88	153	27	98°·06	6°·84	145	18	100°·94	4°·50	157	15	93°·74	9°·90
„ 3rd „	88	22	89°·14	14°·76	155	15	94°·82	10°·08	140	19	101°·88	3°·56	139	11	90°·68	13°·
„ 4th „	78	16	86°·	18°·9	...	...	...	...	151	22	102°·74	2°·70	114	9	88°·14	15°·5
„ 5th „	...	17	83°·3	21°·6	...	...	...	...	117	22	103°·46	1°·98	93	7	85°·64	18°·
„ 6th „	...	16	80°·78	24°·12	...	...	...	...	140	24	104°·9	°·54	74	6½	83°·48	20°·16
„ 7th „	...	...	79°·34	25°·56	68	6	82°·4	22°·5	150	27	105°·08	°·32	56	6	81°·5	22°·14
„ 8th „	...	...	...	...	44	7	80°·78	24°·12	...	...	...	...	45	5	80°·24	23°·4
„ 9th „	26	11	75°·2	29°·7	35	7	79°·52	25°·38	176	31	103°·1	2°·34	...	...	...	...
„ 10th „	Death.				31	7	78°·44	26°·46	...	...	...	...	39	5	79°·16	24°·48
„ 11th „	...	...	...	...	28	7	77°·36	27°·54	...	...	101°·66	3°·70	...	...	...	...
„ 12th „	...	...	...	..	24	8	76°·1	28°·8	160	25	101°·3	4°·14	38	5	79°·7	24°·
	...	...	...	...	...	...	...	...	Died after thirty hours.				Before death, 22nd hour,			
					17th hour died		71°·6	33°·3	...	...	...	...	13	...	73°·	30°·6

Dog. Division of the pneumogastric nerves; a tube was inserted into the trachea.				
			Rate of Cooling.	
	Pulse per min.	Resp. per min.	Actual temperature.	Loss of temperature.
Before operation	85	10	102°·	...
Time of operation	180	4½	97°·	5°·
Average 1st 12 hours	215	6	99°·2	2°·8
„ 2nd 12 hours	190	5	99°·1	2°·9
„ 3rd 12 hours	183	6	98°·6	3°·4
„ 4th 12 hours	106	4	85°·1	16°·9
During 5th period of 12 hours: 3rd hour	58	5	78°·1	23°·9
6th hour	39	4	72°·86	29°·14
9th hour	24	5	70°·5	31°·5
12th hour	23	3	69°·26	32°·74
Death.				

disturbed hive rose to 102°, while that of an adjoining hive was only $48\frac{1}{2}$°. Among fishes, the eel is scarcely warmer than the surrounding medium, while the bonito, whose gills are amply supplied with nerves, has, according to Dr. Davy, a temperature $18\frac{1}{2}$° above that of the sea. For numerous interesting illustrations of the dependence of the power of generating heat, on the possession of nervous energy, I refer to Dr. Carpenter's work on comparative physiology.

We find on all sides evidence that the evolution of animal heat is dependent on the exercise of the nervous influence. It is the possession, not of a larger or smaller nervous system, but of a higher or lower nervous energy, which regulates the production of animal heat.

On the combined Action of Respiration and the Nervous Influence on the Evolution of Animal Heat.

The experiments of Sir Benjamin Brodie, while they prove that the nervous system controls the evolution of animal heat, seem at first to show that animal heat is not evolved by the chemical action of respiration; since a decapitated animal subjected to artificial respiration, although it produced almost the normal amount of carbonic acid, cooled more quickly than a recently killed animal left undisturbed. These experiments, which form an era in the knowledge of the development of animal heat, and the functions of the nervous system, stimulated physiologists to further inquiry.

M. Legallois divided the spinal marrow and kept up artificial respiration in a rabbit, and he found that less oxygen was consumed and less carbonic acid evolved than had been consumed and evolved by the same rabbit when breathing naturally. He also found that the rabbit in which artificial respiration was performed cooled less quickly than a rabbit whose body was left undisturbed after being recently killed.

M. Chossat, in the experiments given in the table at page 196, found that the dog on which artificial respiration was performed after its brain was crushed, cooled less quickly during the first seven hours, and more quickly during the last four hours of its sustained existence, than the dog whose body was left undisturbed after the division of the spinal marrow between the second and third cervical vertebræ.

In Sir Benjamin Brodie's experiments, the artificial respirations were performed at the rate of from 30 to 35 in a minute.

Sir Charles Hastings found that when the lungs were inflated fifteen times in a minute in a rabbit just killed, the rate of cooling was diminished. In one of his experiments the rabbit on which artificial respiration was performed cooled only 4°, while that which was left undisturbed cooled 7°·5. Dr. Wilson Philip killed two rabbits, one he left undisturbed, and on the other he performed artificial respiration thirty times in a minute; in half an hour the latter had lost 4°, the former only 3°·7. He now inflated the lungs only twelve times in a minute, and in another half hour the rabbit had only lost 2°·5 in addition, while the undisturbed rabbit had lost in the same time 3°·5. This experiment at once confirms and explains the previous experiments of Sir Benjamin Brodie.

These experiments prove that animal heat is evolved during artificial respiration; that the evolution of animal heat is proportioned to the amount of carbonic acid generated; that respiration in its chemical actions is a warming process; and that respiration in its physical action is a cooling process.

Respiration is a warming process throughout the whole organism by means of the formation of carbonic acid and by other chemical changes. It is also probably a warming process in the lungs, inasmuch as it causes the conversion of oxygen from the gaseous to the liquid form when it is taken by endosmosis into the blood. During this process the latent heat must become sensible, and cause an elevation in temperature of the blood in the pulmonary veins. Dr. Davy found the blood in the right cavities 1° warmer than that in the left; and he also found that the temperature of venous blood, when exposed to the air, rose from 1° to 2° under the influence of the absorption of oxygen.

Respiration is a cooling process, inasmuch as it causes the conversion into vapour of much of the watery part of the blood, which vapour escapes from the lungs during expiration, at a temperature of 98°, while the air which enters is cooler in proportion to the external temperature. This is the merely physical part of respiration, and is the same in effect with cutaneous perspiration; the same in effect also with ordinary evaporation. If any one enter a stove heated above 100°, the evaporation from the lungs and surface keeps down the temperature of the body. Delaroche and Berger placed a porous vessel containing two moistened sponges at a temperature of 100° to 106°, and a frog at 75°, in a stove at 126° to 142°. In a quarter of an hour the jar, the sponges, and the frog were all about blood-heat (98° to 100°), and in two hours they still retained that temperature. Here the physical effect of evaporation caused these bodies to retain a temperature from 28° to 42° below that of the surrounding medium.

Respiration, as a chemical or warming process, raises the temperature of the body throughout, but respiration, as a physical or cooling process, tends to lower the temperature. If the temperature of the surrounding medium be below the standard of animal heat, the chemical or warming processes of respiration overbalance the physical or cooling process, and the body is warmer than the atmosphere. If the temperature of the air be the same with that of the standard of animal heat, then the warming and cooling processes counterbalance each other, and the atmosphere and the body are alike in temperature. But if the external temperature be above the standard of animal heat, then the warming is over-balanced by the cooling process, and the body retains a temperature below that of the surrounding medium.

In Sir Benjamin Brodie's experiment, the cooling over-balanced the warming process, inasmuch as the cool air with which the lungs were inflated was warmed in the lungs at the expense of the heat of the body; and the warm blood in the course of its circulation was conveyed in continued currents from the centre to the surface, where it was cooled rapidly by cutaneous evaporation. Notwithstanding the rapidity of the artificial respiration, the undisturbed body cooled almost as quickly as the other. It is clear that some animal heat must have been generated, to compensate for the greatly augmented rate of cooling called into play by the currents of circulation and of artificial respiration.

The experiments of Legallois show that the chemical or warming processes of respiration are not performed so efficiently during artificial as during natural respiration; and those of Dr. Wilson Philip and Sir Charles Hastings show that when the physical or cooling process of respiration is not performed with undue vigour, the cooling of the body is delayed, instead of being hastened, by artificial respiration, and that consequently a considerable amount of animal heat must be evolved under the influence of that process.

The proofs that the evolution of animal heat is dependent on respiration in co-operation with the nervous influence are not confined to the experiments with artificial respiration detailed above; they are derived also from careful and accurate observations made on animals when in a state of hybernation and of sleep.

On the 21st of January 1806, the temperature being 29°·3, M. Saissy irritated a hedgehog, a dormouse, and a bat, when in a state of profound hybernation; the temperature of the two former was 37°·4, of the bat 39°·2. The dormouse awoke in three-quarters of an hour; in an hour its temperature was 77°, and in two hours 95°·8. The bat awoke at the end of an hour, when its temperature was 69°; and in two hours it was 80°·6. The hedgehog did not awake for two hours, when its temperature was 54°·5; in three hours it was 86°, and in four hours 89°·6. If the rise in temperature had been solely due to the awakened nervous energy, the increase in temperature would not have been so slow and progressive. That it was really due to the combined influence of the respiration and the aroused nervous energy, is proved by M. Saissy's experiments, detailed in the accompanying table, from which it will be observed that as the warmth of the animals declined under the influence of the declining external temperature, the number of respirations and the amount of oxygen diminished *pari passu*. Thus, on the 8th of November, when the animals were still conscious, the amount of oxygen consumed by the bat was about $\frac{1}{5}$th of the normal proportion, and its temperature was reduced to 53°·6: the consumption of oxygen by the hedgehog was reduced to $\frac{1}{3}$rd, and its temperature had fallen to 56°·5: the dormouse, however, still consumed as much as $\frac{2}{3}$rds of the normal proportion of oxygen, and its temperature had only fallen to 69°·8. When those animals were in a profound state of hybernation they consumed no oxygen, and their temperature was as low as 38°·5, but when, owing to slight disturbance, the hedgehog consumed $\frac{1}{10}$th and the

TABLE showing the number of cubic inches of oxygen consumed in an hour by the respective hybernating animals, in Summer and Winter, under increasing degrees of cold and insensibility; and the temperature of the animals in the armpit, made from various details in M. Saissy's Researches on Hybernating Animals.

CUBIC INCHES OF OXYGEN CONSUMED PER HOUR, BY

	Hedgehog.		Dormouse.		Bat.	
	Temperature of Animal.	Oxygen consumed.	Temperature of Animal.	Oxygen consumed.	Temperature of Animal.	Oxygen consumed.
12th of August, 1806. Temp. 64°·4; animals lively	...	80·8	...	34·6	...	17·88
6th of August. Temperature of animals	95°	...	97°·5	...	86°	...
8th of November. Temperature of air 44°·6, animals still conscious	38°·5	26·59	69°·8	20·53	53°·6	3·84
1st of February. Temperature of air 29°·3, animals hybernating but breathing; the temperature rose during the observation	38°·5 rising to 44°	2·03	38°·5 rising to 44°·6	1·15	...	...
2nd of February. Temperature of air 32°, animals hybernating profoundly, not breathing	38°·5	...	38°·5	...	37°·4	...

NUMBER OF RESPIRATIONS PER MINUTE:—

	Hedgehog.	Dormouse.	Bat.
8th of August. Temperature 68°	16	45	70
10th of November. Temperature 44°·6; animals conscious	10	30	8
When hybernation was commencing	4 to 5	9 to 10	5 to 6
Profound hybernation	...	...	...

CIRCULATION. NUMBER OF PULSATIONS:—

	Hedgehog.	Dormouse.	Bat.
9th of August, 66°·2	75	105	30
11th of November, 44°·6	25	60	30
Beginning to hybernate	...	20 to 25	...
Profound hybernation	9 to 10	9 to 10	9 to 10

dormouse $\frac{1}{30}$th, of the normal amount of oxygen, the temperature of those animals rose during eight hours, the hedgehog from 38°·5 to 44°, and the dormouse from 38°·5 to 44°·6.

The experiments of Dr. Marshall Hall afford additional proof of the dependence of animal heat on the combined influence of the nervous energy and respiration. He found that a bat in a perfect state of hybernation did not absorb any oxygen for the space of ten hours. After the lapse of that period, it was gently roused from time to time, and in two hours and ten minutes it had absorbed one cubic inch of oxygen. It was then much roused ; it moved about incessantly, and in one hour it had absorbed five cubic inches of oxygen. From another observation, he found that an animal in a perfect state of hybernation absorbed 3·4 cubic inches of oxygen during sixty hours. Dr. Marshall Hall roused a bat in a state of hybernation by inserting a thermometer into the stomach, when the temperature was 39° ; an hour afterwards the animal was lively and respiring quickly, and the temperature of its stomach was 95°.

The whole subject is illustrated in a very interesting manner, and the dependence of animal heat on the combined influence of the nervous energy and of respiration is proved by the observations of Mr. Newport on the Temperature and Respiration of Insects in the *Philosophical Transactions* for 1835 and 1837.

Mr. Newport found that the temperature of the full-grown larva of the sphinx, when inactive, was ·3° above that of the atmosphere ; but when, owing to its being excited, it became active, it rose to 1°·3 above the surrounding medium. The number of respirations and the amount of carbonic acid evolved were much greater when the larva was active than when it was inactive.

The temperature of the undisturbed pupa is not perceptibly higher than that of the atmosphere; when disturbed, it may rise from 1° to 2°. The larva of the sphinx at a temperature of 70° produced ·086 cubic inch of carbonic acid gas in an hour, while the pupa only produced ·0012 cubic inch in the same period when exposed to a temperature of 46°. The production of carbonic acid by the pupa was increased to ·0022 cubic inch in an hour when it was exposed to the higher temperature of 58°.

When the insect is in its perfect state, its temperature is higher while its respirations are more rapid and its production of carbonic acid is greater than in either the larva or pupa state. The temperature and respiration of the perfect insect vary much, accordingly as it is in a state of activity or repose. The Sphinx Ligustri, shortly after it had changed from the pupa to the perfect state, had a temperature of only 4° above the atmosphere; in two hours and a quarter it had risen to 5°·2. Another specimen, which had been exerting itself for a longer period, had a temperature of 9° above the surrounding medium.

The Bombus Terrestris, when first caught, being then in a state of excitement, respired 120 times in a minute; in half an hour, the insect being at rest, the respirations were only 58; in 140 minutes they had sunk to 46; and in 180 minutes they were no longer perceptible. The Bombus Terrestris, when first captured, evolved ·345 inch of carbonic acid in the hour, but when at rest during twenty hours, the quantity evolved in the hour was reduced to ·015, or less than the twentieth part. On placing these insects in a box, it was found that when they were quiescent their temperature was 4° above the surrounding medium, but that, when they were excited, it rose to 11° above the atmosphere. There are certain individuals among these bees, named nurse bees, which have the remarkable power of raising their temperature at will, in order to impart warmth to the young bees in the cells by brooding over them. To do this, the bee fixes itself on the occupied cell, respiring at first very gradually; it quickens its respirations to 120 or 130 in the minute, and excites in the comb a temperature 22° above the atmosphere. On one occasion the temperature of the hive was 40° above that of the surrounding medium. In winter, when the bees were quiet, the temperature of the hives was sometimes the same with that of the atmosphere. On tapping the hive, the bees were excited, respired quickly, and generated a great amount of heat. Once, on tapping a hive, its temperature rose to 102°, 67°·5 above the atmosphere! At the same time the temperature of a neighbouring hive was only 14° above the surrounding medium.

The various kinds of insects differ remarkably in the power of generating heat. This power is higher in volant than in creeping insects, in diurnal than in crepuscular insects. In all the various species, the individual temperature corresponds with the respiratory power,—the respiratory power with the habits of the insect. The degree of the respiratory power does not depend on the possession of a larger or a smaller nervous system, but on the possession of a higher or lower nervous energy. The higher the nervous energy the higher is the temperature and the greater the exercise of respiration.

The experiments in which artificial respiration was performed after the division of the nervous centres, the observations made on mammalia in a state of hybernation, and those on insects in their larva, pupa, and perfect state, in their torpid and active condition, prove that the evolution of animal heat is controlled by the nervous influence and generated by respiration. The nervous influence and respiration co-operate *pari passu* in its production; respiration, the chemical agent, being regulated by the nervous influence, and excited in exact proportion to the nervous energy.

The co-operation of the Nervous Energy, Respiration, and Circulation in the Evolution of Animal Heat.

The circulation being an integral part of the apparatus of respiration, the energy of the circulation is of necessity increased when the action of respiration is augmented. Indeed if, from any cause, circulation be increased, respiration must be increased also. These positions are amply proved by observation and experiment.

In ordinary death, respiration ceases before circulation. If the animal be pithed, or destroyed by the wourali poison, the movements of respiration cease, but the circulation of the blood continues. The action of the heart, and finally the circulation in the capillaries also cease, unless respiration be maintained artificially. Circulation, then, outlives for a time pulmonary respiration; in the frog, indeed, circulation can be carried on independently of pulmonary and in virtue of cutaneous respiration; the circulation, in fact, lasts for a considerable period after the cessation even of cutaneous respiration.

In the hybernating animal, the circulation maintains a condition almost parallel with the respiration, but the circulation continues during profound hybernation, when the respiration seems to be entirely suspended. M. Saissy observed, on the 9th of August, 1806, the temperature being 62°·2, that the heart of a dormouse pulsated 105 times in a minute; on the 15th of November, temperature 44°·6, the animal being still conscious, the heart beat 60 times. When the animal began to hybernate, the pulsations were reduced from 20 to 25, and when it was in a state of profound hybernation, the circulation in the arteries was not perceptible, the veins of the abdomen were congested, and the heart pulsated feebly only from 9 to 10 times in the minute. The parallel conditions of the respiration and temperature may be seen in the table given at page 196, from which it will be observed that as the external temperature fell, the animal heat, the respiration, and the circulation fell at equal rates, until the external temperature had been lowered to a certain extent, at which period the animal heat had fallen to about 38°, respiration was almost or altogether at a stand-still, and the circulation, though very feeble, was still in motion.

Dr. Marshall Hall observed the circulation, under the microscope, in the small vessels of the wing of the bat when in the state of complete hybernation; and although the respiration was suspended, the blood circulated slowly in the minute vessels, the pulsations being 28 in the minute.

The increase of circulation with that of respiration, and the increase of respiration with that of circulation, may be observed daily in the various acts of life.

Mr. Newport noticed that the rate of the circulation in the insect corresponded with its respiration, temperature, and activity. When the Sphinx Ligustri was greatly excited, the pulsations of its dorsal vessel were 139, and its respirations 42 in the minute, and its temperature was 5°·5 above the atmosphere. When at rest, half an hour later, the pulsations were 49, the respirations 18, and the temperature 5°. After an additional rest of three-quarters of an hour, when the insect was perfectly quiet, the pulsations were only 42, and the respirations 15 in the minute, while the temperature was nearly 2° above that of the atmosphere.

In the larva, and still more in the pupa state, the lower condition of the activity, temperature, and respiration of the creature is attended by a correspondingly lower condition of circulation. When the larva of the sphinx was asleep, its pulsations were about 30 in the minute, and its temperature varied from ·0 to ·5° above the atmosphere; when it was aroused and active its pulsations were 36, and its temperature was ·9° above the surrounding medium. When the larva of the sphinx changed to the pupa state, its pulsations were only 12 in the minute, while its temperature was ·3° above the atmosphere; as the pupa became more quiescent, the pulsations were undoubtedly less perceptible. It appears that the pulsations are more rapid in the earlier than in the later stages of the larva condition: the larva of the sphinx having 108 pulsations in the minute when ten days old and asleep, while it had only 26 pulsations when thirty-three days old, just before it had entered the earth for changing: but the pulsations, though quicker, are feebler in the earlier stages than the later.

The pulsations are diminished when the insect is asleep, but are increased in force and frequency immediately the insect awakes.

It appears then that in the order of the phenomena, the increased nervous energy and increased activity of the animal precedes the increased rate of circulation, of respiration, and of temperature.

ON THE MECHANISM OF RESPIRATION.

The decomposition and removal of the effete materials of the organism, and the evolution and regulation of animal heat, constitute in all animals the great purposes of respiration. In every animal, respiration is in exact accordance with the vital energies; if the vital energies be suspended, respiration is suspended; if they be active, respiration is active. In every being, whether there be or be not a special respiratory apparatus, such is the adjustment of the mechanism of respiration that the function of respiration can be suspended, diminished, or increased, in exact adjustment and proportion to the suspension, diminution, or increase of the energies of life.

The great purposes, the essential nature of respiration being alike in all beings, however simple or complex they may be in construction and function, the causes which excite respiration must be the same in principle in all classes of animals; and, as I shall have to draw many of the illustrations and proofs of those causes from the various classes of animals, I shall briefly review the principal varieties in the mechanism of respiration with which the different orders of beings are endowed.

Respiration has not been closely observed in those beings which are not endowed with a circulation. In the classes destitute of circulation, respiration must be carried on by the absorption of air through the integument and the organism from without inwards. In many of them the organs of locomotion, the cilia, constitute also organs of respiration, by causing the repeated renewal of the water in contact with the surface. In others, as the acalephæ, respiration is carried on through the medium of numerous channels diffused throughout the organism.

In all those animals which possess a circulation, the circulation must be regarded as an essential and subservient part of the mechanism of respiration. The circulatory apparatus is in every instance adapted to the respiratory apparatus, and not the respiratory to the circulatory. It is the object of every respiratory apparatus to present a surface capable of absorbing the oxygen of the atmosphere, and of passing it inwards to the blood through the walls of the blood-vessels. The oxygen received into the blood is transmitted onwards by the circulation through the whole organism.

Some creatures, as certain snails, the leech, and the lowest forms of crustacea, have no special respiratory organ ; and in these respiration is altogether cutaneous. The constant renewal of fresh aerated water, or of air to the surface, is, in these beings, kept up, in some, by the motion of cilia, in others, by the movements of the animal itself. The rapidity with which the air enters the organism, according to the varying wants of the individual, is regulated by the varying rapidity of the animal movements, and of the circulation of the blood. In those animals whose respiration is exclusively cutaneous, the greatest proportion of oxygen is contained in the blood circulating in the cutaneous capillaries, and in the vessels proceeding from those capillaries. All those animals which are endowed with a special respiratory apparatus are also endowed with cutaneous respiration. If the act of the special respiratory apparatus be suspended, the respiration may in some animals be carried on entirely through the medium of the skin. Thus a frog may sustain its life indefinitely by cutaneous respiration, the action of the lungs being suspended, provided the animal functions be not performed with vigour.

It may perhaps in one sense be said that all respiration is cutaneous, since whatever be the variety in form of the special respiratory apparatus, it essentially consists in a prolongation and development of the integument, the cutaneous development being outwards in the branchial forms, and inwards in the tracheal and pulmonary forms of the respiratory apparatus.

There is great variety in the form of the special respiratory apparatus in different animals, the apparatus being beautifully adapted to the habits of the animal. In each species, as the habits of the individual change during its progressive development from the embryo to the perfect condition, one kind of respiratory apparatus is exchanged for another to meet the change in the habits of the species. If, from some peculiar circumstances, those habits do not undergo the usual change, the form of the respiratory apparatus remains unaltered; and if, on the other hand, the habits be prematurely changed, a fresh form is prematurely substituted for the former one.

Among the inhabitants of water, some, as the holothuria, respire by means of ramified tubes; the water being alternately admitted into and expelled from the respiratory tubes, Others, as the annelida, possess, on their exterior, ramified branchial tufts generally, but, as Dr. T. Williams has shown, not always covered with cilia, and connected with the organs of locomotion, the respiration being thus increased when locomotion is excited. The circulation in the different species is peculiarly and beautifully adapted to the various modifications of the respiratory apparatus. Others, as the mollusca, possess either a highly vascular mantle or pouch, or highly vascular branchial plates, covered with cilia; in these the aerated water is usually renewed by the motion of the cilia; in all of them the supply of fresh water is augmented by the movements of the animal. In the highest of them—the cuttle-fish—the alternate renewal and removal of the water is secured by the alternate expansion and contraction of a special branchial chamber. In the mollusca, the action of the heart sends the blood first through the systemic capillaries, thence through the systemic veins to the branchiæ, and thence through the branchial veins to the heart. The cuttle-fish is, in addition, supplied with special branchial hearts. Others, again, as the fishes, have subdivided branchiæ, devoid of cilia, occupying branchial chambers, the blood to which is sent directly from the heart; the renewal of the water is secured by the opening and closure of the mouth and opercula. Finally, certain amphibia, as the siren, possess ramified branchiæ, exposed externally, and covered with cilia, the motion of which secures the renewal of fresh water. These, like the fish, possess a branchial heart, but the heart sends its blood simultaneously to the branchiæ, the lungs, and the system.

All these animals can renew the supply of water over the branchiæ. The exposed branchiæ of the branchial amphibia, the mollusca, and the annelida, being destitute either of independent motion or of mechanical adjustment to remove and renew the water, are supplied with cilia, which, being in continual motion, cause constant currents of fresh water to wash the gills. How far the motion of the cilia may be augmented or diminished, according to the necessity for increased or diminished respiration, I know not, but the energy of the circulation, and therefore of the respiration, can be and is increased or diminished in these beings to meet their varying wants.

The higher crustacea and fishes are supplied either with movable branchiæ or with a special apparatus for renewing the water, and their branchiæ are devoid of cilia. It is manifest that those gills which are covered with cilia cannot absorb the oxygen from the water so readily as those which are devoid of cilia, and that the aquatic respiration of the higher crustacea and of fishes is more perfect than that of the annelida, the mollusca, and the branchial amphibia. The active energetic habits of the crustacea and of fishes correspond with the higher development of their respiratory organs, while the comparatively sluggish life of the mollusca and the branchial amphibia is in keeping with the lower development of their respiratory organs. In harmony with their higher energies, the former class also possess a greater power of varying the amount of respiration; if they be torpid from cold or excessive heat, their respiratory mechanism is at a stand-still; but if they be excited by a due temperature or by exertion, then their respiratory movements are increased in exact proportion to the increased excitement. These classes enjoy, in fact, greater vital range, owing to the greater variety of their respiratory functions, and in connection with the greater vigour which they exert in capturing their prey.

The increasing energy of the various species in the ascending scale of crustacea and of fishes is proportioned to the increasing development of the respiratory apparatus and functions. Among crustacea, the lower and feebler forms are devoid of any special respiratory apparatus, while the higher forms, as the crab and lobster, possess a highly developed branchial apparatus. Among fishes, the lower forms have a temperature equal to or only from 1° to 2° above that of the surrounding medium, while, according to Dr. Davy, the bonito possesses a temperature 19° above that of the sea.

There are two great varieties in the form of the respiratory apparatus of air-breathing animals,—tracheæ or air-tubes, minutely sub-divided; and pulmonary air-sacs, simple or minutely sub-divided.

Insects, and some of the arachnida, are supplied with a complete system of ramified tracheæ, which convey the air through their infinite sub-divisions directly to every part of the organism. The circulation of insects is imperfect. The rapid and complete double circulation in the higher animals, conducting the blood from the system to the respiratory organs, and from the respiratory organs back again over the whole system, is not required by insects, endowed, as they are, with perfect respiratory channels diffused through every, the minutest, part of the organism. The respiratory system of insects may, in one sense, be said to be the most perfect of all respiratory systems, inasmuch as, from its universal distribution, that great function of respiration, the production of animal heat, can be performed more quickly by insects than by any other class of beings, however high in the scale of organization. For instance, when the thermometer stood at 17°·5 in the air, the temperature of a hive was raised in sixteen minutes from 30° to 70°, by merely tapping the exterior of the hive, and so arousing the bees; while, when M. Saissy roused a hedgehog from profound hybernation, it did not awake properly for two hours, when its temperature had only risen from 39° to 54°, and it was not until a lapse of four hours that it had attained the temperature of 89°·5. The extraordinary rapidity with which insects, especially bees, can raise their temperature, is in harmony with the rapidity with which they can pass from a state of rest to a state of the highest and most sustained activity, and with the rapidity with which it is required that one nurse bee after another shall raise its temperature, while brooding over the cell of the young bee just before it is hatched. The circulatory apparatus of insects is adapted to the respiratory apparatus. The blood moves rather in channels than in vessels, the tracheæ and the various structures being bathed in the blood, which is propelled slowly forwards by the long many-valved dorsal heart, and by muscular movements, which taking effect in each limb, give to each member a partial special circulation of its own. This circulation is at once systemic and respiratory.

Although the tracheal form of respiratory apparatus, branched as it is throughout the system of the insect, and capable of rapidly and extensively raising its temperature, constitutes that interesting little creature, the bee, the type of respiratory power; yet the pulmonary form of respiratory apparatus, in its highest organization, is the most compact, concentrated, and highly developed.

There is every grade of pulmonary respiratory apparatus, from the simple sac of the snail to the infinitely sub-divided lung of the mammal.

In the snail, the air-sac on one side of the body is opened by the circular retraction of its mouth and walls, and closed by their contraction. The heart is systemic, the blood being sent first through the system and then through the walls of the air-sac.

In spiders and scorpions, the tracheæ of insects are replaced by pulmonary sacs, sub-divided by laminæ into cells, with gill-like partitions ; while the heart, long and many-valved in the insect, is concentrated into one cavity, which sends the blood over the system, and then in whole or part over the air-sacs.

Amphibia, reptiles, birds, and mammals, are all endowed with lungs.

In the frog there is one large sac, the walls of which are honey-combed with highly vascular shallow cells.

In the serpent the lung is in part a mere membranous air-sac, in part its walls are cellular, as in the frog.

In the turtle the cells extend so as to fill up the lung.

In the mammalia the air-cells are minute and universally diffused, being constituted of very fine capillaries. In the porpoise and whale the cells fill the whole lung, which is devoid of interlobular partitions. In the other mammalia fibrous partitions sub-divide the lungs into lobes and lobules.

In birds the sub-divisions of the capillaries are exceedingly minute, the lobules are long, and convulated at the surface, the fibrous tissue is absent, and air-sacs communicating with the lungs are diffused through the system.

In all the pulmonary animals, from the pulmonary snail to the bird, the respiratory surface of the air-cells is devoid of cilia. In the vertebrate pulmonary animals the air passages are lined by columnar epithelium, tipped with cilia. The cilia never extend into the air-cells ; indeed, if they did, seated as they are on columnar epithelium, they would impede the aeration of the blood, completely fill the air-cells, and solidify the lungs.

The circulatory apparatus is developed, in the ascending scale of pulmonary animals, in proportion and relation to the development of the respiratory apparatus.

In the frog a common ventricle receives the blood from a pulmonic and a systemic auricle, and propels it simultaneously to the system and the lungs. When the respiration is entirely cutaneous, the systemic auricle alone receives the aerated blood.

In the turtle the ventricle is so partitioned that the greater part of the venous blood passes to the lungs, while the greater part of the arterial blood is told off to the system.

In the crocodile the heart is double, one side systemic, the other pulmonic, but owing to a peculiar arrangement of great vessels, a part of the venous blood is sent to the system.

In birds and mammalia a complete double circulation is established.

Movements of Respiration in the Lung-breathing Animals.

The frog, which is destitute of ribs, distends its lungs gradually, by a frequent deglutition of air, and empties them at once by the action of the abdominal muscles.

The serpent inspires by elevating its ribs, which are altogether vertebral, and by separating the opposite ribs from each other, so as to deepen and widen the pulmonary cavity.

The bird has a sternum and sternal ribs, as well as a vertebral column and vertebral ribs, which so combine their movements as to widen and deepen the chest during inspiration, and to contract it during expiration. The diaphragm is only rudimentary.

The mammalia possess a large and efficient diaphragm, which, at each inspiration, lengthens the lungs to a considerable extent, they, therefore, require a totally different arrangement in the bony framework of the chest from that which obtains in birds.

In mammalia the upper part of the chest is roofed over by the progressively narrowing series of ribs and cartilages which, with the sternum, encase the lungs, and by the strong muscles which raise the first ribs. If the upper part of the chest were not thus covered in, but were left exposed in front without a strong protecting and expanding bony covering, as is the case in birds, the upper portion of the lungs would collapse and be pushed downwards and backwards under atmospheric pressure, when the whole lung is lengthened and drawn from above downwards by the descending movement of the diaphragm. The movements of the upper ribs and diaphragm are so beautifully adapted to each other that when that muscle lengthens the lungs downwards the upper ribs lengthen the lungs upwards and expand them forwards.

In mammalia, while the upper ribs meet in front through the medium of the cartilages and the sternum, the space between the lower ribs of opposite sides is open in front owing to their cartilages being unattached. The opposite arrangement obtains in birds, for while in them the space between the upper ribs of opposite sides is open in front from the absence of corresponding sternal ribs, the space between the lower ribs is closed in front, through the medium of corresponding sternal ribs and the sternum. Thus in mammalia the upper part of the lung is protected by a bony covering, while the abdomen is exposed ; whereas in birds the upper part of the lung is unprotected, while the abdomen is shielded by a bony covering.

Owing to the arrangement of the ribs rendered necessary by the presence of an efficient diaphragm, the relative movements of the upper ribs to each other differ from those of the lower ribs ; for while the upper ribs converge during inspiration, the lower ribs diverge ; while the upper ribs expand the upper lobes upwards, forwards, and sideways, the diaphragm and the lower ribs expand the lower lobes downwards, backwards, and sideways.

In conformity with the different relative movement of the upper and the lower ribs, the intercostal muscles between the upper ribs have a different action from those between the lower ribs. While the external and internal intercostals between the uppermost of the thoracic ribs are in great part inspiratory, the external and internal intercostals between the lower diaphragmatic ribs are in great part expiratory. The intermediate ribs are raised during inspiration by the external intercostals, and are depressed during expiration by the internal intercostals. This action of the external and internal intercostals is the natural action of those muscles when no modifying influence is introduced to change the relative form and movements of the ribs ; it is the same action which obtains throughout in the serpent and the bird, all the external intercostals being in them inspiratory, and all the internal intercostals expiratory.

I find that in the mammalia the relative size of the anterior and posterior lobes of the lungs, the relative extent of movement of the anterior or thoracic ribs, and of the posterior or diaphragmatic ribs and diaphragm, are regulated by the position and function of the fore-limbs.

In the herbivora, the animal, when grazing, rests firmly on the fore-limbs; it is, therefore, important that the scapulæ on each side of the ribs should not be widely separated at each inspiration; consequently the chest is narrow and deep, the anterior or thoracic ribs are strong, and have but a limited range of motion, the anterior lobes are small, the posterior lobes are large, the diaphragm is extensive in size and motion and the posterior or diaphragmatic ribs are comparatively numerous, and have great play during respiration. The horse, which of all animals requires the most powerful support and use in the fore-limbs, is the type of this class.

In the porpoise, the seal, the kangaroo, the bat, and in man, the fore-limbs, which are not used to support the animal, have complete freedom of motion, and their varying separation does not interfere with their action, whether in swimming, flying, or prehension; consequently the chest is broad and full, the anterior or thoracic ribs are slender and long, and have an extensive range of motion, the anterior lobes are large, the posterior lobes are not, relatively to the anterior, so large as in the herbivora, the diaphragm is not so extensive in size and motion, and the posterior or diaphragmatic ribs are fewer in number, and have less play during respiration. The porpoise may be considered the type of this class.

THE CAUSES AND MEANS WHICH EXCITE AND INFLUENCE RESPIRATION.

EXCITEMENT OF RESPIRATION BY EXTERNAL STIMULUS.

The first shock of a cold shower bath excites a deep involuntary and almost convulsive respiration. In like manner if cold water be dashed suddenly on the face or body; if the hands or feet be suddenly dipped into cold water; if the body be suddenly plunged into a cold or a warm bath, a deep quick inspiration is immediately induced.

Dr. Marshall Hall relates that Dr. Heming witnessed the following interesting fact:—An infant just born, and covered by the bed-clothes, did not breathe. After waiting a few seconds, Dr. Heming proposed to himself to adopt some measure for this asphyxia, and lifted up the bed-clothes. The contact of the cool atmosphere instantly excited an act of inspiration.

Dr. Hartley, in his "Observations on Man," remarks that vigorous impressions from the cold air and cold handling of the midwife may excite the strong respiration and crying which take place upon the birth ordinarily. When the new-born child fails to respire freely the methods used to make it do so are, applying volatiles to the nose, swinging the child to and fro, and other methods which excite the muscles to contraction by making strong impressions on the neighbouring sensory nerves.

Dr. Marshall Hall observes that in the very young kitten, even when asphyxiated to insensibility, every touch, contact, or slight blow—every jar of the table, any sudden impression of the external air, or that of a few drops of cold water—induces at once energetic reflex movements and acts of inspiration. The nostrils, the tail, the soles of the feet, the general surface, are all extremely susceptible, and in degree in the order mentioned.

In syncope, circulation and respiration are almost or altogether suspended; the dashing of cold water or the blowing of cold air on the surface usually excites a deep inspiration; the repeated renewal of the dashing excites again and again renewed deep inspirations, and at length leads to the restoration of consciousness, as is illustrated in cases given below. In laryngismus stridulus, and sometimes in the fits of hysteria, although the inspiratory muscles are acting with convulsive power, inspiration may be altogether stopped by the closure of the glottis, owing to the forcible contact of the vocal chords. When cold water is dashed on the surface the vocal chords are immediately drawn asunder, and a deep inspiration follows.

In the epileptic fit, although the expiratory muscles are in violent convulsive action, the expiration cannot be performed, owing to the closure of the glottis by the forcible contact of the vocal chords; if cold water be dashed upon the face and body, the vocal chords are usually drawn asunder, when an act of inspiration is excited, and the convulsion is interrupted; by the repetition of such excited acts of inspiration the fit is finally put an end to.

In all these instances the act of inspiration is excited through the reflex function of the nervous system—the sudden impression made on the skin stimulates the extremities of the incident nerves; the stimulus is conveyed by the incident nerves to the spinal nervous centre, and is thence transmitted back over the motor nerves of inspiration. That these respiratory movements are purely excito-motor, and performed without the intervention of sensation, in many of those instances in which the excited movements are most energetic, is proved by the ease with which remarkable movements of respiration were occasioned by stimulating the surface in cases of syncope, hysteria, and epilepsy, cases in which sensation was altogether absent, and was only restored after repeatedly stimulating the surface, and so inducing deep reflex inspirations again and again by exciting the incident nerves. In many of those instances in which consciousness was present, the movements were evidently excito-motor, and quite independent of sensation. In some instances, especially where deepened and quickened inspirations were excited in connection with pain and with exalted sensation, there is reason to believe that reflex movements were excited by the sensation itself, conjointly perhaps with the excito-motor influence on the one hand, and independently of volition on the other ; in many of these instances it would appear as if the excited inspiratory movements were at once both consensual and excito-motory.

It is to be observed, as a general rule, that wherever there are nerves with an incident or excito-motor function, there are there nerves with a sensory function. Whether the sensory and incident functions are blended in one nervous filament, or whether separate sensory and incident filaments are blended in one nervous trunk, has not as yet been distinctly shown.

In considering the causes which excite respiration it is important to bear this in mind, that wherever a nerve exists possessing sensory functions, there a nerve exists possessing incident functions; wherever the nerves of sensation are numerous, there the incident nerves are numerous ; and that wherever sensation is very exquisite, there the reflex functions of the true spinal system are very readily excited.

The extent to which the act of inspiration is excited by the application of a stimulant to the surface depends on the intensity of the stimulus, the extent of the surface, and also the impressibility of the part of the surface to which the stimulus is applied.

If the impression be sudden and powerful, and applied over a great extent of surface, or to a part of the surface supplied with many incident nerves, then the act of inspiration is deep, and all the inspiratory muscles are called into play. The nostrils are dilated, the mouth is opened, the fauces being widened, the glottis is extensively enlarged, the shoulders are much raised, the chest is expanded to a great extent, and the diaphragm descends considerably.

On the other hand, if the impression be slight, applied over a large extent of surface, or to a part of the surface supplied with only few incident nerves, then the act of inspiration is limited, the supplementary muscles are not called into play, the mouth is not opened, the nostrils are not dilated, and the glottis is only inconsiderably widened.

The stimulus exciting the inspiration is in every instance so distributed through the incident nerves and the spinal marrow, along the motor nerves, that the outer apertures, the mouth and nostrils, and the aperture at the glottis, are dilated in exact proportion to the expanding force exerted by the muscles of inspiration over the cavity of the chest.

The extent to which the apertures are dilated is, I repeat, in exact proportion to the force exerted by the respiratory muscles, and not necessarily in proportion to the extent to which the lungs are expanded. Indeed the external apertures dilate quite as much in those cases in which air cannot enter the lungs, and in those in which the whole of the inspired air passes through a large opening in the trachea, as they do when the inspired air enters wholly through their external apertures. After opening the trachea in a dog I divided the vagi, and the inspirations were immediately performed with power by the whole of the inspiratory muscles ; notwithstanding that the whole of the air entered through the divided trachea, the nostrils, mouth, and fauces were opened and dilated to the fullest extent, the head being at the same time thrown backwards so as to raise the upper jaw, and the same movements were excited when the opening into the trachea was closed. I observed a similar phenomenon in a man who, after laryngotomy, breathed entirely through a tube in the trachea; though no air entered the nostrils, yet they dilated with power at each inspiration.

This fact, that the muscles expanding the inspiratory apertures act even when no air can enter through those apertures, shows how perfectly in harmony with each other and with the extent of the cause exciting inspiration, are the various inspiratory muscles. The whole of those muscles are, in the instances alluded to, perfectly obedient to the influence stimulating their combined action to effect the common purpose of inspiration, and that, even although the action of a number of those muscles could not, under the circumstances, aid inspiration. This shows how completely respiration is usually automatic, that is to say, under the dominion of the excito-motor function of the nervous system, and withdrawn from under the dominion of the will, even when volition is active, unless the will be specially and energetically directed to the control of the respiratory movements; indeed, in the instances just referred to, even although the will could repress or modify the respiratory movements as a whole, I doubt whether it could repress any of those movements in part.

If cold water be dashed suddenly on the whole body, or if a man plunge into cold water, or into a hot bath, deep, energetic, often sobbing, almost convulsive respirations will be excited, even although the will should struggle to repress them. If the cold water be dashed upon the face only, the inspiration excited will be less energetic, but still the will can scarcely ever repress or control them. If the highly-sensitive nostril be alone stimulated, as for instance by the point of a feather, or by ammonia, or by snuff in a person unused to it, a deep inspiration will be excited, followed by sneezing, in spite of the will. In these instances the stimulus was either intense, or was applied extensively, or to a surface highly sensitive, and possessing many highly impressible incident nerves, and the effect was an uncontrollable deep inspiration, the inspiration varying in depth, in proportion to the nature and suddenness of the stimulus, the extent of the surface stimulated, and the impressibility of the portion of surface stimulated.

If, when the person is conscious, cold water be dashed suddenly, but to a small extent, on the back, or if the feet or hands be dipped suddenly in cold water, an inspiration will be drawn, varying in depth in proportion to the stimulus and the excitability of the surface, but such inspiration is under control, and may be repressed by an exercise of the will.

In the instances given above, in which an inspiration was excited by stimulating the surface, the stimulus was instantaneously and suddenly applied, and the effect on the respiration was instantaneous and fleeting. The surface was stimulated, a deep inspiration was drawn, but, with the exception perhaps of the next few inspirations, respiration speedily resumed its ordinary character.

This is an illustration of the general law—that whenever a reflex movement is excited through a stimulus applied to an incident nerve, that movement is instantaneous in accession and short in duration. If any incident nerve be pinched an immediate reflex movement follows, but this movement soon ceases, even if the pinching be continued; if the same stimulus be withdrawn, and then again repeated, another similar reflex movement will be excited. This may be repeated again and again until the excitability of the incident nerve by that particular stimulus be exhausted.

If respiration be suspended, owing to the deprival of oxygen, or to the respiration of noxious gases, or of gases destitute of or deficient in oxygen, or by the action of poisons —provided the suspension of respiration have not lasted too long, or have not been occasioned by too extensive an influence from the noxious agent—respiration will frequently be stimulated to renewal by the mere exposure of the surface to the atmospheric air, with or without external warmth.

Sir Humphrey Davy performed the following experiments:—

A stout and healthy young cat, of four or five months, was introduced into a large jar of nitrous oxide. For ten or twelve moments he remained perfectly quiet, and then began to make violent motions, throwing himself round the jar in every direction. In two minutes he appeared quite exhausted, and sank quietly to the bottom of the jar. The heart beat with extreme violence, and there was a strong and quick pulsation of the carotids. In about three minutes the animal revived, and panted very much; but still continued to lie on his side. His inspirations then became longer and deeper, and he sometimes uttered very feeble cries. In four minutes the pulsations of the heart appeared quicker and feebler; his inspirations were at long intervals and very irregular. In five minutes the pulse was hardly perceptible; he made no motions, and appeared wholly senseless. After five minutes and a quarter he was taken out and exposed to the atmosphere before a warm fire. In a few seconds he began to move, and to take deep inspirations. In eight or ten minutes he was able to walk; and in about half an hour he was almost completely recovered.

A rabbit was immerged in hydrogen for nearly half a minute, and was restored to the atmosphere apparently inanimate. In less than a minute he began to breathe and to utter a feeble noise; in two minutes he was able to walk, and in less than three minutes appeared perfectly recovered.

A small water-lizard was introduced into nitrous oxide gas.

In two or three minutes he began to make violent motions, appeared very uneasy, and rolled about the jar in every direction, sometimes attempting to climb to the top of it. At the end of twelve minutes he was lying on his back seemingly dead, but on agitating the jar he moved a little; at the end of fifteen minutes he did not move on agitation, and his paws were resting on his belly. He was now taken out stiff and apparently lifeless, but after being exposed to the atmosphere for three or four minutes, he took an inspiration, and moved his head a little; he then raised the end of his tail, though the middle of it was still stiff, and did not bend when touched. His legs remained close to his side, and were apparently useless; but on pricking them with the point of a lancet they became convulsed. After being introduced into shallow water he was able to crawl in a quarter of an hour, though his motions were very irregular. In an hour he was quite well.

These experiments show that an animal, either warm or cold-blooded, after ceasing to breathe when in a noxious gas, being apparently lifeless, may have its respiration again excited by the simple stimulus of exposure to atmospheric air. The stimulus is here applied externally to the skin, not internally to the lungs, nor yet to the brain nor spinal marrow, but directly to the skin, and through the skin to the incident nerves; their excitability, exhausted by the noxious gas circulating in the blood, is first roused by the atmospheric air, and then they are excited by the air, so as to induce reflex acts of respiration.

Dr. Goodwin relates the following interesting experiment, in which, after submersion, exposure to the air re-excited respirations:—

"I confined a large toad on a plate of metal; I then removed a part of the sternum, and his heart and lungs were exposed to view. The lungs were then filled with air; the blood in the pulmonary veins was florid, and the heart contracted forty-four times in a minute. In this state he was immersed in a small quantity of transparent water. When he had remained in the water fifteen minutes the blood in the lungs began to put on a dark colour, and the contractions of the heart were diminished to thirty. In fifteen minutes more the dark colour of the blood was increased, and the contractions of the heart were eighteen. The animal now made several struggles to relieve itself, and threw some air out of its lungs; but the pulmonary blood becoming still more dark-coloured the contractions of the heart were diminished still further; and in forty minutes more they ceased, although the sinus venosus and auricle and the trunk of the vena cava were filled with black blood. The animal was now removed from the water, without any signs of life; but before the expiration of two minutes he opened his mouth and took a large quantity of fresh air into his lungs. Soon after he emptied them almost entirely, and this was repeated several times. During the process the blood in the pulmonary veins began to be florid, and the heart to renew its contractions; and in fifteen minutes from the first inflation the contractions of the heart were thirty-five, all the functions were recovered, and he walked about without any expressions of uneasiness."

In this interesting experiment it is possible that the exposure of the lungs, as well as the skin, to the atmospheric air may have had some influence in exciting the renewal of the respiration.

In the following experiment, performed by Dr. W. F. Edwards, and related in Dr. Hodgkin's *Translation*, the skin alone was exposed to the action of the air, after submersion in water:—

"If a frog, deprived of its heart, and immersed in water, be drawn out and exposed to the air at the moment when all signs of life have disappeared, it immediately begins to recover. If it be again plunged in water all appearance of life instantly ceases; and it may thus be made several times alternately to lose and recover its motion and sensibility. This confirms, in a striking manner, the vivifying effect of air and the deleterious effect of water on the nervous system."

A similar experiment was performed by Dr. Marshall Hall. He divided, in a frog, the spinal marrow, near the cranium, and left it immersed in water:—the excito-motor power seemed to have ceased; there was no respiration, no movement on irritating the toes: on being removed from the water, and placed in the free open air, respiration and the excited reflex movements were gradually restored.

Professor Müller illustrates this subject by some experiments performed by himself and Professor Bergmann:—

"I kept a frog during four hours in hydrogen; at the end of that period it was apparently dead, the heart's pulsation ceased for minutes at a time; but the animal revived when restored to the air."

"The arterial blood is very beautifully shown to be the cause of the continuance of the respiratory movements throughout life, by my experiments on frogs, in which I made the animals breathe for several hours in hydrogen; after a time respiration ceased, although life was not extinct. For a time the respiratory movements were renewed when the vessel in which the animals were included was agitated; but, after a longer period had elapsed, this was no longer the case. If, after being thus confined in hydrogen for two or three hours, the frogs are taken out and exposed to the atmosphere, they appear perfectly dead; not the least sign of motion or sensation is observable in them. The heart being laid bare, if it is found to have ceased to beat, the animal will revive. If it still beats, though at intervals of half a minute or a minute, the frog will generally recover without any external stimuli being applied, merely from the gradual oxidation of the blood in the vessels of the lungs, the want of which arterialization was the cause of the asphyxia. The blood, impregnated with oxygen, however slow the action of the heart, must at length reach the brain and the medulla oblongata, which then begins again to emit nervous influence. The first signs of the revival of a frog, which lies quite motionless, is the retraction of the extremities when the skin is pinched; after a short time it is seen to respire at longer intervals, and in a few hours is quite lively. The cause, therefore, of the continued action of the medulla oblongata in determining the respiratory muscles to action is the arterial blood."

I have given the whole quotation in justice to Professor Müller, remarking at the same time, that while we accept the facts, we cannot accept the opinions with regard to the aeration of the blood in the lungs and in the medulla being the cause of the renewed inspiration. Dr. Baly justly remarks upon this experiment:—"It appears to the translator to be more probable that the blood was arterialized in this experiment chiefly through the medium of the skin; for we know that frogs will live many hours after their lungs are extirpated; while, immersed in oil, they die in less than an hour; and in an asphyxiated frog the entrance of air to the lungs, and its renewal, must be very limited."

In Dr. Edwards's experiment the frog was deprived of the signs of life in water, but recovered its motion and sensibility when exposed to the air. Here the heart had been previously cut out, consequently the renewal of life was strictly due to the action of the air on the cutaneous nerves and capillaries.

I conclude that in all the above instances the renewal of motion on pinching, and the renewal of respiration, was due to the renewal of the excitability of the cutaneous incident nerves; the stimulus of pinching the surface, previously without effect, then excited reflex motion, and the stimulus of the air, applied to the different cutaneous nerves, then excited reflex acts of respiration.

The experiments detailed by Dr. Alston in the *Medical Essays*, show that after a frog has been deprived of life, to all appearance, by opium, it may possibly recover by the mere exposure to the atmosphere. In those experiments he inserted opium in solution into the stomach of the frog :—

"This experiment we frequently repeated, and it had always the same appearance and event. The recovery, however, of one of the frogs, which for a considerable time seemed to be dead, is not to be omitted. My friend and I one evening killed, as before, a couple of frogs with opium; one of them, which was the strongest, I laid half in water, on a tile in the bottom of the water-pot, that if it recovered it might sit wet or dry, as it liked best; the other I left on the earth, dry, under a hedge. Next morning, when I returned to the garden, I found the one under the hedge dead, as I left it, but the other in the water-pot was alive, and appeared to be in perfect health."

Taking the above observations on the vivifying effect of exposure to the atmosphere, after respiration and animation were suspended, and looking on them in a group and as a whole, we may conclude that in those instances the renewed respiration was excited reflexly by the stimulus which the incident nerves of the skin received from the atmosphere acting on the tissue of the skin and aerating the blood in the capillaries.

Effects of the Narcotic Poisons on Respiration, through the medium of the Incident Nerves.

The effects of the narcotic poisons, and the treatment of those effects, afford an interesting practical illustration of the effect which the excito-motor phenomena, stimulated at the surface, have in exciting and influencing respiration.

The narcotic poisons, though properly grouped in one class, differ exceedingly in their effect on the system. The characteristic effect of some, as belladonna and stramonium, is upon the brain; that of others, as chloroform and ether, is upon the brain and the spinal marrow; while that of others, as prussic acid, is more markedly upon the spinal marrow and the incident nerves. While the characteristic effect of each of these groups is upon the parts of the nervous system just indicated, it may be said that each of them acts more or less both upon the brain and spinal marrow as central organs, and on the nerves at their periphery, both in their incident and sensory functions. I confine myself at this place to the effect which all these poisons have on the afferent, especially the cutaneous nerves at their periphery, through the medium of the blood circulating in the superficial capillaries.

The influence of opium on the capillary circulation and on the afferent nerves is shown in the following experiment, which is a modification of that made by Dr. Alston, just referred to:—

"I attached a frog to Mr. Goadby's frog-holder, plunged the left leg into a test-tube containing a watery solution of opium, and the right leg into one containing water. The tubes were so arranged that they could be withdrawn, and either web placed under the microscope without disturbing the frog.

"Before the immersion of the left leg in the solution of opium the circulation was very rapid; the corpuscles in the arteries moved so quickly that they could scarcely be distinguished; those in the veins and the large capillaries moved rapidly, while those in the small capillaries moved slowly. After an immersion of ten minutes the motion of the blood in the smaller capillaries of the left leg was quickened, and the blood circulated through many capillaries previously devoid of corpuscles. The movement of the blood in the arteries and veins was less rapid. The circulation in the right leg was unaltered.

"After a further immersion of the left leg in the solution of opium for forty minutes that leg was swollen, being, evidently to the eye, more vascular than the right. All the capillaries were now much enlarged, several corpuscles moving slowly, side by side, through capillaries that were previously empty. The blood moved much more slowly than before, both in the arteries and the veins.

"The circulation in the right leg was now very perceptibly modified, and, as nearly as could be observed, to the same extent as that in the left leg, after it had been immersed in the solution of opium for ten minutes.

"The effect on the excito-motor phenomena was marked; whenever the skin was touched, either on the left or right leg, the frog cried out in a peculiar manner, the creature being severely convulsed. The skin was touched repeatedly and in rapid succession, with the invariable effect of producing renewed convulsions, which became less and less strong each time they were excited. At length the convulsions could no longer be excited by touching the left leg, and after a time they ceased also to be excitable in the right leg. After a little rest the convulsions could again be excited.

"After re-immersion for an hour and a half, the frog being then perfectly relaxed in all its limbs, quick feeble tetanic spasms of both limbs were excited by the slightest motion, by walking across the room, by touching the microscope, or by touching the skin of either leg. These convulsions ceased after the legs had been touched repeatedly and in rapid succession; the left leg first lost its excitability, and then the right. The convulsive movements were slighter in the left leg than elsewhere.

"It was found, during this observation, that the frog was quite unconscious, and had ceased to breathe.

"The capillaries were now very much enlarged in the left leg, being greatly distended and almost blocked up with the accumulation of blood corpuscles, the motion of which was but just perceptible. The movement of the blood in the arteries and veins was exceedingly sluggish. The right leg was similarly affected, but the capillaries were not so much distended, and the circulation was not so slow as in the left leg. The circulation became progressively slower. The convulsions, after a time, were no longer excitable.

"About four hours after the first immersion of the leg in the solution of opium, the heart was exposed, pulsating slowly, emptying itself on each contraction, and receiving and sending out but little blood. After the heart was cut out the movement of blood in both webs continued, though it was very sluggish, and in the left leg was only observable in the large artery and vein."

This experiment shows that under the influence of opium the circulation in the capillaries and great vessels becomes obstructed, the quantity of blood in them being increased This is unequivocally due to the local action of the poison absorbed through the skin locally, and conveyed by the blood generally, producing relaxation of the walls of the vessels, enlargement of the capillaries, and increased amount but slower motion of the blood in all the vessels,—in fact, general congestion. Under the influence of the poison, applied locally, and conveyed through the blood, the incident nerves are at first morbidly excitable, but finally their excitability is exhausted.

The following instructive experiment is described by Müller :—" I dissected out the ischiadic nerve in toads, and left the leg connected to the body by this nerve only, which, together with the leg, I then immersed in a strong watery solution of opium ; in a short time the nerves and muscles lost all susceptibility of the influence of galvanic or chemical stimuli." It is manifest that in this experiment the excitability of the incident nerves was destroyed, as well as that of the motor nerves and the muscles, since no reflex actions were excited by electricity, although the nervous communication with the spinal marrow, through the medium of the ischiadic nerve, was uninjured.

M. Chossat injected a solution of opium into the veins of a dog, and noticed the effect on the pulse, the respiration, and the temperature. The details are given in the table at p. 196. During the first hour the respiration and the pulse rose respectively from 8 and 102 in the minute, to 20 and 173. The respiration, after the first hour, gradually fell, hour by hour, to 15, 11, and 9, until, at the seventh hour, they were below the original number. They continued falling steadily, and during the last hour they were between 2 and 3 in the minute.

In man the excito-motor phenomena are not so markedly increased in excitability by the narcotic poisons, owing to the reflex functions being more strongly controlled by the brain in man than in the lower animals. While opium always excites tetaniform convulsions in the lower animals, it seldom excites convulsions in man. A much larger proportion of children are affected with convulsions, when under the poisonous action of opium, than of adults, because of the superior control exercised by the brain over the reflex functions in the adult than in the child.

The effect of opium on the human subject is thus well described by Whytt:—"A child of five years of age, having, at seven o'clock in the evening, swallowed, by mistake, about a drachm and a half of liquid *laudanum*, soon became merry and laughed, then delirious, and in half an hour was seized with a sleepiness and stupor; at ten her breathing was high, with a snoring noise, her pulse full and equal, though slow; she could not be fully awaked, but looked up a little, and seemed to be sensible of pain when severely pinched: about eleven her face became pale, her eyes fixed and glazed, and her breathing would often gradually decrease, and at last stop for near a minute; then it began again with a very deep inspiration and sighing. At first, when the breathing began to be thus interrupted, the intervals were shorter, but became gradually longer till the patient died. While the motions of respiration were decreasing, the pulse was smaller; and when they were altogether stopt it was very weak and slow, but equable, and without intermissions: when respiration began to be renewed the pulse recovered its strength and became less slow."

It is of the more importance to preserve this case in our literature, since, happily, no such opportunity of observing the undisturbed phenomena of the effects of opium on the respiration and circulation can again occur, now that the treatment of such cases is so well understood.

I conclude that, under the influence of opium, the respirations are at first quicker and fuller, owing to the increased excitability of the incident nerves of the surface—the respirations being excited by a reflex action from the incident nerves, those nerves being stimulated by the opium in the blood circulating in the systemic capillaries. After a time the increased excitability gives place to diminished and exhausted excitability of the incident nerves, and consequent diminution and cessation of respiration. Further proofs of this position will be afforded in considering the treatment of narcotic poisoning.

All the narcotic poisons possess, like opium, the property of causing relaxation of the capillaries, and increase of blood and obstruction to the circulation in the capillaries, arteries, and veins. Under the influence of belladonna and stramonium the face is frequently rendered red, and it has been noticed to be bloated or swollen under the action of cicuta virosa, aconitum napellus, œnanthe crocata, and strychnia. Professor Simpson and Mr. Nunnelly have observed that chloroform applied locally, either as a liquid or a vapour, causes great reddening of the surface. Mr. Nunnelly observed that the mouth was rendered intensely red by the administration of prussic acid.

Tobacco and digitalis cause such excessive congestion of the pulmonic capillaries that but little blood can be sent round through the lungs to the left side of the heart and the system ; the right cavities are, consequently, enormously distended, and owing to the distension, these cavities cease to contract. The systemic vessels are scarcely supplied with blood, owing to the detention of the blood in the lungs, and the arrest of the heart's action. The important experiments of Dr. Blake, made with the hæmodynamometer, show how remarkably these poisons obstruct the circulation through the systemic capillaries.

These instances show that when a poison enters the blood, the poisoned blood accumulates to an unusual extent in the systemic capillaries, unless the obstruction in the pulmonic capillaries be excessive, and that the poison is thus presented with an accumulating effect to the extremities of the afferent nerves.

The effect of ether and chloroform on the respirations was observed in a very instructive manner in an experiment on a dog, which I performed, with the valuable aid of Dr. Snow and Mr. Marshall.

The ether and chloroform were administered by Dr. Snow from a balloon impregnated with the vapour, and adapted to the almost divided trachea. All stimulus to the larynx was thus avoided, and the effect on the respirations, at first of the application of the agent to the mucous membrane of the lungs, and then of its diffusion over the whole system, was observed.

When ether was administered the respirations were not accelerated at first; in 10 or 15 seconds they increased in number; on withdrawing the ether the increased rate continued for about 10 or 15 seconds, when the respirations began gradually to diminish. The chloroform was administered with the same general effect.

The following observations of the number of respirations during each successive 10 seconds were made on the renewed application of chloroform.

During the first 10 seconds that the chloroform was readministered there were 10 inspirations; during every successive 10 seconds there were respectively 12, 14, 13, 14, 16, 17, and 19 respirations; after a lapse of about 40 seconds there were, during successive 10 seconds, 16 and 20. When the bladder containing chloroform was withdrawn, the rapid respirations continued without material change, 19 in 10 seconds When the respirations were at this rapid rate, acts of deglutition, whether automatic, or excited by stimulating the pharynx through the larynx, caused complete temporary suspension of respiration. After this the respirations were 17, 20, and 20 in 10 seconds. After two more minutes (it was then 21 minutes past twelve o'clock) the respirations fell to 14 in 10 seconds.

	No. of respirations in ten seconds.
At 12 h. 23 min. the number of respirations in 10 seconds was from	13 to 10.
At 12 h. 24 min. ,, ,,	12 to 13.
12 h. 25 min. ,, ,,	12.
12 h. 26 min. There was now a short renewal of the inhalation of chloroform. The number of respirations in ten seconds was unchanged, being still .	12.
At 12 h. 27 min. the number of respirations in 10 seconds was	11.
12 h. 28 min. ,, ,,	8.
12 h. 42 min. ,, ,, from	6½ to 5.

It was evidenced from this administration, as from those made previously, that the increased number of inspirations did not take place immediately after presenting the vapour to the lungs, but that it took place gradually after the vapour had entered the circulation for a sufficient length of time to diffuse itself through the medium of the blood over the system, and so to excite everywhere the incident nerves of the system.

Just before the division of the vagus, the respirations were 30 to 39 in the minute. They had been about 20 in the minute before the experiment commenced.

At 12 h. 47 min. the right vagus was divided, and the number of respirations fell immediately to . . .	10 in the minute.
All the inspirations, which were previously quiet, (the mouth being unopened, the nostrils undilated,) were now, and continued to be, performed with unusual energy. The nostrils dilated, the mouth gaped widely, the head being thrown back so as to raise the upper jaw, the fauces were dilated, and all the inspiratory muscles acted with great vigour.	
At 12 h. 51 min. the number of respirations was .	8½ in the minute.

At 12 h. 57 min. both vagi were divided when the respirations fell to . . . 6 in the minute.
and they continued to be performed steadily at the rate of 6 in the minute, even when the dog was disturbed and excited.

At 1 h. 39 min. a sponge, saturated with ether, was applied to the opening in the trachea ; during the first minute the inspirations were . . . 6 in the minute.

At 1 h. 40 min. the respirations were . . . 7 in the minute.
1 h. 41 min. the respirations were . . . 7 in the minute.
1 h. 42 min. the respirations were . . . 7 in the minute.
1 h. 43 min. the sponge was removed, the respirations were . . . . 8 in the minute.
1 h. 46 min. the sponge, saturated with ether, was re-applied ; the number of respirations was . . . 7 in the minute.

At 1 h. 47 min. the respirations were . . . 9 in the minute.
1 h. 48 min. the respirations were . . . 9 in the minute.
1 h. 49 min. the respirations were . . . 9 in the minute.
1 h. 50 min. the respirations were . . . 6 in 38 seconds.
1 h. 51 min. the sponge was withdrawn ; the respirations were still . . 9 in the minute.
The repeated renewal and the final removal of the sponge caused no difference in the number of respirations . . . . . . 9 to 9½ in the min.

At 2 h. 7 min., when the dog was standing, the respirations rose to . . . 10 in the minute.
After the dog had been moving about the respirations were . 11 in the minute.

At 2 h. 12 min. chloroform was administered. The respirations were then from . 8 to 9 in the min.
2 h. 13 min. the respirations were from . . 8 to 9 in the min.
2 h. 14 min. the respirations were . . . 18 in the minute.
2 h. 15 min. the respirations were . . . 30 in the minute.
The mouth no longer opened wide during each inspiration, the respirations being apparently natural. The chloroform was withdrawn about this time.

At 2 h. 18 min. 7 respirations in 15 seconds, or at the rate of . . . . 28 in the minute.

2 h. 21 min., after the dog was subjected to excitement, there were 16 respirations in 10 seconds, or at the rate of . . . . . 96 in the minute.

On nearly closing the trachea, the gaspings were renewed, but they ceased after about a minute.

At 2 h. 25 min. 4 respirations in 15 seconds, or at the rate of . . . . 16 in the minute.

2 h. 29 min. 3 respirations in 15 seconds, or at the rate of . . . . 12 in the minute.

3 h. 29½ min. 5 respirations in 30 seconds, or at the rate of . . . . 10 in the minute.

After the administration of the chloroform, it was found that the reflex functions were very excitable, muscular movements of the limbs being easily and indeed constantly excited, by slight external irritation.

At 2 h. 34 min. 25 respirations in 15 seconds, or at the rate of . . . . 100 in the minute.

2 h. 35 min. 10 respirations in 10 seconds, or at the rate of . . . . 60 in the minute.

8 h. 37 min. the gaspings were renewed.

The conditions which preceded the rapid increase just stated are not mentioned. The experiment was shortly afterwards put an end to by the rapid and fatal administration of chloroform ; the respiration ceased ; the heart continued beating. About 30 or 60 seconds after regular respiration had ceased, deep inspirations with gaspings were taken ; the heart's impulse was no longer perceptible.

From this experiment we see that after the division of the vagi ether increased the respirations slightly, although no reflex influence from the incident nerves of the lungs could have been transmitted through the medulla oblongata. Under the influence of chloroform the respirations rose from 10 to 30 in a minute. After this, movements on the part of the animal, and obstruction to respiration through the trachea, quickened the respirations exceedingly, so that they were about 90 in a minute ; while previously to the administration of chloroform, but after the division of the vagi, and after the administration of ether, the respiration only rose, during exertion, from 9 or 10 in the minute to 11.

It is to be observed that the excito-motor functions were abnormally excitable when the respirations were so much quickened under the influence of chloroform.

At a later period, when the chloroform was pushed, so as to produce diminution and cessation of the respiration, the excito-motor functions were no longer capable of being stimulated by external impressions, though the muscles could be induced to contract by the direct action of electro-magnetism, or by such action transmitted through the motor nerves. In fact the excito-motor nervous arc was broken, not on the reflex or motor side, but on the incident or excitor side.

Under the influence of most of the narcotic poisons, the respirations are at first accelerated and panting, then laboured and slow, and then fetched with increasing intervals, until they finally cease.

The effect of ether, chloroform, and alcohol, on the respiration, has been just illustrated.

Sir Humphrey Davy's experiment, related at p. 226, shows that when an animal is immersed in nitrous oxide respiration is first accelerated, then retarded, and finally abolished.

Mr. Nunnelly put a cat into a jar containing one part in four of common coal gas ; in two minutes she was convulsed for 30 seconds, then became still and insensible, with the respiration quick, then irregular and slow ; at three minutes and a half it nearly ceased for a minute; at four minutes and a half she breathed once or twice.

Sir Benjamin Brodie applied a drop of the essential oil of bitter almonds to the tongue of a young cat. She was instantly seized with violent convulsions; then lay on one side motionless, insensible, and breathing in a hurried manner; the respirations became laboured, took place at longer and longer intervals, and at the end of five minutes from the application of the poison had entirely ceased.

The same distinguished physiologist applied less than a drop of the empyreumatic oil of tobacco to the tongue of a young cat. Instantly violent convulsions took place in all the muscles, and the respirations became very frequent. After eleven minutes she retched, but did not vomit; in fifteen minutes she appeared to be recovering. The poison was renewed; she was again seized with violent convulsions, and became insensible, breathing at long intervals, and in two minutes from the second application respiration had ceased.

At twenty-one minutes past four I injected into the stomach of a rabbit the eighth of a grain of wourali, dissolved in water. The poison was given to me by my distinguished friend, Mr. Waterton:

H.	M.	
4	24	Respirations much accelerated (175 in the minute).
4	26	Moves the head and body at each respiration.
4	28	Convulsive movements of the whole body.
4	31	The animal ceases to breathe.

Additional observations might be adduced, showing that the usual influence of narcotic poisons is first to accelerate, then to retard, and finally to arrest respiration, but this were needless. The same phenomena are evidenced in all cases of narcotic poisoning. The poisoned blood moves slowly and in increased quantity in the capillaries. The excitability of the incident nerves is first increased, then diminished, and finally exhausted by the poison ; and the respirations are in consequence first accelerated, then retarded, and finally arrested.

The depressing effect of tobacco on the muscular and respiratory functions would appear to except that poison from the usual action of the narcotics.

Sir Benjamin Brodie injected four ounces of infusion of tobacco into the rectum of a dog. In four minutes he retched, but did not vomit ; he then became faint, and lay motionless on one side ; at the end of nine minutes the heart could not be felt ; he gasped for breath at long intervals ; and in another minute there was no appearance of life. The heart was much distended and motionless.

The following experiment, also performed by Sir Benjamin Brodie, in which tobacco was given to a dog after being beheaded, when compared with the experiment just related, shows the different influence exerted by that poison on the reflex functions when the brain is present and when it is removed.

" In a dog, whose head was removed, I kept up the circulation by means of artificial respiration. I then injected into the stomach and intestines nine ounces of infusion of tobacco. At the time of the injection, the body of the animal lay perfectly quiet and motionless on the table ; the heart acted regularly one hundred times in a minute. Ten minutes afterwards the pulse rose to 140 in a minute ; the peristaltic motion of the intestines was much increased, and the voluntary muscles in every part of the body were thrown into repeated and violent spasmodic action. The joints of the extremities were alternately bent and extended ; the muscles of the spine, abdòmen, and tail alternately relaxed and contracted, so as to turn the whole animal from one side to the other. I made pressure on the abdominal aorta for more than a minute, so as to obstruct the circulation of the blood in the lower extremities; but the muscular contractions were not lessened in consequence. Half-an-hour after the injection of the infusion the artificial respiration was discontinued. The heart continued to act, circulating dark blood; the muscular contractions continued, but gradually diminished in strength and frequency. I tied a ligature round the vessels at the base of the heart, so as to stop the circulation, nevertheless the muscular contractions still continued, though less frequent and forcible than before, and some minutes elapsed before they entirely ceased."

In this experiment, the disposition to contraction in the muscles was very much increased, instead of being diminished, as in those experiments in which the living animal was poisoned in like manner by an infusion of tobacco.

In this experiment, in fact, the influence of the poison on the nervous system was limited to the incident nerves, in their excitor functions, the motor nerves and the medulla spinalis; the brain and the medulla oblongata having been removed. In the former experiments just referred to, the excito-motor phenomena were speedily annihilated; in the experiment just detailed, the excito-motor phenomena were remarkably exalted, the incident nerves being stimulated by the poison circulating everywhere in the capillaries.

The last experiment which I shall add to illustrate the action of the narcotics on the incident nerves, and through them on the respiration, is thus related by the experimenter, Professor Müller:

"The following experiment, which I have performed on frogs, and which on repetition affords the same results, is very instructive. Having divided all the vessels and muscles of the thigh, and separated them from the bone, leaving the nerve uninjured, I poisoned the frog with nux vomica. The irritability of the sound leg was lost much sooner than that of the leg of which the muscles and vessels had been divided. After the usual effects of narcotic poisoning on frogs, namely, the state of excitability in which a slight touch generally excites convulsions, had ceased, the muscles of the calf of the injured leg still contracted on my touching any point of the surface of the body; the leg, therefore, which received no blood was sensible to the influence of the spinal cord much longer than the other limb, the nerves and muscles of which had been exposed to the action of the poison circulating in the blood; so that it is going too far to maintain that the poisons act on the central parts of the nervous system only; they act likewise on the nerves through the medium of the circulation."

From the cases and experiments detailed above, I conclude that the narcotic poisons act through the medium of the circulation, not only on the brain and the spinal marrow (myelon) as central organs, but that they also act either through the circulation, or by absorption from without, on the peripheries of the afferent nerves, affecting both their sensory and their excito-motor functions; that they first exalt, then depress, and finally exhaust, first the sensibility and then the excitability of the incident nerves; and that they, through the medium of those nerves,—putting out of sight, for the present, the influence on the brain and spinal marrow,—first increase, then diminish, and finally arrest respiration, unless means be used to resist those effects, and to excite respirations by stimulating the incident nerves, which important practical subject I shall now illustrate and consider.

Treatment of the Effects of the Narcotic Poisons, by stimulating the exhausted excitability of the Incident Nerves, and so exciting respiration.

Under the deep influence of opium the respirations become exceedingly slow. This is well illustrated by the case detailed by Whytt, given at page 236, and by Chossat's experiment on a dog, page 196. The respiration, in fact, becomes slower and slower, until it ceases, the circulation being, however, maintained for a time ; at length, respiration having ceased, circulation ceases also, and death ensues.

In the treatment of narcotic poisoning, the great objects are to stimulate and maintain respiration and circulation until, through the various channels of exit, and through chemical changes, the poison shall have been eliminated from the system, or rendered harmless by entering into fresh chemical combinations.

Dr. Alison gives, in the twenty-third volume of the *Edinburgh Medical Journal*, the following instructive case of poisoning by laudanum.

The man, aged 35, had swallowed an ounce and a half of laudanum. At first, twenty minutes after taking the poison, his face was flushed, his skin warm, his pulse full, strong, and frequent. Mustard, sulphate of zinc, and ipecacuanha were administered successively, and the fauces were irritated in order to excite vomiting, but in vain. He was now rapidly becoming comatose ; face turgid and purplish, breathing stertorous and irregular. He was roused by dashing cold water on his face, applying ammonia to his nostrils, and repeatedly irritating the fauces, and vomiting was at last procured, nearly an hour after taking the poison. Coma, however, supervened. The stomach was emptied through Bryce's tube. He was still unconscious, but made feeble efforts to scratch his legs. He was now stript naked, and cold water was dashed over his head and shoulders. By this he was powerfully excited; he sprang from his seat, and fell forwards, gasping strongly and repeatedly; after this he fell asleep, but was roused from time to time. At six his appearance was altered for the worse. He was quite insensible; his countenance pale and ghastly; lips livid, and jaws fallen; his skin generally cold, although warmth had been applied; his respirations only four or five in the minute, and the inspirations performed with a convulsive start; the pulse small. He had the usual appearance of a person dying comatose; neither dashing cold water on his face, nor pushing a feather dipped in the aqua ammonia up his nostril, produced any immediate effect upon his respiratory muscles.

However, by persevering in the application of ammonia to his nostrils, closing his mouth at the same time so as to secure its complete introduction in the act of inspiration, by pouring a little of the aqua ammoniæ on his breast, and rubbing it strongly in with warm flannels, continuing the application of hot bottles to his feet and stomach, he was at length roused from the state of coma. First his breathing became gradually more frequent and regular, and was apparently excited by the vapours of ammonia; then he moved his head from side to side on the irritation of his nostrils, and finally threw his head forward and opened his eyes. The natural temperature of his skin was not completely restored till about ten o'clock, by which time his pulse had become much fuller.

As Dr. Alison remarks, this case illustrates "the peculiar efficacy in a case of poisoning by narcotics, both of the affusion of cold water, and of the stimulation of his nostrils by ammonia. These expedients seem peculiarly useful in this case (just as in the common case of syncope), not merely as general stimulants to the nervous system, but as exciting sensations which have a specific effect on the respiratory muscles. The sensations thus produced, whenever they are strongly felt, uniformly excite the action of inspiration, and thereby, in cases of this kind, contribute to prevent the failure of respiration; and we know, particularly from the experiments of Sir Benjamin Brodie, and from the case recorded by Mr. Whately, that the failure of respiration is the immediate cause of death from the truly narcotic poisons."

In the following case, related by Mr. Walne, in Dr. Bright's Reports, a girl had taken an ounce and a half of laudanum. She was in a state of insensibility. "We raised our patient, and from a pail of cold water kept dashing mugfulls upon her head, sometimes in her face. In a very little time she showed signs of sensibility, drew her breath suddenly on receiving the dash of water, moaned dissatisfaction, and sometimes made efforts of resistance. Whenever we discontinued the effusion for a few minutes together she relapsed into a state of insensibility. We continued this treatment, with short occasional intervals, for nearly four hours; in the course of this time we injected a quantity of ammonia into the stomach,—she retched several times, and brought up portions of this and some mucus. Her feet, being cold, were put in hot water. At the end of about four hours the whole skin became cold; she was less roused by the dashing of the water; the heart's action was feeble. We had her placed in a dry bed, and friction, with flannel over the limbs and chest, was used; while hot bricks were applied to her feet. The friction roused the heart and restored warmth, but she continued insensible. In about two hours from the time of discontinuing the cold affusion the jaw fell; the pulse became hardly perceptible; and her breathing was beginning to be impeded by mucus in the air passages. I determined to try the injection of brandy into the rectum." The sphincter was in a relaxed state. "Four ounces of brandy were thrown into the rectum and quickly and forcibly rejected. It however raised the pulse, and the jaw recovered its natural situation almost immediately after. In about half-an-hour the same quantity was thrown in and retained. She seemed revived by this, slept profoundly, but had a better pulse, and breathed freely. The patient perfectly recovered."

In each of these instructive cases respiration was excited and augmented by stimulating the afferent nerves. That the stimulus acted through those nerves on the spinal marrow and the motor nerves of respiration by an excited reflex action, and not through sensation and the direct action of the brain, is proved in Dr. Alison's case, by the fact that the breathing became more frequent and regular, while he was still unconscious, and in Mr. Walne's case, by the suddenness with which the breath was drawn when she received the dash of cold water.

I have met with the records of eleven cases of poisoning by opium, in which the cold dash roused the patient, doubtless with the effect of quickening the respirations. In seven of these cases powerful emetics had been given previously without exciting vomiting; the emetic effect was, however, produced immediately after the stimulus of the cold dash.

When, under the influence of opium, respiration is almost suspended, it may, as we have just seen, be excited by stimulating both the sensory and excito-motor functions of the incident nerves of the surface. Thus, in the cases given above, the lowered respiration was powerfully roused by the sudden dash of cold water on the face and body; by stimulating the nostrils with ammonia; by frictions with ammonia to the surface ; by warmth applied to the surface when cold ; by the injection of ammonia into the stomach; and by the injection of brandy into the rectum.

In other cases, the depressed respiratory powers have been roused by free exposure to a stream of cold air; by sinapisms ; by whipping the surface ; by stinging the skin with nettles; and, as a more powerful excitant than all these, by the external application of electricity.

The cases detailed above show that when any stimulant, such as dashing the surface with cold water, has been repeatedly applied for a long time, it at length ceases to act as a stimulus to respiration, and if pushed further, it exhausts the excitability of the incident nerves. They also show that when the respirations can no longer be excited by one stimulus they can be freely excited by another.

The alternate or successive employment of different stimulants is of the utmost importance, if we would continue to excite the respirations when they have become slow and feeble under the influence of narcotic poisons, asphyxia, or any other cause.

Dr. Marshall Hall remarks, that " the most important of all our remedies in congenital asphyxia is the sudden and forcible impression of cold water on the face and general surface. The quantity of the water should not be great, but it should be applied suddenly and with force. The temperature should not be lowered; on the contrary, the dashing of the cold water should be alternated with the warm bath, succeeded by warm flannels. These, too, may be applied briskly and suddenly.

The efficacy of the remedy is in proportion to the degree, the suddenness, the energy of the *alternation*.

Continued cold depresses the energies of life ; continued warmth augments them. But it is the sudden impression arising from the brisk alternation of the cold and heat, which proves the most efficacious excitor of the respiratory functions, on which recovery depends."

The principle on which one stimulus successfully replaces another, when that other ceases to have effect, is admirably illustrated by the observations and experiments of Humboldt. He exposed a muscle, shortly after its removal from the living frog, to oxymuriatic acid. The effect was first to stimulate and then to exhaust the muscular contractility. This exhaustion may be removed, he found, by opium, which re-excites and then again exhausts contractility. "This exhaustion may be removed by oxymuriatic acid or oxide of arsenic, while opium also is capable of removing the inexcitability produced by them."

Now, as opium, in these experiments, first increased and then exhausted the contractility of the muscles, so in cases of poisoning, opium first increases and then exhausts the excitability and sensibility of the incident nerves, and through their medium first increases and then diminishes the reflex respiratory movements. In like manner, just as oxymuriatic acid removes the exhaustion induced in the muscular contractility by opium, and in time renders it again inexcitable, so the sudden and forcible application of cold water removes the inexcitability of the incident nerves, occasioned by opium, and excites through them increased reflex respiratory movements; on the other hand, the continued renewal of cold water exhausts the excitability of the incident nerves and the reflex respiratory movements.

The following experiment, performed by Mr. Nunnelly, shows the effect of one stimulus in renewing excitability after it had been exhausted by another stimulus. A strong frog, whose hind leg had been subjected to the local action of chloroform, and amputated above the knee without sensation (which, however, was perfectly acute in the other legs), was lying dull, inactive, and flaccid. It was put into a jar with a few drops of oleum ethereum, when it *instantly* roused up, and jumped most vigorously about for one minute and a half, the fluid acting as a most decided stimulant. It afterwards became dull, and was kept in until it died.

The following cases illustrate practically the exhausting effect of opium on the reflex functions; the power to excite respiration by stimulating the surface; and the importance of alternating or varying the stimulant employed.

A little child, about six months old, was admitted into the Nottingham Hospital, under the influence of half a tea-spoonful of laudanum. The child was in a state of profound sopor; the pupils were contracted; the respirations infrequent. A mustard poultice was applied to the body, and cold water was dashed on the face, with the effect of increasing the respirations. Electro-magnetism was applied to the head and face, with the effect of rousing the child and exciting deep inspirations, followed by forcible crying expirations. The child was now roused in some degree from the state of sopor, but it still required repeated stimulation. This was done very effectually and easily by every now and then laying the hands of the child, one on one handle the other on the other handle of the electro-magnetic apparatus. Each time the hands were laid on the handles the child first took a deep inspiration and then cried.

It was interesting in this case to notice the extent to which the respirations and sensibility were excited, in proportion as the electro-magnetism was applied over parts more or less exquisitely supplied with incident nerves. When applied to the body, the surface of which is in comparison feebly endowed with afferent nerves, the electro-magnetism produced but little effect; when applied to the hands, the effect was very marked and instantaneous, the inspirations being deep, and followed by a cry; but when applied to the face, nostrils, and lips, over the extremities of the fifth pair, and especially to the scalp, along the course of the supra-orbital nerve, the respirations and movements were excited to the highest degree, producing the most extraordinary writhings on the part of the child, who was at length roused, and cried loudly and in distress. This case did well.

The other case was that of a young man admitted under the influence of opium, in a state of profound sopor. His breathing was very slow; he could be roused with great difficulty. He was seated in a chair, at each side of which was placed a bucket containing boiling water, his feet were placed in a pail of hot water with mustard, and several blankets were thrown over all, so as to allow the steam to rise around the body, and so to act as a vapour bath. Sinapisms were applied to the body. Electro-magnetism was applied to the face with slight and transient effect. Cold water was then squirted very forcibly over the face and into the ears, from a syringe; this excited the respirations, and caused him to look up for a short time. The electro-magnetism now produced a marked effect, exciting the respiratory functions and causing great annoyance to the poor fellow, who, roused but vacant, said "What, is this eternal torment?" The electro-magnetism was exchanged for ammonia to the nostrils, which likewise roused respiration and consciousness, and that was in turn exchanged for the forcible squirting of cold water over the face, care being afterwards taken to dry the face well and roughly. Each stimulant acted with great effect at first, but each gradually lost power upon repetition, until, by exchanging it for another and that again for another, the excitability to the former stimulus was restored. A catheter was introduced to empty the bladder, and the opportunity was taken to pass electro-magnetic currents in the course of the instrument, with the effect of completely rousing him, at a time when he was excited with great difficulty. After a time consciousness was restored, but he was in a state of great terror; his surface became at the same time remarkably excitable, a mere touch causing an involuntary start. He was placed in bed, provided with nourishment and stimulants, and was roused from time to time. He recovered, but was the subject of melancholia for some time, and for his own safety he was sent to the asylum for lunatics.

It is of the utmost importance, in treating persons poisoned by opium, not to exhaust either the muscular, the excitor, or the sensory functions. There are several cases on record in which the muscular powers failed irretrievably when the patient was being dragged about between two assistants. By the plans just indicated, the patient being seated in a vapour bath, the poison is eliminated through the perspiration, and by employing a succession or alternation of stimulants, the respiratory and sensory functions are excited but not exhausted. The electro-magnetism ought to be applied to the sentient and excitable surfaces of the face and hands, and not sent through the nervous centres, as thereby we run the risk of exhausting the nervous energies; indeed, if the currents be passed from the occiput to the epigastrium, we excite, not increased inspirations, but continued, forcible, and writhing expirations. If the patient cannot be roused by electro-magnetism to the surface, then it may be applied through the medium of the catheter; and if this should fail, as well as every other means directed to the incident and sensory nerves, then it may be necessary to pass one or two powerful shocks through the nervous centres, so as to rouse the excitability of the patient, exchanging this, however, speedily for the stimulation to the surface.

I object altogether to the copious dashing of cold water; the clothes and the surface are rendered wet by it, evaporation goes on, and the surface becomes chilled. Slapping the face vigorously with a cold wet towel, or the vigorous use of a syringe containing cold water, are equally rousing, and are not so likely to cause depression and chill.

In fevers, during the cold stages, the sensation of cold over the whole surface acts as a stimulus to the afferent nerves, and respiration is much accelerated, being often attended with rigors. The rigors and the accelerated respiration cease with the restoration of warmth. This is illustrated by the following case, in which the rigors followed a fall.

Richard Henson was admitted soon after falling from the top of a house three stories high. He was shortly afterwards attacked by a rigor. His respirations were 42 in the minute. At the end of each inspiration the glottis was closed, and the muscles of the chest, abdomen, and limbs contracted firmly, and with a tremulous, convulsive, alternating action, producing shivering. The vocal chords were separated with a low moaning noise, after which he immediately renewed the act of inspiration. Pulse 66, very feeble indeed. He complained of intense cold, especially in the feet; the body was warm to the touch, but the hands and feet were very cold. The reclining vapour bath, and other means for restoring warmth, were had recourse to; and in one minute the number of respirations fell from 42 in the minute to 14 and 16. In this case the respirations fell in number immediately after the surface was warmed. The inference is, that the coldness of the surface stimulated the afferent nerves so as to excite accelerated breathing.

In the hot, dry stage of fever, the pungent heat of the skin, excited by the roused circulation, acts as a stimulus to respiration. The skin is hot and dry, the pulse quick, and the respirations are accelerated. The application of moist sponging to the skin cools and moistens the surface, brings down the pulse, and lessens the number of respirations.

In some cases of fever, and in some diseases, during the later congestive stages, the respiration becomes slow and laborious. In such cases it is of vital importance that the respiration be quickened. This may be very readily effected in almost all cases, by the successive or alternate means of ammonia to the nostrils, of sinapisms, of stimulating frictions and lotions to the surface, and, if necessary, of electro-magnetism. In these cases, as in cases of narcotic poisoning, the stimulation from electricity or any other excitant must neither be too great nor too long continued ; else, while it rouses, it will at the same time exhaust the enfeebled excitability of the incident nerves, and the enfeebled irritability of the muscular system.

In treating cases of the kind just described, bear in mind the following principles of treatment. Arouse the excitability and sensibility of the afferent nerves to such a degree as to render the imperfect respirations valid, and to awaken consciousness ; use a stimulus just strong enough to achieve those purposes ; do not push the stimulus so far as to excite the nervous and muscular energies to excess, lest by exhausting those energies you shorten instead of lengthen life. When one stimulus begins to lose its effect, replace it by another stimulus of a different kind.

There is a large class of persons in whom the whole surface possesses extraordinary sensibility ; I allude to the hysterical. In these a mere touch will often excite exquisite pain. The excitor as well as the sensory functions of the afferent nerves are affected in these persons. Their respirations are habitually quick and short; the excitability of the surface to impression is sometimes exalted to an extraordinary degree, and then the hysterical fit or paroxysm comes on, in which the expiratory and the inspiratory muscles are violently, variously, and irregularly excited. Sometimes the inspirations are impeded or interrupted by the approximation of the vocal chords, a remarkable variety in respiration that I shall consider by and by. Sometimes during the paroxysm the respirations are excessively quick and short; I have observed them 112 in a minute. There is frequently a want of simultaneous co-operation in the various acts of respiration; the vocal chords are often energetically approximated instead of being drawn asunder during inspiration; and in one case, a female in whom the respirations were habitually much accelerated, the nostrils, instead of being dilated during inspiration, were dilated during expiration.

For the description of the respiratory phenomena during an hysterical fit, I refer to the cases given at a subsequent part of this paper. The effect of exposing the surface to cold air, and of dashing cold water on the face and body, when the patient is unconscious and in a fit, in exciting inspiratory widening of the glottis and normal full inspirations, gradually rendering the patient conscious, and putting an end to the paroxysm, is well illustrated in the cases there given. That the deep inspirations are induced through the medium, not of the sensory, but of the excitor functions of the afferent nerves, is proved in the case of Marriott, since, although she was unconscious, when cold water was dashed on the surface an immediate deep inspiration was excited, during which she corrugated the eyelids, opened the mouth, drew back the head at first, and then took several deep inspirations ; she soon, however, relapsed, again taking short quick, noisy inspirations, they being impeded by the stridulous approximation of the vocal chords. She still remained unconscious, and it was not until the repetition of the dashing for eight or ten times that she became sensible ; she being at length roused by the repeated renewal of the stimulus and the augmented circulation and respiration.

The relation of the sensory and excitor functions to each other is well exhibited in the case of hysteria just considered. In hysterical persons the surface is exquisitely sensible, and the excitor functions of the afferent nerves are very easily stimulated. We have seen above, that at whatever part of the surface sensation was exquisite, there the excitor functions are readily excitable. We now see that when sensation is unusually exquisite, the exalted sensory function is accompanied by a relatively exalted excitor function of the afferent nerves. When, however, during the paroxysm, the sensory functions are suspended, the excitor functions are still exalted and abnormal, but are readily stimulated so as to excite normal but exaggerated reflex respiratory movements. When sensation returns, then the excitor functions are somewhat controlled.

The Effects of External Warmth and External Cold on Respiration.

This subject is so important, and so extensive in its bearings, that although it forms a part only of that subject which I am now specially considering—the effect, namely, of external stimulants on respiration, yet I shall devote a separate sub-section to its consideration.

The great purposes of respiration are the same, and the laws regulating the causes of respiration, though they differ in detail, are alike in principle in all animals. I purpose to consider here the effects of external temperature on respiration in those classes of animals which possess a circulation.

The temperature of the great majority of beings is very little above that of the surrounding medium. Consequently, when the external temperature sinks or rises, the temperature of the animal sinks or rises in proportion. I allude here to the whole of the cold-blooded animals. That great purpose of respiration, the decomposition and removal of the used and waste materials of the organism, is not required when the temperature of the animal is so low as to be at freezing point, or a few degrees only above that point. Since then all chemical action is suspended, none of the component parts of the organism are cast off, and no new parts are required to supply the place of effete materials ; food is consequently not necessary, indeed it could not be digested, all chemical processes being suspended under the influence of a low temperature. Indeed, at the temperature referred to the decomposition of the dead body is at a stand-still ; and as that of the living body is then suspended respiration, being unnecessary, is suspended likewise.

When the temperature is at or only a little above the freezing point, almost all those beings which cease to respire, cease to move or to become capable of motion ; they become lethargic and unconscious ; there is no occasion for energy or consciousness on their part, and nature, with her customary thrift, does not endow the creature with consciousness unless its possession be necessary.

Those animals of the higher classes which hybernate do not require the immediate possession of consciousness when roused from torpor, and they recover energy and consciousness slowly. Among hybernating animals, those which require food most quickly regain their consciousness most quickly.

Those higher animals which do not hybernate have the power of evolving sufficient animal heat to maintain their bodies at a certain standard temperature; this power is necessary to the ready possession of full consciousness, and the constant power of quickly regaining consciousness when they awake is necessary in order that they may either attack their prey and defend themselves, or escape if attacked.

Many of those animals which live in burrows or holes, and do not require for self-preservation the immediate possession of consciousness and energy, do not produce during sleep and when exposed to cold the full amount of animal heat requisite for immediate energy and consciousness.

In the warm-blooded non-hybernating animals one of the great purposes of respiration is the maintenance of animal heat at a certain standard; consequently, within certain limits, when the external temperature falls, the evolution of animal heat increases, and when the external temperature rises, the evolution of animal heat diminishes. This is exactly opposite to the effect of external temperature on the evolution of animal heat in those animals which have no proper standard of animal heat, for in them, under ordinary circumstances, the power to evolve heat increases with the rise and diminishes with the fall of the external temperature.

For hybernating animals there is a certain minimum temperature, below which they cannot fall without the loss of life. If they, when they are torpid, fall in temperature to the extent referred to, they are roused from their torpor, and maintain for a time an independent temperature.

The maintenance of animal heat above the atmosphere is required by many of the cold-blooded animals, especially when they require the exercise of unusual energy.

Effects of External Temperature on the Respiration of Snails.

Spallanzani observed the effect of temperature on the respiration of snails. He found that six viviparous snails, the respiration of which is wholly cutaneous, consumed no oxygen during 72 hours, when the temperature was as low as from 37° to 39°. On the 11th of March, when the temperature was 51°.6, six viviparous snails consumed in 80 hours ·03 of a measure adopted by the experimenter, while on the 2nd of August, six of those snails consumed in 80 hours ·05.

Spallanzani observed, that if the common snail be removed from a heated to a cold room, the respiratory dilatation and collapse of its air-sac become less frequent, the pulsations of the heart become slower, and the motion of the fluids in the blood-vessels diminishes. If the temperature be reduced to the freezing-point, the movements of the air-sac, the pulsations of the heart, and the circulation in the blood-vessels, cease. If the creature be kept at this temperature for days, neither circulation nor respiration is to be perceived. If it be replaced in a milder temperature, the air-sac first moves, and then the pulsations of the heart and the circulation in the blood-vessels are renewed.

John Hunter found that slugs had a temperature of $55\frac{1}{4}$°, when that of the air was 54°; he also found that when a snail was placed in air below freezing point, the temperature of the snail fell to 31°, and that then the creature froze and perished.

Spallanzani found that the snail absorbed no oxygen in December, when the external temperature was 39°, and in February, when it was 44°. On the 11th of April, the operculum, which had hitherto been fixed, was in a softening state, the circulation was quickened and the amount of oxygen consumed in a given period was 9 degrees of the measure employed. At a later and warmer period of the year, when the air-sac opened and closed freely and frequently, the six snails consumed 20 degrees of oxygen during the same period.

These observations show, that in the snail the increase of the external warmth causes progressive increase in the respiratory consumption of oxygen, and excites anew the respiratory movements which had ceased, quickening or renewing at the same time the circulatory movements which had become imperceptible to the eye.

The immediate application of warmth to the surface was the exciting cause of the renewed and increased respiration and circulation.

Effects of External Temperature on the Respiration of Insects.

In the beginning of January, Mr. Newport found some of his bees torpid and motionless in a room at a temperature of about 40°; he removed them into another room, the temperature of which was 60°. They soon gave signs of revivescence. At first there were slight twitchings of the tarsi, and feeble irregular contractions of the abdominal segments, which increased in frequency.

In 2 minutes the respiratory contractions of the abdomen became more regular .	58 in the minute.
In 4 minutes, . number of respirations .	63 in the minute.
6 minutes ,, ,, ,, ,, . .	72 in the minute.
11 minutes ,, ,, ,, ,, . .	80 in the minute.
15 minutes, animal began to move its limbs . .	77 in the minute.
20 minutes	87 in the minute.
33 minutes, had regained power of locomotion .	102 in the minute.
When perfectly recovered and in a state of activity	160 in the minute.

The usual number of normal respirations is 40 in the minute.

Mr. Newport found that the pupæ of the Sphinx Ligustri produced a greater amount of carbonic acid in a warm than a cold atmosphere. He placed two of these pupæ in a bottle in the open air, the temperature ranging between 35° and 58°, and another in a room, at a temperature varying from 45° to 60°, and he found that the pupa in the room produced 0·40 of a cubic inch of carbonic acid in 180 hours, while each of those exposed to the colder temperature, evolved only 0·19 of a cubic inch in 156 hours.

During the progress of the year, from the winter to the summer months, as the external temperature increases, the heat of the bee increases likewise ; but this increase of temperature on the part of external medium and the bee is not at equal rates, far from it, for up to the time of swarming the increase in temperature of the insect is far greater than that of the atmosphere. Thus—

During Feb., 1836, mean temp. of atmos.	40°·35,	of hive	50°·10,	excess of temp. of hive over that of atmos.	9°·75
March, „ „	46°·93,	„	58°·59,	„	11°·66
April, „ „	49°·93,	„	73°·07,	„	23°·14
May, Time of swarming,	60°·17,	„	87°·08,	„	26°·91
After swarming.					
June, „ temp. of atmos.,	63°·67,	„	89°·11,	„	25°·44
July, „ „	63°·68,	„	79°·77,	„	16°·09
August, „	67°·64,	„	77°·79,	„	10°·15
Sept., „ „	60°·04,	„	66°·5,	„	6°·46

During the first four months the progressive increase in external temperature leads to a progresssive increase in the independent evolution of heat, owing to the progressively augmented respiration. After the great purposes of swarming have been served, the occasion for an exalted temperature having gone by, the respiratory evolution of heat gradually diminishes.

The following communication, with which I have been favoured by Mr. W. F. Barlow, illustrates with remarkable precision the effect of heat and cold on the respiration of insects :—

"Westminster Hospital, Dec. 21, 1849.

"MY DEAR SIR,—I send you a few short notes of some of the unpublished experiments which I mentioned to you.

"I have observed that the respiratory movements of the dragon-fly become by immersion in cold water slower and slower, and at length very gradually cease ; but on re-exposing the insect to air, it soon begins to breathe visibly again, and the respiratory motions, becoming stronger and stronger, are in the end quite restored.

"I have found that by exposing the insect to hot air or water, I could accelerate its respiratory movements at pleasure. I put one, for instance, (the respiratory movements being about 75 in the minute), into water of the temperature of 100°, and the contractions rose to the rate of 110. On removing the insect, and exposing it to cold air, they soon fell to 50. I have made several other experiments, which show that, within certain limits, elevation of temperature leads to a corresponding quickening of the respiratory movements.

"I have noted that water at the temperature of 130° very rapidly extinguished all motion.

"On the other hand, the respiratory motions may be diminished by applying various degrees of cold. By immersing the insect in water of different temperatures, I have found that the lower the temperature the slower did the respiratory movements become. I made some experiments with a freezing mixture, and found it had the effect of almost instantly arresting the respiratory contractions.

"But an observation of nature, independently of experiment, teaches us the same knowledge. The dragon-fly, when caught on a cold morning at the end of September or the beginning of October, is performing no visible respiratory contractions, or only such as are extremely slow, few, and feeble ; but the same insects captured at noon, when swiftly flying in the sunshine in quest of prey, will be seen to respire with great quickness and full vigour.

"I am, my dear Sir,

"Yours very faithfully,

"Dr. Sibson." "W. F. BARLOW.

In a subsequent note Mr. Barlow states, "I held a dragon-fly, whose cerebral analogue I had destroyed, over water of the temperature of 185°, with the effect of greatly accelerating the respiratory movements.

"I have found also that the respiratory movements of the insect are readily hurried by placing it on a hot surface. I used on one or more occasions a stone bottle, filled with water of a high temperature.

"In whatever way heat is applied, the movements are quickened.

"I have concluded that the heat acts on the periphery of the nerves, and excites the contractions reflexly."

The interesting observations of Mr. Barlow, which he will, I trust, shortly publish in full, taken in conjunction with those of Mr. Newport, show how absolutely the movements of respiration are excited, controlled, depressed, and arrested by external temperature.

At the freezing point respiration is arrested; with the increasing external stimulus of increasing heat the respiratory movements are, up to a certain point, progressively accelerated; at 130° those movements are extinguished. That the stimulus exciting the reflex respiratory movements is applied to the cutaneous nerves, and not to the tracheal nerves, is proved, inasmuch as the respirations, when arrested, are at first excited to renewal by the application of warmth to the surface; indeed in those important experiments in which the insects were immersed in water of various temperatures, the stimulus was applied immediately and only to the surface, the movements of respiration being accelerated in proportion to the increase of temperature, notwithstanding that the submersion prevented the inspiratory admission of air into the trachea. The experiment in which the external application of heat increased the respiration, although the cerebral analogue was removed, proves that the augmented movements are not due to volition.

The observations of Mr. Newport show that there is a certain medium temperature, ranging somewhere between 40° and 50°, at which the bee may when at rest retain the same temperature as the external medium. But if the temperature fall below this range, there will be an independent evolution of heat by that interesting insect, and its temperature will be above that of the atmosphere. Thus—

Date.			Temperature of atmosphere.	Temperature of hive.	Difference between temperature of air and hive.
On the 12th of Nov., 1835,		4 P.M.	41°·2	41°·2	0°
13th	"	7½ A.M.	36°	43°·7	7°·7
16th	"	4½ P.M.	37°·6	46°·7	9°·1
17th	"	7½ A.M.	39°·5	45°	5°·5
"	"	9½ "	43°·6	45°·5	1°·9
"	"	10½ "	45°·2	46°·8	1°·6
"	"	11½ "	47°·4	47°·4	0°

During all these observations the insects were quiet.

Mr. Newport remarks, that "the hive-bee certainly does not become *torpid*, but if entirely undisturbed it passes into that condition in which its temperature of body and quantity of respirations are very greatly diminished,—a state of deep sleep in the combs, but a sleep which, so far from being continued at a very low atmospheric temperature, then becomes broken, and is only continued at a moderate temperature."

It would appear, then, that respiration may be, to a certain extent, excited in the hive-bee by a greatly lowered temperature, with the view of sustaining its temperature, and so enabling it quickly to renew consciousness and increase its temperature to a very great extent, as we have already seen at p. 196.

Thus the hive-bee appears to be endowed with a faculty of which the dragon-fly is destitute, the faculty of evolving heat by respiration at exceedingly low temperatures.

Effects of External Temperature on the Respiration of Fishes.

Spallanzani found that a fish lost its activity in half-an-hour when placed in water at 32°, but it still moved when touched. The opercular movements were seven in the minute.

He almost froze a fish in air, at a temperature of 25°, and he then placed it in water at 37°·4. It showed no signs of life for an hour; it then began to move its fins, and soon after it commenced to breathe. Next day it was dead. A fish, when placed in air at 26°, opened the opercula eight times in a minute; after the lapse of a quarter of an hour it only breathed when touched. When taken in hand it agitated itself. It swam freely in water at 31°, and in the course of the night it absorbed oxygen and produced carbonic acid in small quantities.

John Hunter put two carp into a vessel of water, and placed it in a freezing mixture; they resisted the effect of the cold a long time, moving about violently. At length, however, they were frozen, and when thawed they did not recover.

In an eel, the heat in the stomach, at first 37°, sank after it had been some time in the cold mixture to 31°. The animal at that time appeared dead, but was found to be alive next day.

Dr. Edwards found that if a bleak be placed in five ounces and a half of exposed aerated water, at a temperature of 68°, it dies in a few hours, but when the temperature is lowered to 50° or 53°, and is kept at that degree, the animal lives until its secretions are so abundant as to corrupt the water.

In order to observe the effects of temperature on the respiration of fishes, I noticed the opercular movements of a gold fish, under the following circumstances.

On the 30th of December, at thirty-five minutes past ten, snow being on the ground, the opercular movements of a gold fish in water at a temperature of 51°, were fifty-two in a minute, the fish being perfectly still, and its fins at rest. The water had been in the room all night. (See Table on page 270.)

The fish recovered perfectly.

It is to be observed that boiled water was added to heat the fluid containing the fish, consequently the experiment is complicated, the fish undergoing the conjoint influence of increased temperature and diminished oxygen.

During a previous experiment, the steps of which were exactly the same with that detailed, when the temperature was becoming very high, the motion of the fish became convulsive, startling, and sudden, the opercular movements being very great; afterwards it lay almost still on one side, floating at the top of the water. At length, the temperature was raised to the highest pitch (about 90°?) The fish leaped violently up, so as to have its head out of the water; repeated this, and then lay motionless and side uppermost at the top; the motionless operculum was quite out of the water. At first there were a few faint opercular and occasional convulsive sidelong movements; at length it lay as if dead.

The temperature was lowered by pouring in cold water, and the fish recovered as in the experiment described above.

The experiments and observations given above, show that the respiratory movements of the fish progressively decrease with the decrease of temperature, until at 34° they are not perceptible, and that with the gradual rise of temperature they progressively increase in number and extent, being

	In water at a temp. of		Opercular movements.
10h. 35m.	51°	The opercular movements of the gold fish were	52 in the minute.
10h. 55m.	38° to 34°	Snow was put into the water, the temperature of which fell progressively to 38°, 37°, 36°, and 34°. No opercular movements were perceptible; it was quiet, but moved when disturbed, making irregular body, fin, and tail strokes, about 30 in half a minute	0
11h. 5m.	42°	Warm water was added, so as to raise the temperature to 42°. The fish swam about and then became still	49 in the minute.
		The temperature was then raised progressively by successive additions of hot water.	
11h. 10m.	46°	The fish lay still at the bottom of the dish	24 + 22 in 30″ = 46 in the minute.
11h. 20m.	50°	Body nearly still; some fin movements	66 in the minute.
11h. 25m.	55°	Opercular movements irregular in extent and rhythm; oral, opercular, and fin movements simultaneous	37 + 39 in 30″ = 76 in the minute.
11h. 29m.	60°	Fish stationary; sudden body and tail vibrations; at length it moved away	47 in 30″ = 94 in the minute.
11h. 34m.	65°	Oral and fin movements simultaneous	50 in 30″ = 100 in the minute.
11h. 37m.	64°	After being chased round the dish	23 in 15″ = 92 in the minute.
11h. 38m.		Fish still	30 in 15″ = 120 in the minute.
11h. 45m.	70°	Fish came to the top; very slight movement of pectoral fins with each opercular movement.	62 + 53 in 30″ = 115 in the minute.
11h. 48m.	68½°	Fish undisturbed	30 in 15″ = 120 in the minute.
		After being disturbed	60 in 30″ = 120 in the minute.
11h. 55m.	64½°	The animal in a state of agitation, moving quickly about	58 in 30″ = 116 in the minute.
11h. 56m.	74°	Fish at top; little movement, except of anterior fins	68 in 30″ = 136 in the minute.
11h. 58m.	72½°	After being chased, the fish then moving	69 in 30″ = 138 in the minute.
12h. 1m.	79°	Fish floating at the top; fins and opercula move simultaneously	78 in 30″ = 156 in the minute.
12h. 5m.	84°	Fish moves with a convulsive, wriggling, forward motion. Number of respirations difficult to observe	70 in 30″ = 118 in the minute.
12h. 9m.	88½°	Lying on one side at the top, moving fin occasionally, opening mouth only once in 15 seconds; opercula move slightly	27 in 15″ = 108 in the minute.
12h. 10m.		Opercula at rest	0
12h. 11m.		After a short time very slight oral movements, 5 in 15″	
12h. 12m.		Opercular movement very slight	10 in 15″ = 40 in the minute.
12h. 15m.	84°	Opercular movements slight, but manifest	24 in 20″ = 72 in the minute.
12h. 17m.	83°	Opercular movements more extensive, still irregular	17 in 30″ = 34 in the minute.
12h. 22m.	70°	Cold water added. Fish lay floating on one side at the top, almost motionless; slight fin movements; one or two opercular movements	1 or two in the minute.
12h. 25m.	60°	Occasional fin and body movements; opercular movement very slight indeed	38 in 30″ = 76 in the minute.
12h. 28m.	55°	Fish motionless, and lying at bottom on the belly; 25 body and head movements in 15″	100 in the minute.
12h. 41m.	55°	Fish still at the bottom; opercular movements more extensive	21 in 30″ = 42 in the minute.

excited by the external stimulus; at length, the greatly augmented temperature of 90° exhausts the excitability of the animal; after convulsive movements the respiration comes to a stand-still, being, however, renewed again with the lowering of the temperature.

Although the opercular movements are not perceptible at the freezing-point, they probably take place, while cutaneous respiration evidently goes on, for those fish which are then active still evolve a certain amount of heat. The eel does not seem to possess this faculty, but with the lowering of the temperature appears to become inactive, and to lose the power to evolve heat. Dr. Davy found the temperature of the eel the same with that of the surrounding water.

The difference in the respiratory power and activity at lower temperatures of the carp and the eel, is evidently due to the necessity which the former fish then has for the quick use of its locomotive and sensory faculties, in order that it may elude capture. The eel, being concealed from observation, does not then require the locomotive, sensitive, and respiratory faculties of the more active fishes.

Effects of Temperature on the Respiration of Frogs.

Dr. Edwards put frogs into a pint of Seine water at a temperature varying from 32° to 108°, with the following results :—

Eight frogs, each in 0.35 pint of Seine water, at a temperature of 32°. They died in from					6h. 7m. to 8h. 18m.
Two	,,	50°	,,	,,	5h. 50m. to 6h. 15m.
Four	,,	72°	,,	,,	35m. to 1h. 10m.
Three	,,	90°	,,	,,	12m. to 32m.
Ten	,,	108°	,,	,,	a few seconds to 2m.

Here the progressive increase of temperature caused a progressive increase in the rapidity of death; in other words, the amount of air necessary for the respiration of frogs increased with the increase of temperature.

A frog can live in aerated water, without breathing air, at a temperature below 50°, but if the temperature be above 50° they die after a period varying inversely with the increase of temperature. If they are at liberty, they rise to the surface, and breathe the air, the necessity for breathing the air increasing with the increase of temperature. In winter frogs can live in aerated water by means of cutaneous respiration alone; the lungs may then even be cut out, and yet life will continue. In summer both pulmonary and cutaneous respirations are necessary.

Tadpoles change during the warm season. If the influence of the warmth be not sufficient, their transformation is deferred until the following summer; and if they are limited to cutaneous respiration, not being suffered to breathe the air, their transformation is indefinitely delayed.

In winter, the frog is in an inactive state, and then cutaneous respiration is sufficient for its existence; but in summer its activity is great, and then both cutaneous and pulmonary respiration are requisite.

If the frog be confined, at a moderately warm temperature, to cutaneous respiration in running water, although it lives, its condition is inactive and inexcitable.

A large frog was placed in a small apartment, having a temperature varying from 108°·5 to 112°. The respirations were progressively accelerated.

A progressive decrease of temperature progressively diminishes the respirations of frogs, until, below the freezing point, they are arrested; while a progressive increase in temperature gradually accelerates the respiration of frogs until, beyond a certain temperature, they cannot maintain life.

As we have seen above, a frog placed in a highly-heated atmosphere keeps down its temperature within the limit of 100° by means of cutaneous and pulmonary evaporation.

Berthold found that frogs have usually the same temperature with the surrounding water, but that they have, owing to evaporation, a lower temperature than the surrounding air. Tiedemann observed, that at night, when the water was frozen, a frog had a temperature of 33°, the water around it being unfrozen.

Sir Charles Hastings observed the effect of the extremes of heat and cold on the circulation in the web of the frog's foot. He found that when he applied warm water at 115° to the frog's foot, the blood immediately quickened, the vessels being in some degree contracted. After dipping the foot five times in warm water, the vessels were much dilated, and the blood formed a red mass, moving slowly in the capillaries. After twenty-five minutes he applied ice; in a quarter of an hour the vessels again contracted, the globules re-appeared, and the natural motions were restored.

Sir Charles Hastings, on another occasion, applied ice to the web of a frog's foot. In five minutes the motion of the blood increased, the vessels being contracted. The ice being still applied, the vessels at length dilated, and the blood circulated more slowly.

The immediate effect of external temperature is evidently upon the circulation in the superficial capillaries. The altered circulation, as well as the external impression, acts on the incident nerves so as to quicken, excite, or depress respiration by reflex action.

Effects of External Temperature on the Respiration of Warm-blooded Animals.

External temperature acts, as we have just seen, on the respiration of the cold-blooded classes with a very simple and intelligible uniformity. In these classes increased warmth, up to a certain point, uniformly excites and increases respiration, while increased cold depresses and finally arrests respiration. Their active life is confined to the summer; in winter they are either inactive, torpid, or dead. By a remarkable arrangement in the warm-blooded animals, extremes both of warmth and cold accelerate respiration. These animals possess a certain standard of animal heat. In cold weather the augmented respiration causes the increased evolution of animal heat, so as to maintain that standard above the external temperature. In very hot weather, the temperature being above 100°, the accelerated respiration causes increased evaporation, and so, by acting as a cooling process, maintains that standard below the external temperature. These classes are consequently endowed with energies of equal activity in winter and summer, and often possess even greater energies in cold than in warm climates.

While in all animals the decomposition and elimination of the waste materials of the body constitute the great function of respiration, the evolution of animal heat, in such proportion as to augment the heat of the being up to a certain standard, is an additional essential purpose of respiration in the warm-blooded animals. The more active the decomposition of the materials of the organism, the greater is the evolution of animal heat. The processes of respiration are more energetic in the higher warm-blooded classes in winter than in summer.

We have already seen how completely this condition is reversed in the cold-blooded animals.

Now, although these two classes, taking them, one in its higher, the other in its lower phases, differ from each other so widely, in the season at which they each generate the greatest amount of heat, and in the power of generating heat, yet the higher of the cold-blooded and the lower of the warm-blooded animals approach each other closely in their power to generate heat in proportion to the external cold and warmth. For instance, while the bee can maintain a temperature, both in summer and winter, much above the surrounding medium, thus possessing the qualities of a warm-blooded animal, the hybernating mammalia become torpid under the influence of cold, actually appear to cease to respire, and possess a temperature identical with the surrounding atmosphere. The analogy goes even still farther, for while both the bee and the hybernating mammalia, at a certain low temperature, have apparently a complete suspension of respiration, and a temperature identical with the atmosphere, they each have their respiration roused by a temperature colder than that at which they hybernate, so that, by an independent and conservative evolution of heat, their temperature becomes actually and considerably elevated ; they each also possess the remarkable faculty, if roused by irritation, of evolving a degree of heat which will raise them up to the standard of the highest summer temperature. Indeed, as we have seen already, the bee possesses this faculty in much greater perfection, and can, in fact, exercise it with greater rapidity than the hybernating animal. Guided by these analogies, I will first consider the effect of external respiration on the hybernating animals.

Effects of External Temperature on the Respiration of Hybernating Mammalia.

M. Saissy's observations, given in a table at page 191, show that the hybernating animals possess in summer about the same temperature as the permanently warm-blooded animals.

DORMOUSE.

	Temp. of air.	Temp. in Axilla.	Resp. in min.	Oxy. con. in hour, cubic in., Fr.	Pulsations in min.
Aug. 6th to 12th, lively . .	64°·4 to 68°	97°·5	45	34·6	105
Nov. 8th to 11th, conscious .	44°·6	69°·8	30	20·53	60
Commencing hybernation.			9 to 10		20 to 25
Feb. 2d, hybernating	32°	38°·5		0	9 to 10

We have seen, that with the decline of temperature there is a steady decline in the number of respirations, the amount of oxygen consumed, the temperature of the body, and the pulsations of the heart, until at length respiration and the consumption of oxygen apparently cease when the temperature falls as low as 38°·5, or rather, as Dr. Marshall Hall has shown, as low as the surrounding medium; varying, indeed, with the variations in temperature of that medium.

If the external temperature be much and quickly lowered, respirations are again excited and gradually accelerated, the animal being still unconscious; the animal heat gradually rises, and the creature becomes gradually more and more conscious, until at length it becomes lively.

On the 25th of January, 1807, at ten o'clock A.M., M. Saissy placed a hedgehog and dormouse, their bodies having a temperature of 39°·2, at a window open to the north, the external temperature being 24°·8. Their respiration gave a few feeble signs of existence.

A few minutes before eleven the dormouse awoke, was lively, and ran about its cage. At eleven o'clock its temperature had risen to 77° (38° in one hour), and at twelve o'clock to 96°·8 (58° in two hours).

The hedgehog awoke at half-past twelve, when its temperature had risen only to 53°·6 (14° in two hours and a half); at three o'clock P.M. its temperature was 82°·4 (43° in five hours). The animal remained another hour exposed to the intense cold, when its temperature had fallen nearly 4°.

In these instances the increased cold served as a stimulus, exciting acts of respiration through the impression made on the incident nerves.

These instructive experiments show that the warm-blooded animals, even when of the lower or hybernating class, can elevate their temperature by means of respiration, so as to be, in the instance of the dormouse, 72° above the surrounding atmosphere.

The observations of Dr. Marshall Hall show, that if the intense cold which arouses the hybernating animal continue, the creature will again lose the temperature it has acquired, become torpid, and at length die from exposure to cold. Indeed, hybernation is incompatible with very low temperatures.

Some observations made by M. Regnault on the respiration of the marmot during its hybernating state, and just when being aroused from that state, confirm and illustrate the observations of M. Saissy.

Early in March, 1848, when the temperature was 46°·4, M. Regnault placed in his apparatus for accurately observing the chemical changes induced by respiration a marmot, in a state of hybernation; it exhibited no movement, and its temperature was 53°·6. (It may be remarked that M. Saissy found the temperature of a marmot, in a profound state of hybernation, to be 41°.) He kept the animal under observation for 117 hours, and found that it consumed a very small proportion of oxygen,—only 0·004 per cent. of the weight of its body in the hour.

On the 27th of March, the external temperature being 50°, the marmot was re-introduced into the apparatus: its temperature in the anus was 52°; its state of hybernation was less deep, it opened its eyes when touched, and respired occasionally. On the 30th of March, about 45 minutes before the end of the experiment, the animal became agitated, its movements were more rapid, and the consumption of oxygen was much more considerable; of the whole quantity consumed during the 77 hours the experiment lasted, about one-third was consumed during the last short period, when the creature was lively. At the conclusion of the experiment the temperature had risen from 52° to 71°·8, and five hours later, to 84°·2. The creature was very lively and vicious when it was taken out of the apparatus.

At a later period, when the temperature was 59°, the animal being lively, it was re-introduced into the apparatus just after eating. It remained there for 41 hours 10 minutes, and it consumed, during that time, ·0774 per cent. of the weight of its body of oxygen per hour, or nearly 20 times as much as it consumed when in a state of hybernation.

On the 17th of June, the temperature being 68°, it was again observed for 68 hours. During the first day it was lively, and ate freely; on the second day it fell into a torpid state, when the consumption of oxygen was notably lessened.

Dr. Edwards remarks, that there are some adult species of the class mammalia which, though not passing the winter in a torpid state, closely resemble hybernating animals in their feeble power of producing heat. Mice are of this number. To retain their warmth they make nests, not for their young only, but for themselves. Most of those animals which burrow or inhabit caverns and crevices in rocks or holes, in walls or trees, are of this class. Their dwelling-places serve as a protection from the cold, which many of those animals cannot bear with impunity.

Effects of External Temperature on the Young of certain Mammalia and Birds.

Dr. Edwards has shown that the new-born young of certain mammalia and birds are incapable of supporting animal heat when exposed at ordinary temperatures.

If at a temperature between 50° and 68°, a new-born puppy be removed from its mother, although its respiration be much accelerated, yet its temperature falls considerably, and continues falling until, in the course of three or four hours, it stops a very few degrees above that of the surrounding air.

On the 12th of February, 1819, a kitten, newly littered, removed from its mother and exposed to the air, at the temperature of 51°, being cooled down in nine hours to 64°·4, became stiff, and almost incapable of executing the slightest movements.

Two kittens, one day old, having a temperature of 98°·6, were exposed to the air of a room at 50°. In two hours and twenty-five minutes the temperature of one was reduced to 62°·6, of the other to 64°·4. They were stiff and almost motionless.

In January four puppies, a day old, of the temperature of 95° to 97°, were exposed to the air of a room at 52°. In thirteen hours their temperature had fallen to 55°·4 and 57°. They were then so enfeebled as to be almost motionless.

Dr. Edwards exposed young and adult magpies to a temperature of 39°; while a young bird lost 29° in seventy minutes, the adult only lost 5°.

It appears that young sparrows will live nine times as long in the same quantity of air as adult sparrows. The inference is that they consume a smaller proportion of oxygen.

Respiration is accelerated in the young by exposure to cold, owing to the stimulation of the incident nerves of the surface, respiration being excited by a reflex action.

New-born puppies can live two or three days at a temperature of 64°·4 to 68°; but the air must not be too cold, or they will be deprived of sense and motion, and at length die. When they appeared on the point of expiring Dr. Edwards easily restored animation by placing them before a fire.

Effects of External Temperature on the Respiration of Higher Adult Warm-blooded Animals.

Effects of Moderate Cold.

We have just seen the effect of exposure to moderately cold air, in lowering the temperature and respiration of hybernating animals, and in lowering the temperature while it accelerates the breathing of certain young animals.

Dr. Edwards has made some interesting and exact observations on the effect of exposure to the air of young birds when nearly or quite able to sustain their own heat at a moderate temperature.

A YOUNG BIRD.

Its temperature in the nest.	Resp. per min. in the nest.	Was exposed to air of room at	The respirations were then	It lost in a quarter of an hour
104°	97	64°	120	5°·4

Its respirations were afterwards fuller and slower. It then retained the lower temperature.

ANOTHER YOUNG BIRD.

100°·4	84	64°	108	1°·3

At the end of an hour it had recovered its original temperature, 100°·4. Respirations then 108.

In a third, the respiration was accelerated, and its temperature, instead of falling, rose one degree.

In these instances, the exposure to a moderate cold increased the respirations, the first bird thereby sustained its heat, to within a few degrees of the heat acquired from its mother; while in the third the accelerated respiration, stimulated by the exposure, actually raised the already high temperature of the creature.

In adult age, the rapidity of the respiratory movements is less subject to the influence of external temperature; but in all the experiments made by Dr. Edwards on the refrigeration of the higher adult warm-blooded animals, he remarked an acceleration of the respiratory movements, until, the powers being exhausted, these movements, like all the others, languish and fail.

Vierordt observed the condition of his own respirations for fifteen months, and he found that in cold weather the respiration and pulse are accelerated, that the volume of each expiration is augmented, and that the proportion of carbonic acid contained in each expiration, as well as the total amount of carbonic acid evolved, is increased. He gives the results in the following table, which I quote from Dr. Reid's article on respiration. The observations were taken during temperatures varying from 37°·4 to 75°·2 :—

	Average of the observations		Difference between the higher and lower temp.
	Taken at the lower temperature, 47°·24.	Taken at the higher temperature, 66°·92	
Pulse, per minute	72·93	71·29	1·64
Respirations, per minute . .	12·16	11·57	0·59
Volume of an expiration, cubic inches	33·44	31·76	1·68
Expired air, per minute, cubic inches	406·99	366·97	40·02
Expired carb. acid, per min., cub. in.	18·25	15·72	2·53
Carbonic acid in 100 parts of the expired air, cubic inches . .	4·48	4·28	0·20

Lettellier found that the following warm-blooded animals evolved twice as much carbonic acid at the freezing-point as at a high temperature. He gives his observations in the subjoined table. The observations of temperature are supposed by Dr. Reid to be measured by the centigrade scale:—

CARBONIC ACID PRODUCED,

	At the freezing-point.	The surrounding temperature being From 15° to 20° (59° to 68°.)	From 30° to 40° (86° to 104°.)
	Grammes.	Grammes.	Grammes.
By a canary . .	0·325	0·250	0·129
a pigeon . .	0·974	0·684	0·366
two mice . .	0·531	0·428	0·268
a guinea pig .	3·006	2·080	1·453

It is ascertained, then, that the respirations are accelerated in the higher warm-blooded animals by external cold; that the amount of carbonic acid then evolved is increased; and that thus the standard of animal heat is maintained, notwithstanding the diminished temperature.

Thus, if the external temperature be .	90°,	the standard of animal heat	100°,	the excess is only	10°
While if	32°,	"	100°,	"	68°.

It is a matter of necessity that a greater amount of animal heat must be evolved by the animal, through the medium of respiration, at a low than a high temperature.

Effects of Extreme and continued Cold on the Respiration of the Warm-blooded Animals.

We have already seen that a moderately low temperature will eventually destroy certain imperfect young animals, the cold first accelerating respiration, but the respiration being insufficient to maintain the standard of animal heat. The temperature of the creature gradually diminishes; after a considerable period lethargy comes on—the movements of the animal diminish and cease—the respirations diminish and cease—and the animal dies, unless it be exposed to warmth.

Dr. Edwards observed the effects of extreme and moderate temperature on the vitality and respirability of kittens in the following manner:—

He immersed and asphyxiated kittens in water at . .	32°	They ceased to give signs of sense and motion in	4′ 33″
„ „ „	50°	„ „ „	10′ 23″
„ „ „	68°	„ „ „	38′ 45″
„ „ „	86°	„ „ „	29′
„ „ „	104°	„ „ „	10′ 27″

Thus kittens live more than eight times as long in water at 68° than at 32°, and nearly four times as long in water at 68° than at 104°. Thus a moderate temperature promotes the duration of life, while either a very cold or a very warm temperature excites augmented respiratory and other movements, and speedily exhausts vitality.

Sir Astley Cooper put a kitten, six weeks old, into water kept at 32°·5 by means of ice. The mouth was above water. It died at the end of sixteen minutes. Its nose, lips, and gums, which were previously pallid, soon after immersion became of a beautiful vermilion colour. During almost the whole of the first five minutes it lay quiet in the water; it struggled violently during the second five minutes; between the tenth and the sixteenth minutes it lay quietly. It breathed first quickly, then laboriously, and lastly at long intervals, when it died. Upon introducing a thermometer, immediately after the last breath, into the chest, it stood at 52°. The heart did not act. The blood was of a florid red in the left side of the heart. When touched the heart acted; but it was quite motionless unless thus stimulated. The peristaltic action of the bowels continued.

An hour and thirty-five minutes after its apparent death, warm water at 90° or 100° was poured into the chest. The heart began to act, and continued to do so for more than two hours, four hours, therefore, after the chest had been laid open.

In this experiment the intense external cold at first stimulated the circulation and excited the respiration by stimulating the afferent nerves. The sensory, the incident, and the motor functions of the nervous system were at first excessively excited, but speedily yet gradually the sensory and excitor functions of the nerves and the excitability of the muscles were exhausted—the latter being re-excited by external warmth.

Dr. Hodgkin placed a swallow, at a temperature of 106°, in a deep glass vessel, immersed in a mixture of ice and salt. Although the bird remained quiet, its respiration soon became greatly accelerated, and its temperature, in somewhat less than an hour, was reduced about 20°.

It appears, then, that although at moderately low temperatures the augmented respiration, excited by exposure to cold, is sufficient to counterbalance the increased loss of animal heat induced by the exposure, yet if the temperature be very low, although the respiration be exceedingly accelerated thereby, the heat evolved by the augmented respiration is quite unable to compensate for the heat extracted by the exposure to cold, and the body, consequently, becomes colder and colder. The increased respiration retards the cooling but does not prevent it. The smaller the animal the greater in proportion is the rapidity of cooling. In the unequal struggle to compensate for this disproportionate loss of warmth, the smaller animal has its respiration much more accelerated than the larger animal.

The recent researches of Regnault, confirming those previously made, show that, in connection with their greater rapidity of cooling, all the smaller warm-blooded animals consume much more oxygen, in fact respire more than the larger animals. Thus,

					Per cent. of the weight of its body of oxygen.
A young greenfinch,	weighing	17·5	grams.,	consumes in the hour	1·405
An adult ditto,	,,	25·	,,	,,	1·300
Crossbeak,	,,	28·6	,,	,,	1·097
While a fowl,	,,	20·22	,,	,,	0·0935

We thus see that the greenfinch consumes during respiration fourteen times as much oxygen, in proportion to the weight of its body, as the fowl.

Sir Benjamin Brodie classes the effects of cold in the following order:—"1. It lessens the irritability and impairs the functions of the whole nervous system. 2. It impairs the contractile powers of the muscles. 3. It causes contraction of the capillaries, and thus lessens the superficial circulation, and stops the cutaneous secretion. 4. It probably destroys the principle of vitality, equally in every part, and does not exclusively disturb the functions of any organ."

Chossat and Prevost found that when death was occasioned by exposure to artificial cold, the temperature of the body at the time of death was very variable,—sometimes 78°·8, but on one occasion it was as low as 62°·6. These experiments were most probably made on adult animals, for in Sir Astley Cooper's experiment, detailed above, a kitten, six weeks old, had a temperature of 52° in the chest immediately after death from cold. Indeed the experiments of Dr. Edwards, detailed before, show that the young will cool down much further than adults before they are destroyed by the cold. So that, although their power of sustaining animal heat is much less, their power of sustaining life at a low temperature of the body is greater than in adults.

In those suffering from exposure to cold, the accelerated breathing gradually gives place to diminished breathing, the respirations towards the end being taken at longer and longer intervals. It is not until the state of drowsiness, weakness, and torpor comes on, that respiration becomes so materially lowered.

We have already seen that diminished nervous energy, from whatever cause, whether the removal of the brain or the division of the spinal marrow, or the division of the vagi, or the action of narcotic poisons, leads to the lowering of animal heat along with the lowering of respiration. We have also seen that the cold-blooded animals are precisely those which have a low nervous energy, and that in each of those animals the amount of nervous energy is proportioned both to the generation of animal heat (as in bees) and to the acquisition of a higher temperature from without. In winter the body is cold, the nervous force dormant, respiration absent; in summer the body is warm, the nervous force energetic, the respiration active. Thus, as we have seen, it is also with the hybernating mammalia: with a low temperature, torpor creeps over them, with torpor, the gradual and complete suspension of respiration. Rouse the animal, even by excessively lowering the cold, and the exercise of nervous energy brings about augmented respiration, circulation, and temperature,—and these, in their turn, bring about a higher nervous energy. This effect of the nervous energy on respiration, circulation, and the production of animal heat, is the key to the different effects which external cold produces on the respiration, circulation, temperature, and nervous energy of the cold-blooded and the warm-blooded animals. In the cold-blooded animals the afferent nerves are not excited by the cold ; on the contrary, their excitability is depressed or exhausted, the circulation is lowered, and respiration is suspended or lessened. In the warm-blooded animals the incident nerves have a higher life, are more excitable than in the cold-blooded ; the cold stimulates the sensory and excitor functions of the afferent nerves, stimulates also the circulation, and as a first step, and by a reflex action transmitted from the surface, stimulates the muscles of respiration.

The imperfect young of certain warm-blooded animals have a less developed cerebral and nervous energy, and they possess much less power of generating heat than the adult. In proportion as their nervous energy increases, their power to generate heat, and to sustain the standard of heat, independently of the parent, increases. If the young are born prematurely, the nervous energies are much less developed, and their power of evolving heat is in proportion less developed also.

Certain warm-blooded animals, as the mouse and rabbit, possessing low nervous energies, have those energies blunted by a degree of cold that will not have that effect on the more energetic mammalia, as the lion and wolf. Those possessing the lower nervous energy respire imperfectly, and evolve an insufficient amount of heat in winter, and they, therefore, require additional protection in the form of nests and burrows.

Infants prematurely born possess a low nervous energy, and a correspondingly low power of sustaining animal heat.

New-born infants, though capable of evolving sufficient animal heat if properly protected from cold, soon cool down below the standard of animal heat if their bodies be not so protected. It is important, while the body of infants is protected from cold, that the face, highly endowed with nerves of sentient and excitor functions, should be freely exposed to a fresh bracing dry air, which excites through the trifacial nerve reflex movements of respiration.

Certain adults possess a low cerebral and nervous energy. In them the evolution of heat is less perfect than in the robust, and they require greater external protection from the influence of cold.

In every one the respiration and the power of generating heat is lowered during sleep, and when the mind is engrossed by depressing passions or deep thought; at such times additional external warmth or covering is demanded.

If those who are exposed to cold be alert, cheerful, and energetic, they resist the external cold by the increased evolution of animal heat; but if they become depressed or drowsy, and especially if they fall asleep, then their power of evolving heat is lowered, and they can no longer resist the low external temperature, they therefore part with animal heat, and sink accordingly.

M. Chossat has shown that at the period when death takes place from inanition, the temperature of the body is much lowered, is, in fact, lowered to the same extent that it is when death takes place from exposure to cold. The average temperature of the body at the time of death from inanition, in forty-one animals, was 77°,—of these, eighteen had a temperature varying between 64°·4 and 75°·2 at the time of death. All of these animals died with the identical symptoms of death from exposure to cold. The great lowering of temperature did not take place until the last day of life, and then not until the time of stupor. During the last six hours, the average number of respirations in six dying turtle-doves was twenty-five in the minute, while the average number in healthy turtle-doves is forty-nine. The respirations, after having become gradually slower and slower, sometimes become, just before death, more and more distant and insensible, sometimes, on the contrary, they become excessively accelerated and panting.

Under the influence of inanition the creature is tranquil at first, then it becomes agitated; on the last day the agitation gives place to general feebleness and a state of partial stupor. The animal becomes more and more feeble, the respiration slower, sensibility and the excitability of the incident nerves diminish, often the eyelids, half open, do not close when touched, complete stupor is established, and death takes place, sometimes in a calm and tranquil manner, sometimes with slight convulsions, and sometimes with tetanic rigidity of the body.

This, which is the history of the last day of inanition, is the history also of the last stage, just before death, from exposure to cold.

Napoleon's retreat from Russia, and similar events, have shown that towards the close of life, under the destructive influence of cold, the senses are benumbed, the muscular power is weakened, torpor comes on, the respirations become slower and slower, and death ensues. Sometimes death is preceded by muscular tremor, sometimes by tetanic convulsions and muscular rigidity.

Under the influence of external cold, the circulation at the surface is at first roused, the sensory and incident nerves are stimulated, the respirations, by a reflex action, transmitted from the excited cutaneous nerves, are accelerated, and an increased amount of animal heat is evolved. If the cold be not excessive, the quickened respiration and augmented evolution of animal heat are permanent, and the creature maintains the standard of animal heat. If, on the other hand, the cold be excessive and continuous, the excitability of the sensory, excitor, and motor functions becomes lessened and exhausted, the circulation in the capillaries is diminished and arrested, the muscular powers are enfeebled and exhausted, mental energy gives place to drowsiness and torpor, the respirations become slower and slower, the animal heat sinks rapidly, and death ensues, either with the simple cessation of respiration, with convulsions, alternating with relaxation, or with tetanic convulsions and muscular rigidity.

Effects of external warmth and extreme heat on the Respiration of Warm-blooded Animals.

I continue the narrative, and relate the effect of external heat on animals expiring, or having ceased to breathe, under the influence of cold.

M. Chossat took a turtle dove which was on the point of expiring from inanition, owing to the loss of its animal heat, and exposed it to the warmth of a stove. Just before applying warmth the temperature of the animal was 73°.4. The creature was unconscious, the eyelids were open and fixed, and did not wink when irritated. Irritating the toes caused only the slightest movement of the hind limbs. Respiration was no longer appreciable.

In two minutes after applying the warmth the respirations became very marked ; in six minutes the respirations were good ; the creature was more animated, and it moved its head. In seven minutes winking was re-established ; in ten minutes respiration was natural. In forty-three minutes the creature's life seemed re-established, and it was then left. On being again observed, after exposure to the warmth for two hours and seven minutes, it was dead ; the head being thrown backwards, in a state of opisthotonos. The heat in the cloaca was 118°.4.

This experiment was repeated in twenty-five birds, when on the point of death from inanition. Food was given to them and three recovered; the rest died. Eight died in convulsions. In these there was a progressive diminution of sensibility and muscular force; they became drowsy, and at length lay extended. The successive attacks of convulsions which came on were sometimes violent, sometimes slight, and generally accompanied with opisthotonos. There was usually complete relaxation between the attacks; sometimes there was a general rigidity of the body, which usually indicated death.

Dr. Edwards found that when the young imperfect mammalia appeared on the point of expiring, some being, indeed, motionless and apparently dead, from exposure to cold, he easily restored animation by placing them before a fire. He cooled birds which were almost entirely fledged, so that they became very weak, and seemed ready to expire. These recovered as rapidly as the younger birds, when warmed artificially, but the recovery was only temporary, since they mostly died in one or two days.

John Hunter observed that when intense cold had forced blackbirds to take shelter in out-houses, such of them as had been caught, and were, from an ill-judged compassion, exposed to a considerable degree of warmth, died very soon. The death, he remarks, was owing to the degree of heat being increased too suddenly for the proportion of life remaining in the animal. Warmth causes a greater exertion of the living powers than cold; and an animal in a weakly state may be obliged by it to exert a quantity of the action of life sufficient to destroy the very powers themselves. These remarks of John Hunter's cannot be borne too strongly in mind in attempting to recover those almost or apparently dead from exposure to cold.

Sir Astley Cooper opened a snake, rigid and supposed to be dead, after having been immersed in alcohol. The heart was beating, and it showed some voluntary power. He put it into cold water, and the heart's action became languid and slow. It was then thrown into warm water—the action of the heart became quick and vigorous, and it began to move freely, recovering its voluntary power. It was then returned into cold water,—its voluntary power lessened, and its heart acted less frequently and vigorously.

Mr. Barlow relates,—"I decapitated an eel. I observed gaspings in the separated head, which ceased after a time. I now introduced my finger into the mouth, and pushed it into the posterior part of it, but failed to excite the act of deglutition, which would have followed had the excito-motory principle been vigorous. It struck me that I could restore the reflex actions by the use of warmth ; and therefore I put the head into water of about the temperature of 90°. Then there appeared frequent and energetic gaspings, and the act of deglutition could be induced by the same stimulus which was perfectly fruitless previous to the immersion." In this interesting experiment gaspings were re-induced by the external application of warm water, which restored the excitability of the incident nerves, and then excited reflex actions, after the functions of the nerves had been exhausted by comparative cold.

Cold, which at first stimulates the reflex functions, at length exhausts the excitability of those functions, while warmth restores their excitability ; but we must bear in mind John Hunter's experiments, and the pregnant examples afforded above in the treatment of narcotic poisoning. We must recollect that warmth, after restoring, may again exhaust—may even altogether annihilate the vitality of the excitor functions. In rousing the excitability of the reflex function we must not exhaust and annihilate it by the over use of one stimulant, such as warmth. Employ warmth in the degree suited to the remains of vitality ; do not prolong it—but, alternate with the warmth, some other stimulant, even cold itself, or friction, or ammonia, or even electricity ; whatever is done, however, must be proportioned to the remains of vitality. It is not the object to get a quick revival, ending most probably in fatal collapse, but to get a permanent recovery. In rousing the excitor-motor, we should attempt to rouse also the higher sensory functions, that so we may rouse the brain, one great fountain of nervous energy, and through it, of circulation, of respiration, and of the evolution of animal heat.

If the surface be exposed to a high temperature, the respirations are augmented in fulness and frequency. Mr. Barlow informs me that in descending into a warm bath, at a very high temperature, he can at first restrain the respirations ; but when the warm water covers a greater extent of surface, respiration is increased in spite of the efforts of the will. Here the reflex function, highly excited, overpowers volition, and respirations, full, frequent, and in continued succession, are excited, reflexly, by the warmth applied to the surface acting on the incident nerves and on the capillary circulation.

Delaroche and Berger exposed a cat, a rabbit, a pigeon, a yellow hammer, and a large frog, to a dry heat of 108°.5 to 112° ; the great number at first remained undisturbed, but in about half an hour they became agitated, and their respiration was progressively accelerated until it became panting. There was then a remission of the symptoms in almost all the animals. They remained exposed to the high temperature an hour and a half, and in half an hour afterwards they recovered. They were subsequently put into a stove at 133°.25, rising to 149°. All, except the frog, perished at various periods, varying from twenty-four minutes to one hour and fifty-five minutes.

The heat at the surface excites accelerated reflex acts of respiration, which tend to counterpoise the heat that excites them. The accelerated respiration increases evaporation, and becomes a cooling process. The same experimenters, as has been already stated, at p. 199, found that a wet sponge, a frog, and a damp porous jar, when placed in a stove at 126° to 140°, remained at a temperature of about 100°.

Under the influence of a moderate temperature the respirations are not so quick, and the generation of carbonic acid, and evolution of animal heat, are not so great as they are under the influence of a lower temperature. If the temperature be high, especially if applied through the warm bath, and still more if it be very high, the respirations are greatly accelerated; but the evolution of animal heat, by the formation of carbonic acid, is more than counterbalanced by the increased evaporation from the lungs. The heat acting on the surface accelerates the respiration by a reflex action.

If the heat be excessive, and long continued, the excitability of the nervous system and the vital energies become exhausted—debility, drowsiness, and torpor come on, the respirations cease, and death ensues, often, it would appear, with tetanic convulsions.

If the circulation and respiration, the excitability of the reflex and sensory functions of the nervous system, the contractility of the muscles, and the cerebral energy be enfeebled or exhausted by long-continued external cold, or by cold induced by inanition, the application of external heat restores circulation and respiration, the excitability of the reflex and sensory functions, the contractility of the muscles, and the cerebral energies; but in the adult animal, if the exhaustion from cold be excessive, and the application of external heat be long continued, and disproportioned to the vital energies, all those functions become again exhausted, and unless they are again restored, death ensues.

Let us once more trace the order of phenomena in which cold acts to accelerate and then retard respiration, and in which warmth re-accelerates and then again retards respiration.

Cold, when first applied, stimulates the circulation in the cutaneous capillaries, stimulates the sentient and excitor functions of the afferent nerves of the surface, and augments and accelerates respiration by a reflex action transmitted from the excitor nerves of the surface.

After being continued for a time, cold diminishes the capillary circulation, blunts sensation, depresses the excitor functions, diminishes and retards respiration, and lowers the animal heat.

At length the continued cold arrests the circulation in the capillaries, destroys sensation and consciousness, exhausts the excitor functions, and finally puts a stop to respiration, the animal heat being lowered from 20° to 30°.

If external warmth, either in the bath or before a fire, be applied immediately, or very soon after respiration has been arrested by cold, it renews the circulation in the superficial capillaries, restores the excitability of the incident nerves of the surface, re-excites respiration through the reflex function, and at length reinstates sensation and consciousness.

If the warmth be continued and moderate, circulation, respiration, the excitory, sensory, and motor functions of the nervous system, and the cerebral energies, are restored to their normal standard.

If, however, the continued heat be excessive, then torpor again comes on, the respiratory and nervous functions are again exhausted, and death ensues, often, apparently, with convulsions.

Influence of External Cold and Heat on the Circulation, and of the Circulation on Respiration.

We have just seen that in the cold-blooded animals external cold diminishes and at length arrests respiration, and depresses and almost arrests the circulation, while external warmth increases the circulation and excites respiration; and that in the active warm-blooded animals moderate cold excites increased respiration and circulation, while moderate warmth causes diminished respiration and circulation. The circulation as well as the respiration are excited or depressed by changes in the external temperature. Not only so, but the circulation in the capillaries is affected before the respiration. If the energies of the nervous system, especially of the nervous centres, be low, as in cold-blooded animals, external cold depresses the circulation at the same time that it depresses sensation and consciousness. If, on the other hand, the nervous energies be high, as in warm-blooded animals, the cold, up to a certain point, stimulates the circulation. If the nervous energies of the bee are roused when it is disturbed during the winter, its circulation becomes augmented. If, on the other hand, the nervous energies of the warm-blooded animal be blunted; if, for instance, it become sleepy or torpid, or pass into profound hybernation, then external cold causes depression of circulation in proportion to the depression of the nervous energy. If, however, the cold be so intense as to rouse the nervous energies, the circulation is then stimulated and augmented. If the nervous energies be lowered by inanition, circulation and respiration are lowered; and if sleep or torpor be superadded to inanition, then the circulation is proportionately still farther depressed. If the surface be suddenly exposed to cold, the peripheries of the nerves are excited, sensation is roused, and the capillary circulation is at the same time also roused; if the external cold be continued, sensation is blunted, and the superficial circulation lowered.

That the increase or diminution of the circulation is due to an action in the capillaries, and not to an action in the heart, is certain, since, if one arm be exposed permanently to cold, and the other to warmth, the circulation in one will be depressed, in the other maintained or exalted, and yet the same heart propels the blood through the blood-vessels of both limbs.

If the whole chain of instances be noticed, it will be observed that the excited or depressed circulation in the capillaries is connected with, and caused by, an excitement or depression of the peripheral nerves; the excitement of those nerves stimulating the capillary circulation, and the depression of those nerves lowering the capillary circulation. The same effects on the circulation are in fact induced, in whatever way the nerves be affected, whether they be stimulated or depressed by external agents, as cold, galvanism, or irritants, or by internal emotions, as rage or fear.

The palpable effect of depressing cold is to shrivel the surface, and to cause constriction of the superficial capillaries; exciting cold, on the other hand, renders the skin ruddy and the capillary circulation more vigorous; in one instance, less blood, and in the other, more blood than usual is admitted into the capillaries.

Warmth causes an increase in the quantity of blood in the surface, and general relaxation of the capillaries.

The circulation of the blood exercises a vivifying influence on the functions of the nervous system. Cut off the supply of blood from a limb, and motion, sensation, and the excito-motor functions of that limb are gradually paralysed; restore the circulation, and the functions of the nerves of the limb are gradually restored. The energy of the whole nervous system, both of the centres and the peripheries, is in proportion to the activity of the circulation. Wherever the incident nerves are numerous, "the fibres are in close approximation with a vascular plexus."

When the blood circulates freely in the organism, its presence serves as a stimulus to the afferent nerves; increased respiration being excited by a reflex action. On the other hand, when the circulation in the capillaries is diminished, the incident nerves are depressed, being deprived of the vitalising stimulus of the blood, and respiration is diminished or even arrested.

In the numerous instances previously given, in which respiration was immediately influenced by external agents applied to the surface, the respirations were manifestly affected through the medium of the excitor functions of the afferent nerves, the spinal marrow, and the reflex motor functions of the efferent nerves. In many of the instances the impression on the surface which excited respiration, excited also sensation, and it can scarcely be denied that here the sensory functions of the afferent nerves may have co-operated with the excitor functions in inducing respiration. In many of the instances, however, consciousness and sensation were absent, and yet the external stimulus produced the same effect on the respiration as if sensation were active. It is certain that in these cases the respirations were caused by the excitor functions of the nerves alone, the sensory functions being suspended. In fact the respirations were caused and influenced by a power which existed when sensation was present, and which existed also when sensation was absent, by a power which operated during sleep, sopor, lethargy, hybernation, and coma, as well as during active sentient life. While it is certain that in all these instances the respirations were excited through the reflex function of the nervous system, it is not proved that they were in any instance excited by sensation. In fact it is the necessary characteristic of respiration that it shall persist when sensation is suspended, else life itself would be dependent on consciousness.

Consensual Respiratory Movements.

While respiration is carried on in the absence of sensation there are some of the phenomena of respiration which seldom exist when sensation is absent, and which are excited by external impressions; among such phenomena are laughter, crying, and coughing.

Laughter may be excited by tickling the soles of the feet, the arm-pits, and in some highly and even morbidly impressible persons, by tickling any part of the surface of the body. I have a patient now under my care affected with symptoms referable to affection of the nervous centres, probably of the corpora quadragemina and adjoining parts; the pupils are small, sensation and motion are somewhat impaired. In this case, at a time when the limbs were unusually deficient in power, uncontrollable laughter was excited by the gentlest percussion over any part of the body; subsequently, when the muscular powers were greater, the surface could be freely percussed anywhere without exciting laughter. In hysterical persons the surface is morbidly sensitive, and in them hysterical laughter may sometimes be induced by merely touching the more sensitive parts of the body. I believe that in such instances laughter is in great part excited through the medium of sensation. Dr. Carpenter and Dr. John Reid have instructively illustrated the subject of the movements excited through the medium of sensation, movements happily classed as consensual by the former physiologist. Those respiratory movements due to sensation are evidently excited in a reflex manner, but such reflex movements differ essentially in character from reflex movements of the true spinal system. When the excito-motor functions are performed, the spinal marrow is the centre of the nervous arc formed by the afferent and efferent nerves. The spinal marrow merely transmits the impression from the excitor to the motor nerve, and is not itself necessarily stimulated to an independent centric action. It appears to me that the consensual reflex movements, such as laughter excited by tickling, are not the result of the mere transfer of the nervous force through the higher nervous centre from the afferent sentient nerve to the efferent motor nerve. I conceive that the nervous centres, probably the corpora quadragemina and adjoining structures, are roused to independent action by the stimulus applied to the afferent nerve; that the nervous centres, thus stimulated from the periphery, now act as a centric force, exciting, in the instance under consideration, laughter, by stimulating the associated motor nerves, not, so to speak, reflexly, but directly; just, in fact, as laughter is excited by certain humorous or ludicrous ideas; the mental emotion stimulates the nervous centre, which, in its turn, stimulates the associated motor nerves.

Laughter may exist during both the hysterical and the epileptic fit, when there is complete unconsciousness; but if the soles of the feet be tickled during sleep, or when sensation is paralysed, respirations and certain movements of the limbs are excited, but laughter is not excited. We thus see that when we stimulate the excitor functions only of the nerves supplying the soles of the feet, reflex movements are excited, but not the movements of laughter, while, when the sensory as well as the excitor functions of those nerves are stimulated, laughter is excited. I conceive that the conclusion is forced upon us that laughter, which is an interrupted, violent, expulsive respiratory act, when it is excited by tickling the surface, is due in great part to stimulation of the sensory functions of the nerves, and the consequent excitement of the nervous centre, and probably in part also to the co-operation of the excitor functions of the nerves.

When laughter is extreme the inspiration is crowing, owing to the noisy approximation of the vocal chords.

Smiling may be excited, as Dr. Hartley says, by gently touching the cheek of the child, it may also be excited by tickling the sole of the foot, so slightly as to be within that degree of tickling which would excite laughter. Smiling is essentially an inspiratory action, being an enlargement of the oral aperture for respiration; but while inspiration is perpetually being interrupted by expiration, and then again renewed, smiling is for a time continuous, whether excited by tickling or by a pleasing mental emotion. Smiling frequently exists with complete unconsciousness; indeed, it customarily takes place towards the end of the hysterical and the epileptic fit, before the restoration of consciousness. I believe that smiling may be excited in the infant by gently stroking the cheek, even when sensation is absent; if this be so, smiling may be induced by stimulating the excitor functions of the afferent nerves. I consider that smiling, like laughter, is essentially excited in the higher nervous centres. It is the characteristic of the act of smiling that it is continuous. This, as I shall have another occasion to show, is the characteristic of the actions excited in the nervous centres; they are thus readily contra-distinguished from the excito-motor or reflex actions—for while the former are essentially continuous, the latter are essentially intermittent, being perpetually interrupted and renewed, with the interruption and renewal of the excitor stimulus.

Crying is a phenomenon of respiration, which, like laughter, is seldom excited excepting in connection with sensation. While a pleasurable or tickling sensation excites laughter, a painful sensation may excite crying. In the young, and in those not trained to repress the emotions, pinching, cutting, or burning the skin, or otherwise causing pain, excites crying. Crying is a forcible expiratory act, accompanied by noisy approximation of the vocal chords. Owing to their approximation, the glottis is narrowed, the air is expelled slowly, and the expiration is prolonged. Groaning is a modification of crying, is excited by less active pain, and is often the irrepressible expression of those who can and do repress crying. Crying is frequently present when the person appears to be unconscious. The exposure of the new-born infant to cold excites a deep inspiration, followed by crying. In this case sensation is almost or altogether absent, and the crying is manifestly caused by the excitor functions only of the afferent nerves. Although crying is usually excited in connection with sensation, it is not so closely dependent as laughter on the sensory function of the afferent nerves. Usually both the excitor and sensory functions of the afferent nerves coincide in exciting crying, but sometimes the excitor, sometimes the sensory, function predominates.

Sobbing is caused by the repeated contact and noisy separation of the vocal chords during the inspiration which precedes crying.

Sometimes when pain is felt from any cause, but when it excites neither crying, groaning, nor sobbing, it occasions a sudden deep inspiration. Probably, in this instance, the inspiration is caused by the excitor function of the afferent nerves.

Coughing is frequently excited quite independently of disease in the lungs, by the mere exposure of the skin to cold. This occurs in persons who are morbidly sensitive to the influence of cold. A hard, dry, unproductive, troublesome cough is excited in them when they get into bed between cold sheets, or leave the warm bed in the morning and expose the general surface to the cold air, or put their feet on the cold ground; when they leave the house on a cold raw day; when they are exposed to draughts of cold air; whenever, in short, the skin is exposed to a sudden transition from warmth to cold. In these persons, instead of the skin becoming ruddy and glowing under the bracing influence of moderate cold, it becomes cold and shrivelled; instead of the inspirations being increased in fulness they are shortened and interrupted by a frequent cough. The employment of Dover's powder in these cases usually increases the capillary circulation, blunts the morbid sensibility of the surface, and checks the cough.

Many hysterical persons, who possess a highly sensitive surface, cough under similar circumstances. Frequently these persons are subject to a constant cough when awake; this cough is aggravated by external exposure, and by any mental emotion that may exalt still more the morbid sensibility of the skin. In these persons belladonna and henbane, in combination with tonics and other means, lower the morbid sensibility of the skin, increase the capillary circulation, and subdue the cough.

It is not usual for cough connected with morbid or exalted sensibility of the skin to come on during sleep; cough, however, does come on during sleep in other cases, and it may undoubtedly be excited quite independently of sensation by irritation of the larynx. In such cases cough is caused by the excitor functions of the superior laryngeal nerve. In that class of cases of which I am now speaking, connected with undue sensibility of the skin, the cough is, I conceive, excited both through the sensory and the excitor functions of the afferent nerves, and it is checked by invigorating the tone of the skin by friction, and by subduing the morbid sensibility by narcotics. It is to be observed that in these cases the morbid sensibility is coincident with a lowered tone of the surface, and an enfeebled constricted capillary circulation; and that as the lowered tone is invigorated and the constricted capillary circulation rendered free and normal, the same stimulus to the surface which previously excited cough then excites free deep respirations.

Effects of External Stimulus on the Expulsive Actions.

Under certain circumstances the expulsive actions, such as vomiting, the voiding of fæces and urine, and the act of parturition, may be excited by undue or morbid stimulus to the skin, especially when the contents of the stomach, the rectum, the bladder, or the womb are abundant and ready to be expelled. Extreme external cold after a full indigestible meal may excite nausea and vomiting. The inclination and effort to expel the fæces are often excited by the exposure of the nates to the cold air. On first getting out of bed there may be no inclination to void urine, but on baring the surface to the cold air the inclination is speedily excited. The flagging action of the uterus in expelling the fœtus, the placenta, or clots of blood, is often roused to efficient expulsive contractions by dashing cold water on the surface, or by exposing the surface to a current of cold air. This subject has received important illustration from Dr. Tyler Smith.

When the expulsive power over the rectum or bladder is feeble, one of the most certain and valuable means of augmenting that power is to rouse the tone of the skin habitually and healthily by external stimulants and friction. It is to be observed that the application of the stimulus to that part of the surface adjoining the viscus to be emptied has more effect on that particular expulsive act than its application to any other part; thus the cold dash over the abdomen rouses the expulsive powers of the bladder and uterus, while cold to the nates excites the evacuation of the fæces. It is an interesting practical illustration of this subject, that in cases of poisoning by opium, after repeated and powerful emetics have failed to excite vomiting, the dashing of cold water on the surface has often immediately led to the forcible expulsion of the poison, the food, and the emetics contained in the stomach. Two interesting illustrations of this are given at pp. 248 and 249.

Excitement of Respiration by Stimulus to the Mucous Membranes.

Professor Müller, by a happy generalisation, has shown that irritation of the mucous membranes induces acts of expulsion which are performed by the muscles of expiration. If any particular mucous membrane be irritated an expulsive action is excited, bearing usually on the region irritated.

If the mucous membrane of the nostrils be stimulated, sneezing, an expulsive effort clearing out the nostrils, is excited; if the mucous membrane of the larynx, trachea, or bronchi be stimulated, cough, an expulsive action clearing the larynx and trachea, is excited; if the fauces, pharynx, or stomach be stimulated, vomiting is excited; if the rectum be stimulated, expulsion of the fæces is excited; if the bladder be stimulated, expulsion of the urine is excited; and if the vagina or uterus be stimulated in the latter stages of pregnancy, the expulsion of the fœtus is excited.

In all these instances, especially if the act of expulsion be powerful, the expiratory effort forms, in whole or part, the expulsive power. I say the expiratory effort, not the act of expiration. The muscles of expiration are all excited to violent action, but owing to the closure of the glottis, or of the higher respiratory apertures, the expiratory expulsion of air from the lungs is arrested. If sneezing be excited the pressure of the tongue and the palate against the back of the fauces prevents the expiration, and the sudden removal of the obstruction permits the violent expiratory action to flush the obstructed nostril. If coughing be induced, the glottis is at first closed, and then suddenly opened by the noisy separation of the vocal chords, and the sudden and forcible expiration that follows expels from the larynx any obstructing secretion. If vomiting be excited the larynx is drawn forwards and pressed upwards under the base of the tongue, so as to prevent the egress of air from the lungs: all the apertures of expulsion are closed except those leading from the stomach; the stomach is compresed in front by the expiratory contraction of the abdominal muscles, and, singularly enough from above and behind, by the descent of the diaphragm, that muscle exchanging its inspiratory for an expulsive action. If the fæces be expelled while every other outlet of expulsion is closed, the sphincter ani is relaxed, the anus is opened, and all the expulsive efforts of the expiratory muscles bear upon that aperture. In like manner with micturition, and in like manner also with the expulsive pains of labour, for the physiological account of which I refer to the work of Dr. Tyler Smith. In each of these instances some individual opening or sphincter is relaxed, and the expiratory muscles are roused to action, through the excito-motory functions, so as to bear alone upon that opening, the respiratory and every other aperture being closed.

It is to be observed that all the expulsive actions are usually preceded by a deep inspiration. The increased quantity of air in the lungs gives a better purchase and greater force to the expiratory muscles of expulsion. It follows from this that the stimulus applied to the mucous membrane excites reflexly a deep inspiration, followed by a violent expulsive effort; the expulsive effort being the object of the whole action.

Of the various acts just spoken of, which may be excited by stimulating the mucous membranes, and which involve the employment of the respiratory muscles, sneezing and coughing are more particularly respiratory acts.

Sneezing is excited in health by tickling or irritating the nostrils. In those who have "a cold in the head," sneezing may come on spontaneously, being excited by the morbidly sensitive or excitable state of the nasal mucous membrane. Sneezing is almost always performed by the healthy person in connexion with excited sensation. When it occurs spontaneously, from an irritable state of the nostrils, it sometimes takes place during sleep; this is evidenced in a little girl now under my care, affected with bronchitis. Although sneezing may evidently be classed among the consensual movements, yet, in some instances, it appears to be caused solely by stimulating the excitor functions of the afferent nerves of the nostrils, and probably it is always, in part at least, an excito-motory phenomenon. When sneezing is excited by a strong light irritating the eye, it is probably in great measure due to excited sensation.

Cough, excited by irritation of the larynx, trachea, or bronchial tubes, does not differ in mechanism from cough excited by the exposure of a sensitive skin to cold. In the latter case the cough is almost always connected with excited and depraved sensation, and is only brought on when the person is conscious: in the former, although it is usually excited only during the waking state, yet it often occurs when the patient is asleep. It is manifest that the cough, in these instances, is caused by stimulating the excitor functions of the superior laryngeal nerve in the larynx, or of the par vagum in the bronchial tubes.

The superior laryngeal nerve, in its excitability to impressions, presents some remarkable and interesting phenomena. Although the mucous membrane of the larynx appears often to be but comparatively slightly irritated by such caustics as the nitrate of silver, yet pure carbonic acid excites instantaneous and complete closure of the glottis. The superior laryngeal nerve would appear indeed to be specially and highly endowed with excitor functions, and yet comparatively but slightly with sensory functions. In this respect that nerve, as well as most of the nerves distributed to the mucous membranes, differs from the afferent nerves distributed to the skin, for those nerves, as we have already seen, are both exquisitely sensitive and highly excitor.

The superior laryngeal nerve is so endowed as to be the guardian of the glottis, and, through it, of the lungs. While carbonic acid, a gas immediately poisonous to the blood, excites, when pure, closure of the glottis, nitrous oxide, hydrogen, and nitrogen, gases not immediately poisonous though incapable of supporting respiration, do not excite closure of the glottis. Carbonic acid, when pure, nitric oxide, and other poisonous gases, are consequently irrespirable, whereas nitrogen, hydrogen, and nitrous oxide, are respirable. The inestimable life of Sir Humphry Davy was saved by this guardian function of the superior laryngeal nerve; for when he attempted to inspire nitric oxide, the stimulus of that gas caused instant closure of the glottis, and the great philosopher escaped; his mouth and fauces only being scorched by the acrid nitrous acid fumes.

It is an interesting fact, that while the superior laryngeal nerves prevent, by the closure of the glottis, the ingress to the lungs of the poisonous gases, they often do not prevent the ingress of air charged with irritating particles; thus the Sheffield knife-grinders can breathe an atmosphere charged with steel dust, which causes in time fatal disease in the lungs; and pulmonic patients can breathe air charged with finely powdered nitrate of silver.

The closure of the glottis, just spoken of, takes place during inspiration, and is usually silent. If the closure be incomplete, the vocal chords being approximated in the vocalising position, the inspiration is stridulous or whooping.

There is a morbid modification of the excitor functions of the superior laryngeal nerve with which it is practically important to be acquainted. Many persons who have no affection of the lungs or heart, are subject to dyspnœa and palpitation if they walk quickly, run, or ascend a flight of steps. This is due to a deficiency in the muscular control over the glottis. In health the vocal chords are drawn asunder during each inspiration, so as to widen the glottis; the extent to which the glottis is widened being exactly proportioned to the volume of the inspiration and the extent of the inspiratory muscular effort. The persons of whom I now speak want this power; they cannot expand the glottis in proportion to the inspiratory effort; in consequence of this the glottis is narrow, and is still farther narrowed by the effort of inspiration, the column of inspired air tending by its pressure to push the vocal chords nearer to each other; an adequate supply of air cannot enter the lungs through the narrow glottis, and dyspnœa and palpitation are the result. The glottis is thus narrowed in persons having an inflamed or irritable larynx; in those affected with hysteria, or with a morbidly sensitive surface and exalted excito-motor functions; and in those also who are deficient in excito-motor power.

In those in whom the excito-motor functions are morbidly exalted, and in those also in whom those functions are enfeebled, the balance of excito-motor power is restored by the same remedial means; I allude to the effect of the general stimulation of the surface by dashing on it cold salt water, and by external friction. These means excite healthy deep inspirations, in which the glottis is expanded in harmony with the inspiratory efforts. It is to be observed that the same phenomenon, deficiency in the circulation through the cutaneous capillaries, may produce in one person exquisite sensibility and an exalted or depraved excito-motor function of the nervous system, and in another, blunted sensibility and enfeebled excito-motor function. It is also to be noticed that in the same person diminution in the capillary circulation at the surface, under the influence, for instance, of external cold, will at first exalt, then depress, and if the cold be long continued and intense, at length extinguish the sensory and excitor functions. In all such instances, in the order of the phenomena, the sensory cease before the excitor functions of the peripheries of the afferent nerves; hence the respirations, excited by the reflex functions, may be carried on for an indefinite time during complete anæsthesia, if the influence exhausting the peripheral functions of the nerves be not too great.

If a person attempt to inhale either the undiluted vapour of ether or chloroform, or pure carbonic acid, inhalation is instantly and completely prevented by the silent closure of the glottis. If the vapour or gas be copiously diluted with air, the mixed atmosphere can be respired freely. If only moderately diluted, inspiration may be sometimes silent and free, sometimes stridulous and difficult, owing to the noisy approximation of the vocal chords, or it may be suddenly checked by closure of the glottis, followed immediately by a noisy cough; the closure of the glottis and the cough being excited in a reflex manner, owing to vapour or gas stimulating, through the mucous surface of the larynx, the excitor functions of the superior laryngeal nerve.

We thus see that a stimulus applied in the larynx to the superior laryngeal nerve, may excite during inspiration, according to its degree, either complete closure of the glottis, stridulous inspiration, or narrowing of the glottis; while during expiration it may excite cough, the cough being hard, dry, and unproductive, or easy and followed by expectoration, accordingly as mucus or a foreign body is present or not in the larynx.

If the sputa be tenacious and tough, or glazed and frothy, or stringy, the expectoration is difficult, the cough long-continued; the sputa not being expelled all at once, but by a series of repeated efforts. If the sputa be in rounded nodules, each portion is expelled by a single easy cough; sometimes, indeed, such sputa are expelled unconsciously and without effort. Bloody sputa, especially the rusty, sticky sputa, of pneumonia, are usually only expelled by a repeated, laborious, and troublesome cough; but pure blood is often, curiously enough, expelled through the larynx from the bronchial tubes in large quantities, without exciting any cough, and with comparatively little expulsive effort; with an expulsive effort, in fact, which often appears to be, and may easily be mistaken for that kind of vomiting by means of which the clear secretions of pyrosis are expelled.

If the sputa cling to the vocal chords, and are with difficulty expelled, they excite not only cough but also narrowing of the glottis, owing to the approximation of the vocal chords. Thus the dyspnœa occasioned in bronchitis by the obstruction to inspiration caused by the presence of mucus in the bronchial tubes, is increased by the additional obstruction caused by the narrowing of the glottis.

Irritation of the larynx tends to excite narrowing or even closure of the glottis, both during inspiration and expiration. If the sputa loiter in the larynx, or if the cough, though dry, be troublesome, the glottis is usually narrowed. In whooping cough it would appear as if the crowing inspiration were occasioned by the irritation in the larynx, caused by the previous severe cough. Public speakers are sometimes affected, when fatigued by long speaking, with stridulous inspiration in the manner pointed out by Mr. Bishop. Laughter often appears to excite crowing inspiration, and crying frequently gives rise to sobbing. Indeed it appears that any stimulus that may excite closure of the glottis during expiration may also excite silent or noisy approximation of the vocal chords, or closure of the glottis, during inspiration. Thus, pain at the surface, or a plunge into a cold bath, may excite in the young both sobbing and crying. Tickling the feet may excite both crowing inspiration and laughter. Irritation to the surface of persons susceptible of the application of cold may excite both stridulous inspiration and coughing.

While it is amply proved that cough may be excited by stimulating the superior laryngeal nerve through the medium of the mucous membrane of the larynx, the proof is not so extensive which shows that coughing may be excited by stimulating the pulmonary branches of the vagus through the medium of the mucous membrane of the bronchial tube. It is, however, sufficient.

Mr. Erichsen inserted a probe through a very small opening into the trachea; when he passed it upwards to the larynx coughing was excited, an effect which has been observed by many physiologists. He then passed the probe downwards into the bronchial tubes, and when he stimulated their surface coughing was again excited. No other experimenter, excepting perhaps Dr. John Reid, has taken the precaution, when inserting an irritating substance through the trachea into the bronchia, of making the tracheal opening so small that all the expired air should pass through the larynx, and none through the tracheal opening. When this precaution is not taken, when all the expired air can rush out through the tracheal opening instead of the larynx, effectual coughing is necessarily replaced by general expulsive movements.

Haller opened the trachea and applied butter of antimony to its lining membrane; the animal tried to cry, but did not cough. In another experiment, irritation of the tracheal mucous membrane with sulphuric acid and the scalpel produced no effect. Brachet found that violent coughing was excited when the fumes of hydrochloric acid, and other irritants were passed into the bronchial tubes, before the division of the vagi; but that after their division no such effect was produced. Dr. John Reid conjectures with reason, that in these experiments the irritant reached the larynx. He found that irritation of the larynx excited violent cough, but the effect ceased when he divided the superior laryngeal nerves. The same physiologist observed, that on injecting cold water into the bronchia, through a small opening in the trachea, in some experiments it excited coughing, in others it did not. In one instance, when cold water was injected into the tube, cough was not induced, but when alcohol was injected, efforts to cough were excited; on injecting the alcohol a second time the animal remained perfectly quiescent. In another experiment, alcohol, when first injected, excited coughing; the vagi were then divided, and the renewed injection of the alcohol produced no effect. In another experiment, after the vagi were divided, alcohol was injected into the trachea, and a drop of muriatic acid was placed in the trachea, without exciting uneasiness or cough.

I divided the trachea in a chloroformised dog (experiment at p. 238); when it had recovered consciousness, I several times passed a probe through the opening in the trachea upwards to the larynx, and I thus invariably excited strong expulsive efforts, analogous to coughing. I then scratched the surface of the trachea without perceptible effect. I afterwards passed the probe downwards, and scraped the surfaces of the larger bronchia, and thus excited strong expiratory or expulsive efforts, evidently analogous to cough; on renewing the friction, the expulsive efforts were renewed with more or less power.

These experiments prove, that while irritation of the interior of the larynx excites violent cough, through the medium of the superior laryngeal nerve; irritation of the trachea causes very little effect on the respiratory movements; while irritation of the bronchia excites coughing through the medium of the pulmonary branches of the vagi, but the cough can neither be so certainly, violently, nor repeatedly excited by stimulating the bronchia as the larynx.

While foreign bodies in the bronchia sometimes do excite cough, sometimes they do not; when they pass backwards into the larynx they invariably cause violent cough and general struggling.

Diseases of the tissue of the lungs, involving the bronchial tubes, while they sometimes do excite cough, sometimes do not. In some cases of phthisis, pneumonia, and bronchitis, cough is not excited unless and until the sputa reach the larynx. In other cases again the cough is constant, dry, and harassing. In these the cough is doubtless excited in the bronchial tubes through the medium of the vagi; and in many cases also by the stimulus of external impressions acting on the skin, and exciting cough reflexly through the afferent cutaneous nerves, as in the instances already related.

I have already considered those cases just referred to, in which violent dry cough is excited, owing to the morbid excitability of the surface, the lungs and air passages being perfectly healthy. Analogous instances are frequent in which the same kind of cough is caused by some affection of the mucous membrane of the stomach or uterus, the lungs being themselves healthy. It may be questioned whether, in some of these cases, the cough is immediately excited by the impression on the incident nerves of the affected mucous membrane, or by the morbid excitability of the surface, which is so frequently induced by the disorders in question of the stomach or womb.

Sometimes, as in whooping cough, when the cough is violent, long-continued, and fruitless, the action of coughing seems to pass into that of vomiting.

In bronchitis, with difficult expectoration, vomiting acts both to expel the food from the stomach, and the sputa from the bronchial tubes. Indeed, it is frequently to be observed, that vomiting is simultaneously an expulsive action from the stomach, and an expiratory action from the lungs, the glottis not being absolutely closed, but permitting a forced noisy stream of air to be ejected from the larynx. Owing to the forcible and continuous compression of the whole lungs, the patient ejects, simultaneously, fluid from the stomach, and sputa, as well as air, from the bronchial tubes, with a relief that can be gained, in extreme instances, by no other means whatever. I have already referred to the extraordinary manner in which blood is often expectorated from the bronchial tubes, as it were by vomiting. In these instances one or two expulsive actions almost clear the bronchial tubes of the effused blood, rendering it difficult to detect the seat of the hæmoptysis, either by auscultation during life, or by autopsy after death.

Excitement of Respiration by Stimulus to the Afferent Nerves distributed to the Serous Membranes and the various Tissues.

We have seen that if the healthy skin be stimulated a deep inspiration is excited, and that if the skin, when morbidly sensitive, be stimulated, coughing or some other expulsive action may be excited. We have also seen that if the mucous membranes be stimulated an expiratory expulsive action, usually preceded by a deep inspiration, is excited.

Acts of inspiration, expiration, and expulsion, may also be excited by stimulating the afferent nerves of the system.

If any of the nerves of sensation be irritated, so as to give pain, loud cries and deep inspirations are excited.

Vomiting may be excited by extensive injuries to the lower limbs, and by injury or disease of any of the abdominal and pelvic viscera.

When the healthy serous membranes are stimulated, as Haller has shown, no apparent effect is produced ; neither sensation nor motion being excited.

If the serous membranes be inflamed, sensory and reflex phenomena are excited. If the pleura be inflamed, cough may be excited. This effect is not, however, invariable, for in many instances of pleuritis, with extensive effusion, cough is quite absent. Cough is most severe, and most frequently present, in those cases in which inflammation affects the pleura lining the diaphragm, and, though less frequently, that lining the intercostal muscles. The cough is, in fact, most frequently present and most distressing in those cases attended with pain. If peritonitis be excited by the effusion into the peritoneum of a foreign irritating substance, such as urine or fæces, vomiting is almost invariably excited.

Influence of the Brain on Respiration.

The brain is not essential to the movements of respiration. Legallois and Flourens found that after the removal of the cerebrum and cerebellum, respiration continues, provided the medulla oblongata be untouched. Although respiration may be performed independently of the brain, yet it is greatly influenced by that organ. We have seen above, from the experiments of Sir Benjamin Brodie and others, the great effect which the brain exercises over respiration, and over the evolution of animal heat, that essential product of respiration.

Chossat removed the brain in a dog. During the first hour (see the Table at p. 196), the respirations were only 11 in the minute; they then gradually increased in rapidity, so that during the third hour they were 101 in the minute; after this they gradually diminished in frequency, sinking to 40 per minute in the sixth hour, and 11 in the seventh. This rate was maintained to the end; the animal survived the operation twelve hours, and during the last hour the respirations were 12 in the minute. During the time that the dog breathed so very quickly, its body cooled with remarkable rapidity, namely 5°·6 in the hour. Another dog killed by division of the medulla, and exposed to the air, cooled in the corresponding hour only 4°, and another, similarly served, on which artificial respiration was performed, lost in the corresponding hour only 3°·8. Afterwards, when the respiration became slower, the rate of cooling diminished materially, so that, at the eleventh hour, when the respirations were but 13 in a minute, the body had only cooled down 27°·5, while the untouched body had lost 29°·8, and that on which artificial respiration was performed had parted with 31°·3. Dr. Reid removed the cerebrum and broke up the cerebellum in a kitten a day old, and the number of respirations fell from about 100 to 40 in the minute. In another kitten, after the like operation, they fell from 120 to 40. It is to be remarked, as probably bearing some reference to the discrepancy, that while Dr. Reid employed kittens, Chossat operated on a full-grown dog.

We see, from these experiments, that the influence of the brain on the mechanism of ordinary respiration is by no means so great as the influence of that organ on the essential processes of respiration which go on everywhere in the organism, and which, while they assist in the removal of the waste, and the renewal of the fresh materials of the frame, at the same time evolve and maintain animal heat. If the influence of the brain be cut off from any particular limb, as it is in paralysis, the respiratory changes do not go on to the same extent in the paralysed as the sound limb ; the former limb being colder than the latter, and the circulation in it less vigorous.

As a general rule, having however numerous exceptions, the larger the brain the more active is respiration. This rule is still more marked with regard to the cerebellum, for there is usually a coincidence between the development of the brain, and the development of the respiratory apparatus and functions. It is not that respiration, either in the excitement of its mechanism, or in its essential processes throughout the organism, is so materially regulated by the cerebellum; but that those animals which have a vigorous physical frame, and an active physical life, possess a highly developed cerebellum, on a law laid down with great clearness by Professor Owen and Dr. Carpenter. When the exercise of the animal powers is vigorous, respiration is vigorous.

Influence of Volition on Respiration.

Voluntary respiration, in the strict meaning of the term, is seldom practised; indeed scarcely ever, excepting by the physiologist when observing the respiratory phenomena; or by the patient or other subject of observation, when desired by the medical attendant to breathe deeply, slowly, or quickly.

When a person speaks, sings, or smells, his respiration is in one sense voluntary; that is to say, it is taken as often, and as fully, as the person requires for the exercise of a function which is strictly voluntary. When I will to speak, sing, or smell, I necessarily will to breathe, but my mind is not occupied with the act of breathing, but with the act of speaking, singing, or smelling.

When we perform the infinite modulations of speech and music our respiration is under the most exquisite and varied control of the will.

The influence of the will over speech and music comprehends the highest manifestation of respiration. This is a subject of which I do not here treat. Its successful cultivation by Professor Müller, Sir John Herschel, Mr. Bishop, Mr. Willis, and many other physiologists and philosophers, enables me to refer with much satisfaction to their monographs on the subject.

Influence of Emotion on Respiration.

Under the influence of violent rage, with a tendency to violent action, the surface becomes instantly excessively red and turgid; the inspirations become quick, full, and energetic, and are performed by the whole associated action of respiration; the nostrils are excessively dilated, the lips are separated, the mouth and fauces are widened, the upper jaw is raised by the action of the muscles depressing the occiput, the lower jaw is depressed, the base of the tongue moves forward and the soft palate is rendered tense; the glottis is excessively widened; the shoulders are raised, the ribs are expanded to the full, and the diaphragm descends to the utmost.

This excited state of the circulation and respiration does not immediately cease on the cessation of rage, but continues for a time, the accelerated condition subsiding gradually; just as we observe that respiration and circulation, once quickened by violent exercise, continue to be accelerated for some time afterwards.

If the rage lead to violent action, the chest is dilated to the full, the breath is held, the glottis being closed, and a powerful and fixed bearing is thus given to all the muscles of the frame, which are exerted with a remarkable and exalted power, under the influence of rage, excitement, or maniacal delirium; so that a feeble frame is endowed for the time with a strength capable of resisting the combined efforts of the strong. Shakspere has thus described this source of power:—

> "Stiffen the sinews, summon up the blood,
> Disguise fair nature with hard-favour'd rage;
> Then lend the eye a terrible aspect;—
> Now set the teeth, and stretch the nostrils wide;
> Hold hard the breath and bend up every spirit
> To its full height!"

During the bursts of deep grief the face becomes flushed and hot, a peculiar sensation is felt in the fauces and top of the nose, tears gush from the eyes, mucus flows from the nostrils, the mouth is sometimes dried up, sometimes filled with saliva; a deep, sudden, often sobbing inspiration is taken, with dilated nostrils, severed and retracted lips, and widened mouth and fauces, followed by a vehement, often crying expiration. The succeeding inspirations are quick and deep, and they continue to be so for some time after the subsidence of the paroxysm, gradually resuming and often even falling below their usual quiet standard.

Under the influence of mirth a deep inspiration is excited, the nostrils are much dilated, and the mouth is opened to the widest, the expansion of it being outwards and downwards, under the influence of mirth, while it is outwards and upwards under the influence of grief; at the same time all the inspiratory muscles are in powerful action. The inspiration is sometimes repeatedly interrupted by the successive closure and opening of the glottis; sometimes it is crowing, owing to the vocalising position of the vocal chords. It is an interesting fact, that under the influence of rage, grief, and mirth, the glottis, instead of being normally widened during inspiration, in exact proportion to the extent of the muscular inspiratory efforts, is in many instances actually narrowed or even entirely closed. When laughter is hearty, the expiration is exceeding powerful, and is made in a series of laughing jerks, the breath being suddenly stopped and renewed by the alternate noisy closure and opening of the glottis. In violent laughter, almost all the muscles of the body and limbs are engaged in the successive and alternate actions of inspiration and expiration.

Under the influence of terror, the surface become excessively pallid and bloodless; a cold sweat breaks out over the skin. The whole frame, as well as the muscles, are relaxed; the sphincters often give way; the respirations are often at first short and panting, and then few, feeble, and irregular.

Under the influence of certain depressing mental impressions the surface is of a deadly pallor, the pulse is almost or altogether absent, the respirations are suspended, or fetched at distant and irregular intervals, all the muscles are relaxed, and the person sinks to the ground unconscious. The unconsciousness follows the cessation of the respirations, the cessation of the respirations succeeds to the universal check to circulation. This syncope may even prove fatal, especially if the body be maintained in a sitting posture.

There is every variety of influence on the circulation and respiration between the extreme effects of depressing emotion and of rage.

In all these instances, with the exception perhaps of laughter, the circulation is first affected by the mental emotion, and then the respiration. Indeed, whenever the respiratory phenomena are affected the circulatory phenomena must be affected also; circulation being, in one sense, a part of respiration, and respiration a part of circulation.

Under the excitement of anger, "scarlet indignation," the surface becomes instantly red from the augmented circulation in the capillaries, and the heart beats with tumultuous power. Under the influence of extreme depressing emotion, the capillaries of the surface become instantly empty and blanched, and a death-like pallor spreads over the countenance and surface. If syncope do not take place, the heart flutters and palpitates irregularly; if it do, the heart's action even ceases, or becomes imperceptible for a time.

The Respiratory and Circulatory Phenomena in Syncope. Cases.

In the following cases, which occurred among the patients of the Nottingham General Hospital, I observed the phenomena of syncope in especial relation to respiration and circulation.

Hannah Seals, a young woman aged 18, in delicate health, became faint, pallid, and bedewed with perspiration, on seeing a boy's finger cut. Pulse very feeble, 84. Respiration 40 in the minute; each act of respiration being very slight. On dashing cold water on her face she drew a very deep inspiration, after which her inspirations (39 in the minute) were much deeper, and the pulse (100) was much stronger than before. She soon revived; and twenty minutes afterwards the respirations were 28 in the minute, the pulse 100.

This person had suffered much from gastric pain. The paroxysm was evidently mixed, being partly but mainly due to syncope and partly to hysteria.

January 9, 1843, Thomas Newton, an athletic, pale-faced man, a frame-work knitter, aged 48. Until very lately he has had very good health. Of late he has been unable to retain his water longer than an hour at a time, and he has had occasional dyspnœa.

He came this morning with fracture of the metacarpal bone of the thumb. When examined he complained of intolerable pain, and began to weep; he suddenly became insensible and sank into a chair, his face being of a deathlike pallor, his pulse quite imperceptible. The respirations could not be perceived, and he became more and more ghastly. The chair on which he sat was placed down on its back, so that his head was lower than his feet. His pulse immediately became perceptible (about 90), and he began to struggle convulsively, owing, apparently, to inability to perform an expiration. On dashing cold water on his face he drew a deep inspiration, and continued to breathe 28 times in a minute. On raising his chair, he being still insensible, the pallor returned ; the pulse (about 50) was very irregular and intermittent, there being sometimes an interval of three or four seconds between the beats ; the respirations were about 12 in the minute. On dashing cold water on the face, the respirations increased to 28 in the minute, the pulse being about 80, irregular. His intelligence gradually returned.

After half an hour, pulse 72, feeble ; respirations 14 to 15 ; his lips were red, his countenance pale.

George Walker, aged 32, suddenly fainted while waiting in the surgery to have a tooth extracted. He was suffering from toothache, and was standing near the fire. He was immediately laid gently on the ground ; his face was dark and livid ; breathing could not be perceived. The dashing of cold water on the face excited an immediate very deep inspiration. The repeated renewal of the cold dash caused each time a renewed deep inspiration. He soon revived.

October 14, 1842, Ann Oakland, a pale, feeble woman, applied with recent stiffening, from injury, of the joints of the ring finger. To restore the power of flexion, the joints were suddenly bent. Severe pain ensued ; she breathed quickly, each expiration commencing with a short cry or moan. Pulse feeble, quick. Her surface became very pale ; large drops of perspiration exuded over her lips and face. The respirations diminished in frequency, but each respiration still commenced with a faint cry. The respirations were 14 to 16 in a minute. Pulse 36, feeble. Her face became ghastly, her eyes were turned up, her appearance was death-like. She was placed in the recumbent posture; the respirations soon quickened; they were short, little air being drawn in during each inspiration, and each expiration being still interrupted with a cry. At first there were 8 inspirations in ten seconds, then 3 or 4, and then the respirations varied. Pulse about 60, feeble. On dashing cold water, and on wafting cold air over her face, she drew deep inspirations. She felt revived; pulse 80 to 100, feeble. A draught of sal volatile was given; the respirations, formerly 20 in the minute, rose to 10 in fifteen seconds, each respiration being still accompanied by a cry. The surface now became warmer and less livid. The expiratory interruption shortly ceased; the respirations varied from 20 to 26; the pulse from 70 to 90, feeble. She recovered slowly. Half an hour afterwards, when near the fire and warm, the respirations were 16 to 20, irregular, occasionally performed with a deep sigh; the pulse 100.

In the case of a lady affected with hæmoptysis, venesection was decided upon. The lancet was plunged into a vein; it gaped wide open, but not a drop of blood flowed. It was then resolved to open the vein in the opposite arm. She said, "Don't you fear me." She took the cup in her own hand and held out her other arm. The lancet was thrust into the vein, and although, like the other, it gaped wide open, yet no blood flowed. The medical attendant, after gazing for a moment on the gaping orifice, turned his glance on the face of the patient, who seemed to be at that moment expiring, her death being instantaneous.

In this remarkable case, which was related to me by Dr. Boott, the mental emotion arrested the circulation before the loss of consciousness. After a time, however, unconsciousness and death instantly supervened, induced no doubt by the arrest of the circulation through the brain.

Having seen above, at p. 290, the effects of cold and warmth on the circulation, I shall here consider the influence of the brain on the circulation (a subject already illustrated at p. 206), and the influence of the circulation in the capillaries on the action of the heart.

The first phenomena observed in Seals were pallor and cold sweat; she was still sensible, but would have fallen unless she had been laid down.

Influenced by the depressing emotion inducing syncope, the circulation instantly ceases in the superficial capillaries, and the blood in them passes onwards, owing to their universal constriction. The retrograde action of the peripheral organs of circulation, the capillaries, on the central organ of circulation, the heart, is in such cases full of interest. The blood, just before the emotion which caused the syncope, had been sent freely onwards by the heart through the open capillaries; under the influence of the depressing emotion, the capillaries are suddenly closed, so that the blood cannot be sent into them; the heart makes powerful efforts to send the blood forward, but, unequal to the task, it is overwhelmed and for a time ceases to beat. Dr. Paris relates, that after death from syncope the heart has been found to be distended with blood to an unusual degree. Zimmerman says that "many observations tend to prove that sudden fear has caused syncope and even death. The face grows pale, the blood seems to stop in the vena cava, or in the right auricle of the heart, the vessels become distended, and the heart itself in these cases has sometimes burst." Philip V. died suddenly, on being told that the Spaniards had been defeated. On opening him his heart was found ruptured. Dr. Stroud, in his work on the *Death of Christ*, relates cases in which the heart was ruptured under the influence of intense mental agony.

The influence of obstruction to the circulation through the systemic capillaries on the left ventricle and auricle, is undoubtedly the same with the influence or obstruction through the pulmonic capillaries on the right ventricle and auricle. The influence of the obstruction to circulation through the pulmonic capillaries on the right side of the heart, has been often and well observed. Sir Benjamin Brodie poisoned a dog with tobacco; immediately after respiration had ceased, he opened the thorax. He found the heart extremely distended, and without evident contraction, except at the appendix of the right auricle. In dividing the pericardium, the fibres of the heart were irritated with the point of the scalpel. Immediately both auricles and ventricles began to contract with considerable force, so as to restore the circulation. Dr. John Reid, Dr. Cormack, and Dr. Lonsdale observed that, under the influence of certain narcotic poisons, the pulmonary circulation was obstructed, and the right auricle and ventricle were enormously distended, the heart's action being suspended. In some of these instances, on relieving the distension by opening the jugular vein, the movements of the heart and the circulation were resumed. In like manner, the influence of the obstructed circulation through the systemic capillaries, during syncope, causes excessive distension and suspended motion of the left ventricle and auricle.

Under the influence of rage, with a tendency to violent action, the opposite effects to those in syncope are excited on the circulation. The emotion of rage calls immediately into the capillaries an increase in the flow and amount of blood. The surface becomes instantly scarlet; the pulse is bounding, and the heart beats violently. In this case, the capillaries are at first increased in size by the emotion; they are not, however, excessively relaxed. The flow of blood into and through the capillaries, instead of being interrupted or impeded, as in syncope, is rendered more free and rapid. The heart consequently propels the blood onwards with greater facility, and in larger quantity, than it does ordinarily.

The effect of the emotions on the circulation is transmitted, by the nerves, from the brain to the systemic capillaries ; in syncope, the capillaries are contracted, in rage they are enlarged. The heart's action, so to speak, is affected in a retrograde manner ; being overcome in syncope by the effective resistance offered to the flow of the blood through the capillaries, and by the consequent excessive distension of the organ ; and being increased in power by rage, owing to the increased facility for propelling the blood onwards through the capillaries and to the increased supply of blood received by the heart.

The subject is illustrated by the difficulty experienced in working a fire-engine when the hose is twisted and the stream obstructed, and, on the other hand, by the ease with which it can be worked when the hose is cut across.

That the brain acts on the heart through the medium of the capillaries, and not on the capillaries through the medium of the heart, is additionally proved by the fact, observed by Dr. Wilson Philip, Sir Charles Hastings, Professor Müller, and others (and which I have myself observed on several occasions), that after the heart is cut out there is for some time a certain oscillatory movement of the blood in the capillaries, both in the web of the frog's foot and in the mesentery of the rabbit. The instantaneous influence of the brain on the capillary circulation is well illustrated by an observation of Dr. Thomson, who noticed that when a frog was merely touched the circulation in the web stood still for a moment. That this was owing to the emotion of fear was evident, since, if the touch was repeated again and again, so as no longer to excite emotion, the circulation was no longer affected. How remarkably does not this sudden action of the brain, through the nerves, on the capillary circulation contrast with the comparatively feeble and slow influence of cutting out the heart, in arresting the capillary circulation.

Dr. Wilson Philip and Sir Charles Hastings found that on crushing the brain, the capillary circulation and the heart's action ceased instantaneously. Dr. Marshall Hall observed, that on crushing the thigh, the heart's action ceased or became feeble. I conceive that in both these instances the enfeebling or arrest of the heart's action was due to the sudden interruption to the circulation through the capillaries. If the capillary circulation be diminished or arrested by exposure to cold, the same effect in diminishing or arresting the heart's action is induced as when the capillary circulation is interrupted by emotion. In all these instances the effect upon the heart's action is of course retrograde from the capillaries.

The state of the pulse depends more upon the circulation through the capillaries than upon the force exercised by the heart. We can, indeed, accurately anticipate the state of the pulse by the appearance and feel of the limb. If one arm be cold and pallid, the other warm and ruddy, the pulse of the pallid arm will be feeble, of the ruddy arm comparatively strong. This difference in the pulse of each opposite arm is equally observed, whether one arm be cold from external exposure, while the other is warm, owing to external covering; or whether one arm be paralysed, and therefore cold, owing to disease of the brain, while the opposite arm, being healthy, is warm. If the resistance to the circulation through the capillaries be diffused, as in syncope, over the whole body, instead of being confined to one limb, the obstruction in the capillaries will necessarily re-act in a retrograde direction upon the heart, and oppress, retard, or even arrest its action.

The mechanism of the retrograde influence of the circulation in the capillaries on the action of the heart may be readily imitated. If you adapt a large tube to an india-rubber bottle containing water, the slightest pressure will suffice to expel the fluid quickly; but if you adapt only a very fine tube, the most powerful pressure can only force out the fluid slowly and with difficulty. If, while the liquid is coming off slowly in a very fine stream, you continue to force more water through a valvular opening into the bottle, it will necessarily be more and more distended. The left ventricle, in relation to the capillaries, exactly takes the place of the india-rubber bottle. The blood is forced onwards with difficulty when the capillaries are obstructed, and as the right ventricle acts as a forcing pump, the left ventricle is more and more distended.

This interesting subject is practically illustrated by the following cases, occurring in the Nottingham Hospital:—

October 28, 1842, William Daniell, a smith, aged 51; when standing at work, he suddenly became insensible, and fell forward, with his chin on the anvil. On admission, his face was pale, his surface cold; he was torpid, but was capable of being roused, and his pupils contracted under the influence of light. The respirations were 20 to 22 in the minute; the pulse was feeble. He was placed in the horizontal vapour bath. In about five minutes the surface became more warm, the intelligence more active. The respirations 14 in the minute, full; the pulse 76, much stronger. The mercury in the sphygmometer, applied over the artery, which rose only 2° at each beat when he was admitted, now rose from 6° to 8°. He felt better. He had had no headache, dizziness, or other premonitory sign, and he did not know that he had fallen. Owing to want of work he had been under-fed for about a week. The day before his admission he returned to work, and had his usual allowance of food. In this case the retrograde effect of the improved capillary circulation caused increased power in the heart.

Richard Henson, referred to already at p. 256, was admitted soon after falling from the top of a house. He had rigors, and the surface was very cold. External warmth was applied, when the rigors ceased, and the pulse, previously very feeble, became much stronger, and the respirations, previously 42 in the minute, fell to 14. At a subsequent period the influence of the brain on the pulse and respirations was well shown. Thus, at 20 minutes past 8 p.m., about three-quarters of an hour after admission, his intelligence was imperfect and incoherent, his pulse (66) was very feeble, and his respirations were 8 to 9 in the minute. An hour later, his intellect being then clear, the pulse was 76, much stronger, and the respirations were 16 in the minute.

The reality and rapidity of the action of the brain through the nerves is illustrated by every emotion. As Dr. John Reid remarks, "The effects of shame in producing the sudden suffusion of the face in blushing; the instantaneous paleness of the face and the abundant secretion of sweat in terror; the flushing of the forehead in anger; the increased secretion of tears and the diminished secretion of saliva from grief; the effects of the sensation of pain, and of the depressing passions of the mind in diminishing, vitiating, or arresting the secretion of the gastric juice; the increased amount of blood in the erectile tissue of the penis and clitoris, the increased secretion of seminal fluid in the testes, and of an increased quantity of mucus in the vagina, from certain sensations and animal desires; and the increased secretion of milk in the mamma, from the pleasing emotions that arise in the mind of the mother as she looks upon her offspring, all illustrate the effects of the sensation, the mental emotions, and passions, upon the capillary circulation and the secretions." In these instances the influence of the emotion arising in the brain causes a local increase in the circulation of the capillaries. This is of necessity independently of the heart's action, since the heart supplies, not only the affected capillaries, but also those of the whole frame.

The exciting emotions, as love, joy, desire, hope, success, all increase the force of the circulation ; while the depressing emotions, as fear, dislike, sorrow, indifference, despair, failure, all lessen the force of the circulation. With the increased force of the circulation, muscular power and nervous energy are increased; while, with its diminished force muscular power and nervous energy are diminished. If the circulation be cut off from any cause whatever, whether from the ligature of a great artery (as the aorta, in relation to the lower limbs), or great loss of blood, or long-continued exposure to intense cold, or the depressing emotions; first the sensory, and then the excitor functions of the nerves are suspended or destroyed, and the muscular power is paralysed. On the other hand, when the circulation is from any cause unusually vigorous, as from the stimulating influence of moderate cold or of exercise, from external stimulants, or from the exciting emotions, the sensory and excitor functions of the nerves are exalted, and the muscular powers are invigorated.

That an influence is transmitted from the brain by the trunks of the nerves to their peripheries is evidenced by the peculiar thrill or feeling of vibration over the surface excited by various emotions. Suddenly-imparted good news causes a thrill of delight. A sudden catastrophe excites a thrill of horror. The stirring eloquence of an earnest orator, expressed in vibrating tones, excites an universal thrill through the whole assembled audience. Music, with some persons, causes thrill after thrill, varying in extent and situation, to play over the surface.

Dr. Reid truly observes, that in all those cases where sensations and mental emotions act on the capillary circulation and the secretions, "the effects upon the capillary circulation and secretion are produced by an agency sent outwards from the encephalon along the nerves distributed in the structures, whose functions are thus influenced ;" but when he states that "the efferent nerves which convey this are not the motor encephalic nerves and the anterior spinal nerves, but the sensiferous encephalic nerves and the sympathetic, and probably also the posterior roots of the spinal nerves," I must express my complete dissent from that profound physiologist. Is it in harmony with the vital laws of nature, that a nerve shall simultaneously, or even consecutively, transmit impressions from the centre to the surface, and likewise from the surface to the centre ? that the nerve of sensation, an afferent nerve, shall also be an efferent nerve, transmitting impressions from the nervous centres to the surface? No, the sensiferous encephalic nerves and the posterior roots of the spinal nerves can scarcely be both afferent and efferent nerves. Dr. Reid brings forward neither proof nor argument in favour of such a supposition, and, failing these, his view must necessarily fall to the ground. Neither can we consider, as being at all more tenable, his supposition, that the influence from the nervous centres is transmitted through the sympathetic. There can be no doubt that the sympathetic nerves transmit the influence of the separate ganglionic centres on vascularity and secretion ; but that they should transmit a like influence from the great nervous centres cannot be regarded as possible, since the connection between those centres and the sympathetic are comparatively scanty, while their connections with the various sympathetic ganglia are numerous and universal.

The great physiologist, Sir Charles Bell, has thus accurately stated what nerves convey the influence of the brain over the vascularity of the surface :—

"When the anatomist shall find both the portio dura of the seventh and the fifth going to the integuments of the head and face, he may naturally ask, why are there two nerves to the surface ? and he will probably reflect, that although the principal office of the nerves of the skin is to convey impression to the sensorium, yet the influence of the mind is conveyed to the surface. The condition of the mind in passion, for example, is as forcibly communicated to the skin as to the muscles themselves; and therefore, if a branch of the fifth be necessary to convey sensation from the surface to the sensorium, the seventh is necessary to the change of vascular action, and to the condition of the pores when affected by a cause proceeding from within outwards."

I consider that the motor or efferent nerves are undoubtedly the nerves which transmit the influence exercised by the nervous centres on the capillary circulation and the secretions ; and not the sensory or afferent nerves.

We find, then, that during emotions, an influence is transmitted by the efferent nerves from the brain to the extremities of the cutaneous nerves ; that sensations are thus excited at the surface, and that the capillary circulation is there affected, being increased by exciting, and diminished by depressing emotions.

We have already seen that excitement of the surface stimulates the extremities of the incident nerves, and excites a deep inspiration ; and that the continuance of the source of excitement in the increase for a time of the superficial circulation, as, for instance, when a sinapism has been applied, excites, through the medium of the incident nerves, an increase in the number and extent of the respiratory movements, lasting for some time ; as long, indeed, generally, as the stimulated condition of the surface exists.

Under the influence of the various exciting and depressing emotions just illustrated, the increase or diminution of the respirations I conceive to be owing to the increased or diminished vitality and excitement of the incident nerves, caused by the retarded or accelerated circulation in the capillaries. The first effect perceived is the influence on the circulation in the capillaries, then that on the respiration. In every instance, when the circulation is roused, the incident nerves are stimulated, and the respirations, by a reflex action, are quickened and deepened. On the other hand, whenever the circulation is depressed, the incident nerves are deprived of their stimulus, and the respirations are diminished either in volume or frequency, or both. In both instances mental emotion acts through the medium of the efferent nerves on the state of the circulation, which, in its turn excites or depresses the afferent nerves, and through them induces the condition of the respiration.

The respiratory movements excited by emotion are involuntary ; more than that, they are performed altogether in spite of the will : volition cannot control them. It appears, indeed, that in proportion as the voluntary control of the brain over the excito-motor functions is withdrawn, those functions become more active and powerful. Emotion is, in fact, in contradistinction to, and in contention with, the will. The higher the development of reason, of regulated will, the lower is the influence of emotion. In the child, the reason is undeveloped, but emotion is supreme ; in the educated man, the educated will is supreme, and the results of emotion are repressed. Throughout life, those who have exquisite sensation, an excitable temperament, a proneness to be actuated by emotion, have but little control over their passions, being subjected to the caprice of desire, not to the discipline of reason. On the other hand, those who have the most highly developed and disciplined mind, are in the least degree under the influence of desire and emotion.

During emotion, there are two physiological influences especially at work, the increased excitement of the incident nerves, and the lessened control of the mind over the excito-motor functions.

Those emotional affections, hysteria, laryngismus stridulus, chorea, and some varieties of stammering, are morbid illustrations of the interesting subject now under consideration. In all of these affections the control of the mind over the excito-motor functions is lessened, while the excito-motor functions themselves are exalted. In considering those affections, I for the present put out of sight any centric influence which the medulla oblongata and spinal marrow may exert.

The Respiratory and Circulatory Phenomena of Hysteria. Cases.

The subjects of hysteria have exalted sensibility and great susceptibility to emotion ; their minds are feebly disciplined, and their emotions readily overwhelm the control of the brain over the reflex movements.

In the following selected cases, the fits of hysteria were closely observed, with especial reference to the respiratory and circulatory phenomena :—

Matilda Marriot, aged 20, a somewhat pale young person, of full features and of delicate skin, was an in-patient of the Nottingham Hospital, affected with spinal curvature and amenorrhœa. She complained much of headache, which gradually increased in severity. Her face was flushed, and had been so all the morning; her eyes were heavy, and she looked sleepy.

Two or three minutes after sitting up in bed, her face being more flushed than before, she suddenly began to breathe with difficulty, and made a loud noise both during inspiration and expiration. She sometimes breathed very rapidly and irregularly, as often as ten or twelve times in ten seconds; sometimes she drew a very deep inspiration. After a time she made eight or nine inspiratory efforts in succession, about ten in five seconds, so as conjointly to make one inspiration, followed by a deep expiration. Most of the respiratory acts were attended by a vocal noise. On applying the stethoscope over the larynx, a loud, sharp, shrill, piercing noise was heard during each inspiration, and a graver sound during each expiration. The inspiratory vocal noise was loudest at the beginning of the act. Pulse feeble, 120. On lifting the eyelid and bringing the finger near to the eye, the lids did not close; on touching the lashes they did; consciousness was therefore absent, while the reflex functions were active. The face was somewhat flushed. When cold water was dashed on the face, she corrugated the eyelids, opened the mouth, drew back the head, and fetched a deep breath. After this she breathed deeply several times, but soon relapsed, again taking short, quick, noisy inspirations. Sometimes she drew a peculiar, deep inspiration, composed of eight or ten noisy arrested efforts, at the end of each of which the glottis was closed by the contact of the vocal chords. On again dashing cold water on the surface, the same effects were produced, followed again by a relapse. After eight or ten repetitions of the dashing, she became sensible. She complained of headache. Pulse 100, stronger. She still sobbed occasionally. She readily relapsed: when the renewal of the dashing again caused deep, powerful, and repeated inspirations, which were soon however replaced by sobbing. She then gradually became sensible ; but she still occasionally sobbed during inspiration, and shivered during expiration.

February 20, 1842.—Ann Palmer, aged fifty, an out-patient of the Nottingham Hospital, suffering from inflammation of the finger. She had been liable to fits for some years.

While I was removing a portion of nail from a patient, she went into an hysterical fit. Her breathing was quick and laborious; her eyelids were shut; she was speechless and powerless, but she could still hear. When in the fit, standing, the pulse was 190. She nearly dropped to the ground. When placed in a chair, the pulse was 120. She was still in the fit, speechless, and apparently insensible. On wafting cold air repeatedly and forcibly over her face, she came to herself, and spoke. The pulse was then 90 ; in a minute it was 80; and in four or five minutes, 63. The first fit came on twenty years previously, owing to a fright.

February 27, 1842.—Sarah Marshall. Has just been in a fit, insensible. When it came on, she felt as if she would choke. She now breathes with considerable noise, 70 times in a minute. About four or five times in a minute she performs the actions of deglutition. Pulse 84. She complains of great epigastric pain.

March 4.—Immediately after being blamed for not taking her medicine, she began to weep, she breathed quickly, and fell down in a fit. While in the fit, inspiration was impossible, owing to closure of the glottis. After this, she made twelve or fourteen altogether ineffectual efforts to inspire. She dilated the nostrils, and the lips protruded and retracted in rapid succession ; the respiratory muscles of the neck were firmly, and then gently, contracted in rapid alternation. The abdomen protruded and returned in a series of rapid movements, synchronous with those of the cervical muscles. The thoracic parietes remained stationary. These vain attempts at inspiration were repeated during from five to ten or fifteen seconds, and were succeeded by five or six quick, not very full inspirations. Subsequently the respirations were occasionally convulsive, sometimes the inspiration, sometimes the expiration, being interrupted at the beginning by the closure of the glottis. During the whole time she was quite insensible. At length, suddenly, after being in the fit about twenty minutes, she took five or six very deep forcible inspirations, became quite sensible, and asked for water. She breathed very quickly for about twenty minutes after coming out of the fit.

October 24, 1842.—Maria Feeley, an out-patient, while waiting to be seen, suddenly began to cry. The respirations were about twenty in the minute. The inspirations were deep and drawn quickly; the expiration was sometimes crying throughout; sometimes it consisted in a series of noisy interruptions, owing to repeated closure of the glottis. The mouth was distorted, being opened wider during inspiration than expiration, the cheeks being at the same time drawn upwards, and the eyelids corrugated. Sometimes the respirations were noiseless. In a few minutes the convulsive crying gave place to convulsive laughter, when each respiratory act consisted in a rapid, deep inspiration, with widening of the mouth, the angles being drawn downwards, the cheeks being no longer elevated, and the eyelids no longer corrugated; this was followed by an expiration, consisting of several forcible successive expiratory acts, each being suddenly checked by noisy closure of the glottis. The fits of laughter were alternated by ordinary respirations, as well as by respirations in which, while she took a very deep inspiration, six or eight silent pauses were made. Sometimes all the muscles of inspiration were put into action, but silent closure of the glottis prevented the ingress of air. During the fit the pulse was 125; afterwards, the respirations being 24 in the minute, the pulse was 110. After recovering from the fit, she said that last night the drollery of a companion had excited uncontrollable laughter. This was followed by intense headache. The thought of the events of the previous evening brought on the present fit.

February 15, 1842.—Elizabeth Hopkinson, aged 19, is now insensible. Her inspiration begins with a feeble, sharp, cooing sound, and is suddenly checked by closure of the glottis, owing to the contact of the vocal chords. During the time that inspiration is thus prevented, the scaleni act strongly, and the abdomen is considerably protruded. The expirations are not vocal, but purring, in character. The respirations (60 in the minute) are accompanied by permanent convulsive muscular contraction of the arms. On exposing the surface to the air, the respirations gradually became normal.

The characteristic respiratory phenomena in the fit of hysteria would appear to be the frequent approximation of the vocal chords during, in many instances, inspiration as well as expiration, so as to excite either temporary closure of the glottis, with general struggling, during the vain attempt to respire; or stridulous or sobbing inspiration, and crying or laughing expiration. It is to be remarked, that this approximation of the vocal chords is to be observed during most of the emotions and the emotional diseases, when the excito-motor functions are abnormally exalted. This is instanced in the cries of rage, the sob and cry of grief, the crowing inspiration and noisy interrupted expiration of laughter, the interrupted and stridulous inspiration and the crying expiration of laryngismus stridulus, the interrupted, struggling, convulsive expiration of epilepsy, and the noisy, interrupted, and struggling inspiration and expiration of hysteria.

It appears, then, that when the vocal chords, which are usually so obedient as the exquisite instruments of speech and music, are under the influence of emotions and of the emotional diseases, they are then the involuntary and irrepressible agents in general convulsion. They may come into silent contact with struggling attempts at respiration ; or they may come into noisy, vocal approximation, so as to induce sobbing or crowing during inspiration, and crying or laughter during expiration.

It is evident that the respiration may be accelerated and disordered in hysteria quite irrespective of sensation, since the more aggravated forms of hysterical fit existed in Marriott, Marshall, and Hopkinson, although they were quite unconscious, and for a time incapable of being roused. It is certain, then, that in these cases the remarkable and exalted respiratory movements were not consensual, that is to say, they were not called into play by an influence excited in the afferent nerves by sensation, transmitted to the seat of consciousness in the brain, and thence reflected back through the spinal marrow and the afferent nerves, so as to excite the respiratory muscles. In these cases, the reflex movements of respiration must have been excited, not through the sensory, but through the excitor functions of the afferent nerves.

While the fit of hysteria usually comes on when the subject of it is conscious, the cases just alluded to show, that under the influence of the paroxysm the patient may speedily become unconscious. This state of unconsciousness may be induced either by the greatly increased pressure of the blood upon the brain, caused by the violent expiratory efforts ; or possibly by the greatly diminished pressure of the blood upon the brain, caused by the unusual inspiratory efforts.

The cases just recited show that when the paroxysm is severe, owing to the closure or narrowing of the glottis, dashing cold water upon the surface excites deep inspirations, with free opening of the glottis. Consciousness is not usually restored by the first dash; but after it has been effectively renewed time after time, so as to excite repeated deep inspirations, intelligence is at length awakened, apparently under the influence of the circulation of a more stimulating arterial blood through the brain, and of the restored balance of pressure exerted by the blood upon the brain.

In hysteria the fit is evidently occasioned by the emotion and prolonged by the state of unconsciousness. Both of these influences, in fact, by withdrawing the control of the brain from over the direct, or centric, and reflex, or eccentric spinal functions, give to those functions undue predominance. I shall again have occasion to refer to this important point. The repression of the emotion, and the restoration of consciousness, accompanied in either instance by the cessation of the fit, are alike promoted by dashing cold water on the surface, or by any other stimulant that may excite healthy deep inspirations.

Respiratory Phenomena in Laryngismus Stridulus. Case.

In laryingismus stridulus some source of irritation is usually present, morbidly exciting the reflex functions, such as painful dentition, a deranged state of the mucous membranes, or deficient exposure of the surface to the atmosphere out of doors. The fits may be excited by emotion; or they may come on during sleep; in both of which instances the control of the brain being withdrawn, the increased reflex functions become predominant.

I had a recent opportunity of observing the respiratory phenomena in laryngismus in the following case :—

George Newsom, aged seven months, a small, shrivelled baby, fed by hand for six months. A fortnight previously the child was affected with catarrh, and on the following day he had frequent paroxysms of laryngismus stridulus. These attacks occur chiefly when asleep, sometimes about twenty times in the night; they also come on when he coughs, cries, or takes food, and, though less frequently, when he is frightened or fretted. "The quieter he is kept, the more it seems to check the fits." He is evidently less subject to the paroxysms when freely exposed to the air. Strong convulsive fits frequently follow the attacks of laryngismus.

The child had two slight attacks when sitting at my side. During the fit the inspiratory efforts were violent and struggling, but silent; the mouth was wide open, but the air was denied ingress by the closure of the glottis. The surface became livid, the tongue of a dark purple. Blowing on the face and sprinkling it with cold water evidently excited increasing separation of the vocal chords, the inspirations becoming at first stridulous, and finally easy, noiseless, and hurried, 68 in the minute. "Opening the window," the nurse says, "by letting the cold air blow upon the face, seems to bring him to better than anything." The first fit came on when I was feeling the gums; the child cried, and closure of the glottis speedily ensued. The paroxysm, which lasted about two minutes, was cut short by blowing upon the face. The second attack came on when the child was asleep.

A third fit, less severe than either of the former, came on, and gradually went off without any apparent exciting cause. The closure of the glottis was not absolute, but there was stridulous, almost interrupted inspiration. The lips pouted forward all round, forming a tense, prolonged, funnel-shaped, oval orifice ; the tongue was rigidly convex from side to side ; the nose became quite flat on the face, owing to the excessive dilatation and retraction of the nostrils. The limbs, both the legs and arms, were in continual motion, all the muscles being rigid. The stridulous inspiration soon gave place to crying expiration. The glottis now expanded freely, all the other extreme inspiratory movements still continuing. There were thirteen respirations during the next ten seconds after the crying had ceased. He soon became tranquil, his respirations being less frequent, about forty in the minute. Shortly afterwards he fell into a dose, the eyes being half open and the respirations irregular, and often interrupted by a short pause.

For additional cases I refer to the valuable writings of Dr. Marshall Hall, Dr. Ley, Dr. West, Mr. Robertson, and others. The last-named gentleman has detailed many cases in which the free exposure of children, subject to this disease, to the country air, proved of essential service in checking the paroxysms and putting an end to the disease.

In these cases the renewed attacks will frequently be warded off by removing the source of peripheral irritation, as by incising the gums, emptying the bowels of their offensive contents, or improving the quality of the food ; by avoiding emotional influences ; and by rousing the child if its sleep be too profound. Perhaps of all remedies nothing proves so permanently efficient as the free exposure of the surface to a dry bracing air, a plan which usually restores the healthy balance of the reflex functions.

Chorea is an emotional disease, in which the reflex functions are morbidly excited. Respiration is affected in chorea, but not to a degree entitling me to consider further the nature of the disease. In three cases of chorea recently observed by me in St. George's Hospital, the abdominal muscles were permanently tense. In one of these, Dr. Bence Jones pointed out to me the peculiar action of respiration ; the abdominal walls retracted during each inspiration, the diaphragm was inactive, and the inspiration was entirely thoracic. This kind of respiration was not present in the two other cases just referred to. The movements of respiration partake somewhat of the jerking irregular character of the other movements, as was well marked in an interesting case described by Dr. Walshe.

Dr. Todd thus illustrates the emotional character of chorea : —"So frequently do mental causes give rise to chorea that Rufz, in investigating eighteen cases, traced the origin of eleven of them to fright. In chorea the nervous system is obviously peculiarly excitable. Choreic patients are much more agitated in the presence of others than if left to themselves. Of this we have abundant evidence in hospital practice. When the physician approaches the bed of a patient with chorea, accompanied by a crowd of students, the movements become greatly augmented, and continue so until the cause of excitement has been removed."

Effects on the Respiratory Movements of the immediate withdrawal of Cerebral Control over the Reflex Functions.

I have traced, to a certain extent, the influence of the brain over respiration, first through volition, and then through emotion.

While will controls and suppresses the reflex functions, emotion suppresses the influence of the will and excites the reflex functions.

I purpose to consider here the effect on the respiratory movements, of the complete and immediate withdrawal of the control of the brain over the reflex functions.

The effect of the control of the brain over the reflex spinal functions has been ably illustrated by Professor Volkman, Mr. Barlow, Dr. Budd, Dr. Carpenter, and Dr. Marshall Hall. I beg to refer to their respective memoirs, and especially to Mr. Barlow's valuable Essay.

If the spinal marrow of the frog be divided in the lumbar region and one fore-limb be irritated, that fore-limb only is moved; but if one hind-limb be irritated, both hind-limbs are thrown into convulsive movements. Reflex movements are not excited in the opposite fore-limb, owing to the superior control of the brain; while convulsive reflex movements are excited in both hind-limbs, owing to the withdrawal of the cerebral control. The same stimulus that will excite reflex movements when the control of the brain is inactive, will not excite them when it is active.

During sleep the control of the brain over the reflex movements, though not annihilated, is lessened. Mr. Barlow touched the palm of a sleeping child: his finger was grasped by the infant's hand. When the child was awake, no such movement was excited.

In hemiplegia and in paraplegia, if the paralysed limb be irritated, convulsive reflex movements are excited in the paralysed limbs, although no such movements are excited in the limbs which are under the control of the will.

If the reflex spinal movements are morbidly excitable, as in hydrophobia and tetanus, and in those under the influence of strychnia, then the cerebral are unable to restrain the reflex functions, and the slightest stimulus excites violent convulsive reflex movements. In these cases, even in hydrophobia, the convulsive reflex movements may be restrained for a time by a powerful effort of the will. This was instanced in the case of that disease related by Dr. Marcet. When water was sprinkled on his face unawares, violent convulsions were excited ; but when he was prepared for it, convulsions were not so excited, the reflex spinal being held in check by the cerebral functions.

While all other reflex movements are usually kept in check by the superior control of the brain, the ordinary automatic respiratory movements are performed with constant regularity, both when awake and when asleep. These automatic respiratory movements may be restrained for a time, but for a time only, by the will. If cold water be dashed suddenly over the whole surface, an uncontrollable deep inspiration is taken. If the water be dashed on the face unawares, a deep inspiration is excited ; but when the person is prepared for it, the will exerts its superior control, and the inspiration is restrained. If a person walk in the sea, he can at first restrain the respiratory movements; but when he has gone beyond a certain depth, when, in fact, the reflex functions are unusually excited over a greater extent of surface, he can no longer restrain the deep inspiratory movements, which are often interrupted by sobbing.

We have already seen that, under the influence of volition, the reflex movements, even those of ordinary respiration, may be arrested. On the other hand, under the influence of excited emotion, the control of the brain is withdrawn, while the reflex functions are unduly stimulated, owing to the increase in the capillary circulation ; and deep, often convulsive, respiratory movements are excited.

We have also observed that, under the extreme influence of the depressing emotions, not only are the cerebral functions depressed and annihilated, but the reflex spinal functions are also depressed, or even annihilated, by the partial or total suppression of the capillary circulation ; and the reflex respiratory movements are for a time almost or even altogether arrested.

The child, just after its birth, is altogether the creature of the reflex functions; through their agency it breathes, takes its food, expels the fæces and urine, and moves the body in an agitated lively manner. Consciousness is wanting. The educated man almost completely subordinates the reflex spinal to the cerebral functions, since, with the exception of ordinary respiration, all those offices are performed by volition.

Convulsions caused by sudden Comatose Unconsciousness.

When comatose unconsciousness, or unconsciousness from which the person cannot be roused, is rapidly induced, the direct and reflex spinal functions being at the same time either unaffected or exalted, then expiratory convulsions are excited. The control of the brain over the reflex, and, as will be shown hereafter, over the direct spinal functions, being suddenly withdrawn, those functions are unduly excited, and more or less violent convulsions ensue.

By whatever means the complete and sudden unconsciousness is produced, provided the reflex functions be unaffected, convulsions are equally induced. Dr. Burrows tied a ligature round the neck of a rabbit; another he bled to death; each animal died violently convulsed. The brain of the former animal was surcharged with blood; of the latter, almost devoid of blood. In the former the loss of consciousness was owing to the unduly increased pressure of the blood upon the brain; in the latter, to the unduly diminished pressure of the blood upon the brain. In neither of these instances was the spinal reflex function affected; in both of them the control of the brain over those functions was suddenly removed, and in both of them violent reflex convulsions were induced.

In syncope, from mental emotion, comatose unconsciousness is produced with a rapidity equal to its production in the cases just instanced, yet no convulsions ensue; for while in those cases the reflex functions are either unaffected or exalted, in syncope the reflex functions are, as we have seen above, annihilated simultaneously with or even before the production of unconsciousness.

That the convulsions are not owing to any immediate central action of the brain itself is proved by the physiological fact that the brain may be punctured or cut in every direction, and that the cerebral and cerebellar hemispheres may be removed in progressive slices, or at once, provided the medulla oblongata be untouched, without the production of convulsions. When an animal is pithed or beheaded, no convulsions are excited. The absence of convulsions in these instances is owing to the shock which, acting on the whole nervous system, destroys or suspends for a time the reflex functions. That the reflex functions are thus suspended for a time has been conclusively proved by Dr. Marshall Hall. In fact, as in syncope, so when the animal is beheaded, the cerebral and the reflex spinal functions are simultaneously annihilated, and all movements, whether direct or reflex, are suspended.

The effect is quite different if, after beheading the animal, the circulation through the capillaries be maintained by means of artificial respiration. Sir Benjamin Brodie decapitated a dog, and then kept up artificial respiration; the body of the animal, which was previously at rest, was moved in a very remarkable manner by constant and powerful contractions of the muscles of the trunk and extremities. In another dog whose head was removed, Sir Benjamin kept up artificial respiration, and then injected into the stomach nine ounces of infusion of tobacco. At the time of the injection the body of the animal lay perfectly quiet and motionless on the table. Ten minutes afterwards the voluntary muscles in every part of the body were thrown into repeated and violent spasmodic action. The joints of the extremities were alternately bent and extended; the muscles of the spine, abdomen, and tail, alternately relaxed and contracted, so as to turn the whole animal from one side to the other. In the former of these experiments, the body of the animal at first lay still after being decapitated, since, although the control of the brain was removed, the reflex functions were suspended, owing to the shock and the deficient circulation. When, however, owing to the artificial respiration, the arterial blood circulated in the capillaries, and stimulated the excitor functions of the peripheral nerves, spasmodic reflex movements were induced, those movements being no longer held in check by the control of the brain. When the blood was rendered more stimulating by tobacco, the reflex functions were still more stimulated, and the extraordinary alternate movements described above were excited.

Respiratory and Circulatory Phenomena in the Epileptic Convulsion. Case.

The epileptic convulsion is the type of the class of convulsions which attend sudden comatose unconsciousness.

In the following case I observed the respiratory phenomena of the epileptic convulsion.

February 24, 1842.—William Brooks, aged 16. Is in an epileptic fit. He takes two or three deep inspirations, followed by strong expirations; after the second or third inspiration the vocal chords come in contact, so as to close the glottis, and prevent the performance of expiration ; universal convulsions immediately ensue, so violent that four men can scarcely restrain him from injuring himself. All the expiratory muscles are powerfully exerted in the vain endeavour to force asunder the vocal chords, so as to perform expiration. The muscles of the jaws, the limbs, and the back are in violent action. This struggling, violent attempt at expiration lasts for from three to ten seconds, during which time the fearful convulsions continue, the face flushes and becomes swollen, and the pulse is about 180, sometimes very feeble, or even almost imperceptible.

The violent convulsive attempts at expiration above described were renewed at frequent intervals during about fifteen minutes, at the end of which time the respirations were performed freely and uninterruptedly (32 in the minute), and all the muscles became relaxed. Immediately after the fit the pulse beat 36 times during the next ten seconds, or at the rate of 216 in the minute. At the end of the minute they had fallen to 25 in ten seconds, or at the rate of 150, and in about ten minutes the respirations were 17 to 18, and the pulse 100 to 130 in the minute. He still remained unconscious. In about half-an-hour, when still unconscious, he smiled during each inspiration, and laughed during each expiration. Shortly afterwards he said, "I'll not be served so." On tickling him, he renewed the laughter, reflexed all the limbs, and said, "Don't do that." At this time he was manifestly unconscious, for on approaching the finger to the open eyes, the eyelids did not contract, but they closed on touching the eyelashes. After this he occasionally sighed deeply, and in a few minutes became conscious ; he had no recollection of any dream ; he was listless and languid ; his respirations were 15, his pulse 104, in the minute.

February 25.—Is again in a fit. He makes two or three rapid respirations, which are interrupted by closure of the glottis and violent convulsive attempts at expiration ; all the limbs are violently convulsed, the head is thrown forcibly backwards, and all the expiratory muscles are in powerful action ; the whole neck and face are turgid with venous blood, the thyroid body being greatly enlarged ; the sterno-cleido, the platysma myoides, and the fasciæ of the neck, are contracted and tense, apparently just before the renewal of the closure of the glottis and the convulsive attempts at expiration. He gathers himself up for the fit by contracting the pectoral muscles, the muscles of the arm and shoulder, and the fascial muscles of the neck.

February 26 ; half-past eight, P.M.—Has suffered much from pain in the back, which came on during the last fit. The pain is opposite the last dorsal vertebra. He is now in the progress of a fit. Just before he became insensible, he complained of his back, and desired that he might be held. He lay insensible for some minutes, respiring freely, the muscles being relaxed. He was stripped, and the surface was exposed freely to the air; a convulsive effort at expiration was made, followed by free inspiration. Pressure over the last dorsal vertebra excited a convulsion. The seat of pain was fomented, and friction was employed to the surface. The fits are not nearly so violent as on the previous occasion ; their violence appears to have been stayed by exposure to the cold air, the cold dash, and frictions. After making many deep inspirations, he emerged from the state of insensibility.

This case shows the dependence of the epileptic convulsions on the arrested expiration, owing, as Dr. Marshall Hall has shown, to the closure of the glottis. The control of the brain over the direct and reflex spinal functions being withdrawn, those functions became predominant and excessive. During the third attack, as in the cases of syncope and hysteria given above, the reiterated stimulus to the surface excited, reflexly, deep inspirations ; those inspirations restored the balance of pressure of the blood upon the brain, and stimulated that organ by the circulation through it of oxygenated blood. These effects, acting as causes, restored consciousness, renewed the cerebral control over the spinal functions, and put an end to the paroxysm.

The cause of the unconsciousness in many cases of epilepsy is by no means apparent ; but it may be owing to disease of the cranium (Dr. Abercrombie relates three such cases) ; or to disease of the brain (Dr. Abercrombie relates seven such cases) ; or to various causes producing congestion, and consequent increased pressure of blood upon the brain ; or to various causes producing diminished pressure of blood upon the brain ; or to various causes poisoning the blood, the poisoned blood circulating through the brain ; or to exciting or depressing emotions.

In all these instances, comatose unconsciousness may be induced while the reflex functions are unaffected, or are even unduly excited, as by the circulation of poisoned blood.

In some cases affection of the direct and reflex spinal functions acts as the primary cause of the convulsions ; then epilepsy may be occasioned by disease of the spinal marrow (Dr. Abercrombie relates four such cases) ; or by irritation in the stomach and intestines ; or by uterine irritation.

In the latter cases some secondary and additional cause must be at work to produce unconsciousness.

The epileptic fit frequently comes on after a hearty meal, causing great and flatulent distension of the stomach ; in such cases, besides the influence transmitted from the stomach by the par vagum to the nervous centres, there is an increased difficulty to the return of blood from the brain to the heart, owing to the pushing up of the diaphragm and consequent compression of the thoracic organs, as well as the pressure excited by the stomach upon the liver, the blood contained in which is thus unduly thrown upon the heart.

Dr. Marshall Hall, in a recent important paper, has attributed the unconsciousness to the prevention of the return of the blood from the brain, caused by the irregular contraction of the platysma myoides.

The epileptic fits frequently come on during profound sleep, the sleep in such cases passing into sopor, the sopor into epileptic coma.

Puerperal convulsions are of the same general character with epileptic convulsions. Certain differences in the pathology of those diseases have been recently pointed out by Dr. Tyler Smith.

Of 200 cases of puerperal convulsions collected by Dr. Murphy, 46 occurred before labour, 90 during labour, 25 after labour; in 39 cases no precise information could be obtained.

Dr. Murphy attributes the convulsions to excess of blood, loss of blood, and impure blood.

The immediate exciting cause of the unconsciousness and convulsions may be,—increased pressure of the blood upon the brain; diminished pressure of the blood upon the brain; and the circulation of poisoned blood (urea) through the brain and the system.

Comatose Convulsions induced by Narcotic Poisons.

Certain of the narcotic poisons may produce convulsions with unconsciousness; of these the œnanthe crocata may be said to be the type. In ten cases of poisoning by that plant, related by Mr. Bossey, the men fell without warning, insensible and in convulsions.

Belladonna, hyoscyamus, and stramonium produce delirium, followed by coma; convulsions sometimes accompany the coma, sometimes the delirium.

Ether, chloroform, and alcohol at first exhilarate the cerebral functions, then they produce sopor, and afterwards coma. We have already seen that these poisons, as well as the class of which belladonna is a type, at first stimulate, and then exhaust, the reflex functions, through the medium of the excited capillary circulation. Dr. Snow and myself have both observed that when ether and chloroform are administered so as rapidly to produce unconsciousness, muscular rigidity and sometimes even convulsive movements may be induced; but if administered slowly, rigidity and convulsions are not induced.

Opium seldom excites convulsions in man. I have, however, met with 23 cases, scattered through the British journals, in which convulsions were produced by opium. In the lower animals convulsions are always excited by opium, but these convulsions are not epileptiform, but like those produced by strychnine. The lower the animal in the scale, the more frequent are convulsions, the reflex spinal functions being less under the control of the brain in the lower grades. This is in keeping with the fact that convulsions more frequently affect the child than the adult. Thus, of twenty recorded cases in which children were poisoned by opium, ten had convulsions.

This fact is in harmony with the results of an analysis which I made of 150 cases of cerebral disease recorded by Dr. Abercrombie; of these—

78 had convulsions, of whom	39 were above the age of 12. 39 were below the age of 12.
72 had no convulsions, of whom . . .	64 were above the age of 12. 8 were below the age of 12.
In adults, the proportion of cases in which there were convulsions to those in which there were no convulsions, was .	39 to 54.
In children, the proportion was	39 to 8.

If the wourali poison be injected into the veins, struggling convulsions with unconsciousness are very speedily induced; but if the wourali be inserted into a wound, the action of the poison is slow, and either no convulsions, or very slight convulsions, are induced. In such instances I believe this to be the explanation;—when the poison is injected into the veins, the brain is rapidly deprived of consciousness, while the reflex functions are stimulated, rather than depressed; and as the control of the brain over the reflex functions is withdrawn, reflex convulsions follow. If, however, the poison act slowly, the cerebral and the reflex functions are depressed and destroyed simultaneously, and no convulsions ensue.

In like manner prussic acid, coneine, and poisons of a like class, excite or do not excite convulsions with unconsciousness, in proportion as the poison acts rapidly or slowly on the system.

In like manner also convulsions with unconsciousness are sometimes excited when the blood is poisoned with urea, owing to its non-elimination through the kidneys.

If asphyxia take place rapidly, violent convulsions with unconsciousness invariably ensue; but if asphyxia be brought about slowly, convulsions seldom ensue. In the one case the reflex functions are excited, the control of the brain being withdrawn, while in the other case the reflex are destroyed simultaneously with the cerebral functions.

Convulsions are much more frequent in cases of acute than of chronic cerebral disease.

Thus, from an analysis of the cases related by Dr. Abercrombie, I find that—

Of 31 cases in which the brain was *acutely* inflamed	25 had convulsions ; 6 had no convulsions.
Of 29 cases in which the affection of the brain was chronic, as from tubercular disease (12 cases) and abscess (17 cases) . . .	14 had convulsions ; 15 had no convulsions.
Of 23 cases of apoplexy with extravasation	7 had convulsions ; 16 had no convulsions.

We have seen that when the control exercised by the brain over the other nervous forces is suddenly withdrawn, then the direct and reflex spinal functions, previously held in check, are suddenly let loose, and violent convulsions ensue. If, however, the direct and reflex spinal functions are suspended, simultaneously with the control of the brain, then no convulsions ensue.

Influence of the Medulla Oblongata and Spinalis (Myelon) on the Movements of Respiration.

If the brain be removed, respiration still goes on; if the tuber annulare be cut away until within a few lines of the medulla, the facial and buccal respiratory movements cease, owing to the destruction of the reflex arc formed, through the nervous centre, by the fifth and seventh pairs, as incident and motor nerves. On extending the incisions to the origin of the eighth pair, respiration ceases.

If the spinal marrow be divided in successive slices from below upwards, the movement of rib after rib is destroyed, If it be cut across at the lower cervical vertebræ, all the intercostal muscles are paralysed ; but the first and second ribs are still raised by the scaleni, and the clavicles, scapulæ, and sternum, by their proper muscles. The diaphragm continues to descend during inspiration.

If the spinal marrow be divided at the third cervical vertebra, the scaleni and the diaphragm cease to act : but the sterno-cleido and trapezius, and the muscles of the face and neck, are still in action.

If the spinal marrow be divided above the origin of the par vagum, respiration ceases, but gasping of the mouth still continues for a time.

The facts of pathology are in keeping with the experimental facts of physiology.

If the brain be absent in the fœtus, the medulla and tuber annulare being entire, as in the case detailed by Mr. Lawrence, respiration is still performed.'

If the tuber annulare be destroyed by injury, extravasation of blood, or disease, the facial and palatal respiratory movements cease, and the breathing becomes stertorous.

If the medulla oblongata be destroyed by injury or disease, respiration ceases.

Destructive injury or disease of the spinal marrow arrests the movements of all those respiratory muscles which are supplied with nerves from below the seat of the injury or disease.

The depressing effects of the narcotic poisons, such as chloroform, produce, through their action upon the centres and peripheries of the nervous system, the same progressive suspension of the various respiratory movements. During the administration of chloroform the powers of the lower nervous arcs are first suspended, the lower limbs becoming powerless ; then certain of the respiratory movements give way, costal respiration ceasing, while diaphragmatic respiration still continues. Under the depressing influence of chloroform, the functions of the nervous system are not only suspended from below upwards, they are suspended also from above downwards, the facial and palatal respiratory movements being arrested, while the diaphragmatic movements continue. It is not the nervous centres only that are affected by the action of chloroform ; the nervous peripheries are affected also in a corresponding manner, by the diffused circulation of the poisoned blood. With regard to the suspension of the respiratory movements of the face, those movements are probably arrested in great part by the local action of the inhaled chloroform.

In many dying persons the nervous system dies gradually from below upwards ; first motion and sensation cease in the lower limbs ; then the respiratory movements of the ribs are arrested ; then those of the diaphragm ; the nostrils still dilate for a time, but when they do so no longer, the mouth continues to gasp widely, at longer increasing intervals ; finally, a few retractile movements play around the angles of the mouth.

Flourens, after removing the brain, divided the spinal cord just below the last cervical vertebra, and costal respiration ceased. He irritated the cut surface of the lower section of the divided spinal marrow, and inspiratory movements of the ribs were excited. He divided the spinal marrow above the third cervical vertebra, and the diaphragm ceased to act : he then irritated the cut surface of the cord, and so excited a diaphragmatic and costal respiration. He altogether arrested respiration by dividing the medulla at the origin of the eighth pair : he then irritated the spinal marrow, and a complete respiratory movement was excited.

We observe, then, that if we cut across the spinal marrow at any part, the movements of those respiratory muscles, which are supplied with nerves below that part, are arrested; but an extraordinary act of respiration can still be excited by stimulating the spinal marrow itself.

On the direct or centric action of the Spinal Marrow, and its influence on Respiration.

I request your close attention to some important points in the physiology of the spinal marrow. I allude to the mode in which movements are excited, on the one hand, directly, by stimulating the spinal marrow itself, and, on the other, reflexly, by stimulating the incident nerves.

Dr. Marshall Hall pinched the toe of a brainless frog, and immediate universal reflex movements followed: although he continued to pinch the toe, relaxation of all the muscles speedily ensued. If he ceased to pinch the toe he could, after a short pause, re-excite the same reflex movements by a repetition of the same stimulus.

From the researches of E. H. Weber and of Volkmann, as detailed by Mr. Paget, it appears that when the incident nerves are continuously stimulated by a magneto-electric current, alternate reflex contraction and relaxation of the muscles ensue. When the stimulus is withdrawn the movements instantly cease.

It is not so with the direct or central spinal functions. If the spinal marrow itself be continuously excited by the magneto-electric current, fixed muscular contraction is excited, and this fixed contraction continues for a time, even after the withdrawal of the stimulus.

How different are these direct or centric movements from the reflex or eccentric movements: while the latter are intermittent, the former are continuous; while the latter are speedily exhausted and as speedily re-excitable, the former are only exhausted when the life of the nervous system is itself destroyed.

These points, illustrated so well by physiological experiments, are still more instructively illustrated by disease. In meningitis of the spinal cord, as in meningitis of the brain, the central organ is in general permanently stimulated. It will be seen, from the following analysis, which I have made of the cases of spinal disease recorded by Dr. Abercrombie, that of eight cases of spinal meningitis, six were affected with permanent muscular rigidity. In those cases the continued stimulus applied to the nervous centre excited continued muscular contraction; neither the excitability of the nervous centre nor the contractility of the muscles were exhausted.

	HAD					
	Muscular rigidity.	Muscular rigidity with tetanic spasms also.	Ordinary convulsions.	Epileptic convulsions.	Paralysis without convulsions.	Neither paralysis nor convulsions.
In 8 cases of spinal meningitis	6	5	1	0	0	1
In 4 cases of inflammatory vascularity of the cord .	0	0	2	1	1	0
In 19 cases of ramollissement of the cord . . .	5	3	5	0	9	0
In 21 cases of chronic disease of the cord, tubercles, &c.	3	0	11	3	4	0

From this table we see that of 8 cases of spinal meningitis, 6, or 2-3rds, had muscular rigidity; while of 44 of disease of the cord itself, only 8, or less than 1-5th, had muscular rigidity. In the former cases the direct spinal functions were usually exalted, the cord being permanently stimulated; in the latter they were usually depressed, the cord being injured.

It may be laid down, then, as a definite law, that while the reflex or eccentric spinal functions are *intermittent*, the direct or centric spinal functions are *continuous*. Volition, or the cerebral command over the muscular movement, is *temporary;* it is neither so rapidly exhausted as the reflex functions, nor yet so continuous as the direct spinal functions. While reflex movements, excited by stimulating the surface, can only last for one or two seconds, direct movements excited by a continued stimulation of the spinal marrow are permanent; while direct movements, excited by the will, can usually only last about five minutes. It is manifest that the excitability of the incident nerves and the control of the brain are exhausted in these instances, and not the contractility of the muscles, since under the direct influence of the exalted spinal marrow the contractility of the muscles is enduring.

The reflex spinal excitability may be represented thus – – – – – – – – –
The voluntary excitability thus . . . . . ——— ——— ———
And the direct spinal excitability thus . . . ———————————

In this interesting and instructive fact, that the reflex spinal functions are intermittent, while the direct spinal functions are continuous, we have a key to the nature and cause of certain physiological and pathological motor phenomena.

I have already addressed myself to the reflex motor phenomena, and I shall now inquire what muscular movements, in health and disease, are caused by the direct action of the spinal marrow, or, in other words, what movements are continuous?

The action of all the sphincters is continuous, and for that reason I infer that the action of all the sphincters is excited directly by the spinal marrow. Thus the sphincter of the anus, the urethra, and the uterus, the cardiac and pyloric orifices of the stomach, and the œsophagus, are ordinarily always in a state of contraction. That action is only interrupted by a higher or more energetic power; thus, by volition the anal and urethral sphincters can be opened; they can be opened also by strong reflex excitation. By reflex excitation, the cardiac and pyloric orifices of the stomach and the os uteri can be opened.

A series of sphincters are continuously closed or contracted only during sleep, such as the eyelids, the iris, and often the mouth. Open the eyelid of a sleeping person, and the pupil will be seen small and contracted; immediately he awakes the iris springs backwards, and the pupil dilates.

The eyelid is continuously influenced by the spinal cord, but when we awake the brain exercises a higher control than the cord, and the eyelids are open; they cannot, however, be kept open by the exercise of the will beyond a certain time; and an instantaneous rest is every now and then given to volition by their irresistible and momentary closure. The quiet unperceived winking of the eyelids, owing, as I conceive, to the direct action of the spinal marrow exerting its continuous force, and making itself manifest whenever the cerebral action flags, is very different from the forcible reflex closure of the eyelids, caused by touching the lashes, so beautifully illustrated in Dr. Marshall Hall's experiment on the horse just felled by the knacker.

In fact, the direct influence of the spinal marrow never flags; its power, though feebly exercised, is enduring. It is allied to, nay, it is identical with tonicity. The diffused firmness of all healthy muscle is indeed owing to the direct influence of the spinal marrow. Cut off the connection between the cord and the muscles, and their tonicity is replaced by flaccidity.

The reflex action, though it can only last for a second or two, is yet exercised with superior force, and overcomes, by a short powerful effort, the direct spinal action. It is not, for instance, that the sphincter ani relaxes when the contents of the rectum are expelled, but that the levator ani, excited reflexly, overcomes the sphincter, though still in action.

We have already seen that the brain controls the reflex spinal functions ; we shall see that in like manner the brain may control the direct or central spinal functions. In the waking state the control of the brain is predominant, and the direct spinal functions are for the most part in abeyance, with the exception, in fact, of the contraction of some of the sphincters. When persons are about to fall asleep, are fatigued, or are affected with paralysis, a slow stretching of all the limbs is frequently effected, along with a deep, slow, wide-mouthed inspiration or yawn. The slow and continuous muscular action concerned in stretching the limbs is owing, I conceive, to the centric action of the spinal marrow. The brain gradually goes to sleep, and ceases to control the central spinal functions ; at first those functions are performed with unusual vigour, just as the reflex functions are performed with unusual vigour, when the cerebral control is suddenly withdrawn. When sleep is complete, the more exalted centric spinal actions are in abeyance, and the sphincters are alone in action. When a person is suddenly awakened, the same yawning and stretching process is repeated.

When chloroform is administered, especially if it be given quickly, as consciousness disappears, universal muscular rigidity and stretching of the limbs come on. Hence, while the cerebral control is diminished and withdrawn, the centric functions of the spinal marrow, stimulated by the chloroform circulating through it, excite universal muscular rigidity. If the chloroform be persevered in, the centric functions of the spinal marrow are gradually destroyed from below upwards, and the sphincters, as well as the muscles of the frame, relax.

Tetanus presents us at the same time with the type of those convulsions with consciousness which are excited by a morbidly exalted reflex function ; and of that universal continuous muscular rigidity which is caused by the exalted centric excitation of the spinal marrow. The tetanoid convulsions are united with tetanoid muscular rigidity. Owing to this rigidity, the abdominal muscles of expiration are in constant action, and each inspiration is to a certain extent resisted by the action of those muscles.

In persons affected with hydrophobia, and in those under the influence of strychnia, convulsions with consciousness are present ; but there is frequently no permanent muscular rigidity. In such cases I consider that there is morbid exaltation, not of the centric, but of the eccentric action of the spinal system.

In some cases of hysteria there is permanent cataleptic rigidity of the muscles, which is manifestly caused by the exalted centric excitability of the spinal marrow.

In chorea, the muscles of the abdomen are often permanently rigid, owing, I conceive, to the morbid state of the spinal marrow.

In a case of albuminuria, detailed by Dr. Semple, the patient was affected with unconsciousness ; and with rigidity, now of one set of muscles, and then of another. The occurrence of the rigidity indicated that the spinal marrow was being stimulated by some morbid influence. The temporary, local, and migrating character of the rigidity indicated, as the *post-mortem* examination proved, that the rigidity was not due to spinal meningitis, or spinal disease, but to the more general and varying influence of poisoned blood circulating through the nervous centres.

In the violent convulsive movements of hysteria and of epilepsy, asphyxia, and all convulsions with unconsciousness, in the performance of which the vocal cords come together, and the whole muscles of the frame are violently rigid, it appears to me that the closure of the vocal cords, and the muscular rigidity, are owing, in part at least, to a centric morbid excitation of the spinal marrow.

The same may, I conceive, be said of crying and laughter, of sobbing and crowing inspiration, and indeed of all those semi-convulsive emotional movements in which the vocal cords come irresistibly together. In these instances I conceive that, while the control of the brain over the nervous system is lessened or suspended, the centric or direct, and the eccentric or reflex spinal functions are, as in tetanus, simultaneously exalted.

On the Causes which excite Ordinary Respiration.

I have hitherto attempted to explain only those extraordinary acts of respiration which are excited reflexly by stimulating the peripheries of the nerves, either at the surface or in the internal organs; those respiratory acts which are caused by volition, emotion, or comatose unconsciousness; and those which are produced by immediately stimulating the spinal marrow.

In most of those instances, the causes exciting the extraordinary act of respiration are palpable.

It is by no means so easy to discover the physiological causes of ordinary respiration. Inspiration and expiration follow each other with noiseless regularity. We are not conscious that we breathe. The exciting cause of ordinary respiration is not palpable. This is however to be noticed, that respiration and bodily exertion are in exact relation to each other.

In order to estimate, with some approach to exactness, the amount of air respired when at rest and during exertion, I constructed an apparatus, by means of a valved ori-nasal inhaler, and a balloon made of gold beater's skin, to receive the expired air. The balloon held about 600 cubic inches. My breathing capacity is about 300 cubic inches; and I exactly filled the balloon by blowing into it as much air as I could during two of the deepest possible expirations.

							Cubic Inches.
When I sat,	I respired about 16 times in the min.;	I filled the balloon in about	90 secs.,	by from	24 to 26 expirations,	the volume of each expirtn. being abt.	24
When I walked about 4 miles in the hour,	22	,,	30	,,	10 to 11	,,	60
When I ran at a moderate speed,	30 to 34	,,	12 to 18	,,	6 to 9	,,	66 to 100
After running as fast as possible, I stood still almost out of breath. I filled and emptied the balloon seven times in succession;	During the 1st inflation	,,	6 secs.,	,,	5		120
	,, 2nd ,,	,,	12 to 14	,,	8		75
	,, 3rd ,,	,,	16 to 20	,,	10		60
	,, 4th ,,	,,	25 to 30	,,	13 to 14		44
	,, 5th ,,	,,	40 secs.	,,	15		40
	,, 6th ,,	,,	45 ,,	,,	18		33
	,, 7th ,,	,,	50 ,,	,,	20		30
Immediately after running up hill, at the top of my speed, when out of breath,		I filled the balloon by			3		200
When running very fast, on level ground,		,,			4		150

We thus see that I respired the same quantity of air during six seconds immediately after running, that I respired during ninety seconds, when sitting still; in other words, I inspired sixteen times more air when almost out of breath than when at rest.

Every muscular exertion causes increased decay in the muscular structure; that increased decay involves increased oxygenation, augmented respiration, and more rapid circulation. We know that if a muscle or any other organ be exercised, the circulation of blood through that organ is immediately increased. More oxygen is conveyed to the exercised part; its oxygenation and decomposition are consequently effected at the same time that there is, in the increased supply of blood, an increased supply of the materials of nutrition. It is not alone in the muscles that the blood circulates more rapidly and abundantly during exertion, the whole circulation being increased through the cutaneous and pulmonary capillaries.

When the flow of blood through the cutaneous, muscular, and pulmonary capillaries is increased, it is evident that the cutaneous, muscular, and pulmonary incident or excitor nerves will be unusually stimulated.

When the surface is stimulated by the dashing of cold or hot water, or by the application of an external irritant, we have already seen, at p. 247 and elsewhere, that successive deep inspirations are excited ; and that, at the same time, there is increased circulation, with redness of the surface. The increased respiratory movements are excited reflexly by the increased stimulus to the incident or excitor nerves, afforded, I conceive, by the immediately augmented capillary circulation, as well as by the immediate external stimulant.

In like manner, when the muscles are vigorously exercised, the incident nerves of the muscles are immediately stimulated by the muscular movements ; and the incident nerves, both of the surface, the muscles, and the lungs, are unusually stimulated by the increased capillary circulation. The cutaneous, muscular, and pulmonary incident nerves being thus stimulated, chiefly, I conceive, by the augmented circulation, increased reflex respiratory movements are excited. The extent to which the increased respiratory movements are excited is proportioned to the increased capillary circulation.

That the increased movements of respiration during muscular exertion are excited not alone by the muscular movements, but by the augmented circulation also, is evident, since the increased inspiratory movements continue for some time, even after the muscular exertion is arrested. It is clear that the quiescent, perhaps exhausted muscle, can no longer excite the still increased respiration. We find, however, that the circulation is still increased in force, amount, and rapidity ;

and so long as the circulation is so increased, the respiratory movements continue to be increased likewise. In exact proportion as the augmented capillary circulation gradually regains its ordinary level, so do the increased respiratory movements gradually resume their ordinary play.

In the illustration just given of increased respiration, with increased circulation from exercise; just as in the illustrations previously given of increased respiration, with increased circulation from the application of external stimulants; it is evident, I conceive, that the increased respiratory movements have been excited reflexly through the stimulation of the incident nerves by the augmented capillary circulation.

From the table given above, it appears that when I walk at an ordinary quick pace I respire three times as much, and when I run I respire sixteen times as much, as when I sit still. The cause of the increased respiration when I walk is manifestly the same with the cause of the still more increased respiration when I run.

It is evident that there is no difference in the essential nature of respiration, whether we sit, walk, or run; the only difference is in degree. Sitting, walking, and running are ordinary healthy acts of life, and the respiration may then be classed as ordinary respiration, whether performed to a moderate, an increased, or an excessive extent. I consider that the cause of respiration resides in each of these instances in the stimulus which the blood circulating through the capillaries affords to the adjoining peripheries of the incident nerves; and that the ordinary acts of respiration are caused reflexly by the excitement of the afferent nerves by the circulation.

That the ordinary movements of respiration are reflex, is demonstrated by the researches of Dr. Marshall Hall, Dr. John Reid, and other physiologists. The experiments of

M. Volkmann, referred to at p. 360, show that when an electro-magnetic current is passed downwards through the cord, continuous movements are excited, which last even after the withdrawal of the electro-magnetism. If, on the other hand, the electro-magnetic current be transmitted upwards along the afferent nerves, a series of reflex muscular movements take place alternately with muscular relaxation. The *intermittent* movements are reflex, while the *continuous* movements are direct or centric in their origin.

Now intermittent muscular contractions, alternating rhythmically with intermittent muscular relaxation, are characteristic of, and essential to the respiratory movements. Consequently, the movements of respiration are reflex movements, and have the source of their excitation in the incident nerves.

Taking it then for granted that the ordinary tranquil movements of respiration are reflex, the important question that we have now to answer is this, How are the movements of inspiration excited ?

According to Professor Müller, it is the theory of M. Kind, that it is the stimulus of the air, acting on the cutaneous nerves, and transmitted to the spinal cord, which gives rise to respiration as a reflected movement.

That the air frequently does act as a stimulus on the cutaneous nerves, so as to give rise to reflected movements of inspiration, is amply proved in many instances already cited. In a case recorded by Dr. Marshall Hall, a new-born child did not breathe at first, but as soon as the bed-clothes were lifted up, and the surface was exposed to the air, it breathed freely.

In Ann Oakland (p. 324), affected with syncope, wafting cold air over the face excited deep inspirations. When Elizabeth Hopkinson (p. 340) was in an hysterical fit, the surface was exposed to the air, and the hysterical was gradually replaced by normal respiration. In George Newsom (p. 343), when respiration was interrupted or stridulous during the paroxysms of laryngismus stridulus, the exposure of the surface to cold air excited normal inspirations.

Sir Humphry Davy immersed a rabbit in hydrogen until it was apparently inanimate ; he then restored it to the air, and in less than a minute it inspired. On another occasion he placed a water lizard in nitrous oxide; in 15 minutes it lay as if dead ; after being exposed to the atmosphere for three or four minutes, it took an inspiration (p. 227). Dr. Goodwin put a toad into water after exposing its heart and lungs ; in 40 minutes its heart had ceased to beat, and it gave no sign of life. It was now removed into the air, and before the end of two minutes it took a quantity of fresh air into the lung (p. 227). Dr. Edwards took a frog, and having cut out its heart, he immersed the animal in water until it appeared lifeless ; he exposed it to the air, and it immediately began to recover (p. 228). Professor Müller kept a frog in hydrogen for four hours, when it was apparently dead ; but it revived when restored to the air. Dr. Hall divided the spinal marrow of a frog, and immersed it in water ; there was no respiration ; on being exposed to the free open air, respiration was gradually restored. In some cases of poisoning by opium, the depressed respiratory powers have been roused by free exposure to a stream of cold air (p. 229).

The air, especially when it plays in a fresh, cold stream on the surface, has a vivifying effect on the cutaneous incident nerves, exciting through them increased reflex inspiratory movements ; and I may here state that it has a like vivifying effect on the circulation in the cutaneous capillaries.

We see, then, that the stimulus of air, especially if in a cold stream, may re-excite, maintain, and accelerate respiration when it has been recently suspended from various causes.

While it is certain that air, especially when it plays in a current, is one of the most important stimulants of inspiration through the medium of the cutaneous nerves, especially of the fifth pair, we may safely infer that air is not the only such stimulus. Indeed, external warmth, the dashing of cold or warm water on the face, the application of ammonia to the nostrils, and of external stimulants to the surface, as we have already seen, act as excitors of inspiration with even more intensity and vigour than the exposure to a current of air. We have also seen that the increased vigour of the cutaneous circulation excites increased respiratory movements.

External warmth is one of the most important means of restoring respiration when suspended, and of maintaining and accelerating it afterwards.

It is especially in the cold-blooded animals, and in the hybernating mammalia, that external warmth excites respiration. In those animals the respiration is accelerated in exact proportion to the increase, and retarded in exact proportion to the diminution of the external temperature, until, at a temperature at and somewhat above 32°, respiration ceases.

This is illustrated, as we have already seen, in an interesting and conclusive manner by Spallanzani, in snails (p. 262) ; by Mr. Newport and Mr. Barlow, in insects (p. 263) ; by Spallanzani and by myself, in fishes (p. 268) ; by Dr. Edwards, in frogs, (p. 271) ; by M. Saissy, Dr. M. Hall, and M. Regnault, in the hybernating mammalia (p. 276) ; and by Dr. Edwards, in the imperfect young of certain mammalia, and the prematurely born of all (p. 279). In all of these instances, of each of which I would urge your re-perusal, the respirations almost or altogether ceased at or about the freezing point, and increased gradually in number and volume as the temperature gradually increased.

It has been shown above, that this is not so with the higher adult warm-blooded animals, their respiration, within certain limits, being quickened by a lower, and rendered slower by a higher temperature (p. 280). If, however, they are exposed to a temperature above 100°, MM. Delaroche and Berger have shown that the respirations are much accelerated (293). The hot bath, as Mr. Barlow has observed (p. 293), quickens and deepens respiration. Dr. Miller, in his work on "Madeira," relates that "a man entered one of the *estufas* at a temperature of 160°, the air being saturated with water and spirituous vapour from wine. Pulmonary exhalation was suppressed, and, after remaining three minutes and a half, perspiration by transudation was excited to such an extent that sweat streamed from every part of his body. The respiration was increased in frequency, and he appeared so exhausted as to be scarcely able to stand. He continued panting for eight or ten minutes after he came in contact with the external atmosphere, which at the time was from 65° to 70°."

We thus see that in the perfect and healthy mammalia, in man himself, respiration is quickened so as to be even rendered panting by the exposure of the surface to a temperature above 100°.

If the temperature of adult warm-blooded animals be much lowered by long-continued exposure to extreme cold, or by inanition, as in Chossat's experiments (p. 288), the respirations become slower and slower when the animal becomes torpid and is at the point of death. If at this critical point, when the respirations have actually ceased, the animal be exposed to an elevated temperature, in two minutes the respirations become marked, and in six minutes they are quite re-established.

The re-establishment of the respiratory movements by external warmth, after they have been arrested by external cold, is admirably illustrated by Mr. Barlow in the experiment in which he decapitated an eel; after a time the gaspings ceased, but they were renewed with vigour when the head was plunged into water at a temperature of 90° (p. 292).

This is further illustrated in Dr. M. Hall's remarks at p. 329, and in the cases of poisoning by opium related by Dr. Alison and Mr. Walne, in which, after repeated cold dashing, the surface became cold, the respirations slow; but on their applying external warmth the surface became warm and the respirations were accelerated (p. 247).

While in Mr. Barlow's experiment the gaspings were re-excited by heat, independently of the circulation; it is to be observed that in all those instances in which the animal is not mutilated, the restoration of respiration is coincident with or even consecutive to the restoration and acceleration of the superficial capillary circulation. Indeed, in the cold-blooded animals, and in the hybernating mammalia, the circulation continues sluggish, although the respiration is suspended.

The influence in exciting quickened and deepened respiration by dashing cold water on the surface is related at pp. 220, 224, 248, 250, 324, 337; of ammonia to the nostrils, at p. 248; of external irritants, at p. 253; and of electro-magnetism, at pp. 253, 254.

In all these instances the respirations were excited and accelerated in a reflex manner by the stimulation of the incident nerves of the surface.

Cold has a remarkable effect on respiration.

In the cold-blooded animals, and in the hybernating mammalia, in proportion as the temperature is lowered, respiration is depressed, until at and above the freezing point breathing is arrested (pp. 262, 276).

It is quite otherwise with the higher warm-blooded animals; in proportion as their temperature is lowered, respiration is quickened. If, however, the cold be intense and long-continued torpor comes on and respiration is lowered, and at length arrested. Cold in the higher classes excites respiration, so long as the nervous energies are high ; but as soon as they are blunted, cold depresses and extinguishes respiration, in fact, they are then reduced to the condition of cold-blooded animals (pp. 276, 289).

The various external influences, of which I have just spoken, evidently excite respiration under peculiar circumstances ; it may be truly said that they excite or influence ordinary respiration. But when we consider that the movements of respiration are performed for a longer or shorter time under water, and in certain gases, as well as in air, and during extreme heat and extreme cold, it is manifest that the agencies in question do not in themselves habitually excite ordinary respiration.

We have also seen that the ordinary respirations are not excited by the direct influence of the central organs, either the brain or the spinal marrow.

The ordinary respirations are reflex movements, and are necessarily excited by the stimulation of incident nerves.

Those reflex movements, though they can be regulated, cannot be habitually excited by any irregular external influence. Any such influence, after it has stimulated, would necessarily exhaust the excitability of the incident nerves, and so, after exciting, would arrest respiration, unless it were replaced by some stimulus of an opposite character.

The reflex movements of ordinary respiration must then be excited by some stimulus that pervades the whole system ; that, after it has stimulated the incident nerves, and so excited respiration, can reinforce their excitability, and then again rhythmically re-stimulate the incident nerves, and so re-excite respiration. They must be excited by a stimulus from within the organism, that varies in force in proportion to the higher or lower energies of the system ; and to the varying external stimulants that excite or influence respiration. Such a stimulus resides in the circulation, and in the circulation alone.

The circulation of blood is necessary to the excitability both of the incident and the motor nerves. Tie the aorta, and sensation, excitation, and motion are cut off from the hind limbs ; remove the ligature, and with the returning circulation there is returning sensation, excitation, and motion. More than this, the nervous energies rise with the energy of the circulation, and the nervous energies flag when the circulation flags.

When respiration is increased by external stimulants (p. 221 and seq.), by exercise (p. 367), or by mental emotions (p. 320 and seq.), the circulation is in each instance excited in exact proportion to the excitation of respiration ; and after the cause exciting respiration and the circulation has ceased, the accelerated respirations continue as long as the circulation is energetic ; as soon as the circulation regains its ordinary level the respirations resume their ordinary play.

When respiration is depressed or arrested by depressing external agents (p. 262 and seq., p. 290), by exhaustion, by inanition (290), by food, by stimulants, or narcotics circulating in the blood (p. 240 and seq.), or by depressing emotions with syncope (p. 323 and seq.), the circulation is in each instance depressed or arrested in exact accordance with the depression or arrest of respiration.

Professor Volkmann considers that the respiratory movements, reflex in their nature, are excited by the carbonic acid circulating in the blood, throughout the entire organism, acting as a stimulus on all the incident nerves, and by no means exclusively on the vagus.

Now, while blood when charged with carbonic acid and accumulated in the capillaries acts as a most powerful stimulant to the incident nerves, and excites, as I shall show hereafter, those violent convulsive inspiratory movements which take place during asphyxia, it can be conclusively shown that the presence of carbonic acid in the blood diffused throughout the organism does not excite ordinary tranquil respiration.

I would here engage your best attention while I trace the circulation of the blood through the system during ordinary respiration; and its influence in exciting inspiration.

Since the expiration immediately precedes the inspiration, it is quite clear that the physiological cause exciting the inspiration must exist during, or just at the end of, the act of expiration. I remarked the other day, when Dr. Snow was administering chloroform to a patient, that the dilatation of the nostril commenced during the act of expiration. Inspiration begins at the nostrils, and may be excited even during costal and diaphragmatic expiration.

The blood sent over the system by the left ventricle is arterial, and contains less carbonic acid than the venous blood received into the lungs.

The experiments of Poisseuille have shown that during the act of expiration arterial blood is propelled with greater *force* and in greater *quantity* through the whole system, than during the act of inspiration.

The increased force and quantity with which the arterial blood circulates through the systemic capillaries during, and especially towards the end of each expiration, act so as to give an increased stimulus to the incident systemic nerves, especially the cutaneous nerves. I say especially to the cutaneous nerves, not because those nerves are the special excitors of inspiration, but because the great proportion of the incident nerves, possessing both sensory and excitor functions, are distributed to the skin ; the whole of which is exposed to the constant play of external agents. The face is more richly endowed with incident nerves than any other part ; and both the ordinary and extraordinary respiratory movements have one of their chief seats of excitation in the face. I consider that the increased stimulus so applied to the systemic incident nerves, during excitation, excites through the spinal marrow the reflex movement of inspiration.

It is during expiration that the systemic circulation is most energetic ; that the systemic incident nerves are thus stimuated, and that the next inspiration is excited. During inspiration, the excitability of the incident nerves of the system is exhausted. During expiration, the excitability of the incident nerves, exhausted during the previous inspiration, is first restored, and then the nerves are stimulated by the increased energy of the circulation.

There is during expiration and inspiration an *alternation* of increased and of exhausted excitability of the incident nerves with an alternation of contraction and relaxation of the muscles of inspiration.

It is clear, then, that it is not the blood charged with carbonic acid, but, on the contrary, blood charged with oxygen, that is distributed with greater force and volume during expiration, to the systemic capillaries, so as to excite reflexly the next inspiration. Professor Volkmann is therefore manifestly in error when he attributes the cause of inspiration to the carbonic acid contained in the blood diffused throughout the organism ; since the quantity of oxygenated in proportion to carbonized blood circulating in the capillaries is greatest during expiration, when the cause exciting the next inspiration is in operation.

Having shown (I believe on sufficient grounds) that the movements of inspiration are chiefly excited through the incident nerves of the skin, stimulated through the cutaneous capillaries:—I have now to inquire whether the respirations are also excited through the incident nerves of the lungs, stimulated by the circulation through the pulmonary capillaries?

Before considering the influence of the pulmonary branches of the par vagum on respiration, I here insert Dr. Snow's narrative of the experiment already detailed at page 238.

"Dr. Sibson came to perform some experiments on the functions of the pneumogastric nerves. Mr. Marshall was present the greater part of the time. A youngish dog, weighing twelve pounds, was placed in a 3,000 cubic inch jar, into which one drachm and a half of chloroform was put. The dog became gradually insensible, without offering any resistance or exhibiting any excitement; his respiratory movements, which were twenty in a minute before the chloroform was put in, were not materially quickened. At the end of five minutes he was taken out quite passive and relaxed. In the first incision through the skin of the neck, a considerable vein was divided, which caused the loss of an ounce or two of blood before it could be tied. After this, as the dog was recovering from the effects of the chloroform, ether was given to it by means of the small inhaler applied to its nose. The pneumogastric nerves were dissected out to a small extent, and a thread passed under each of them. The breathing was much quickened whilst the dog was inhaling the ether, and the quickness of breathing continued for a minute or two after the inhalation was left off, showing that it did not depend on the presence of the vapour in the air-cells. The trachea was divided, and on irritating the interior of the trachea with a probe, the breathing was quickened a very little. On the probe being passed down, however, to the bifurcation of the trachea, efforts at coughing were excited. On passing the probe up into the larynx, struggles were caused, apparently the result of pain or uneasiness, for the effects of the ether had been allowed to subside before the probe was introduced into the trachea.

"The dog was again made insensible with ether, by applying it first on a sponge to the opening in the trachea, then by introducing into the trachea a brass tube attached to the balloon holding 900 cubic inches; which had been filled up with air after one drachm and a half of ether had been put in. The respirations were rendered exceedingly rapid and forcible at this time. The probe being passed up into the larynx when the dog was insensible, no struggles were occasioned, but the breathing was rendered a little quicker and deeper. On pinching either pneumogastric nerve, the same effect was produced, *i.e.*, the breathing was rendered a little quicker and deeper. On dividing the right pneumogastric nerve, the respirations at once fell to six in the minute, and became deep and full. There was a short pause after each inspiration, and a long pause after each expiration. The division of the left pneumogastric nerve made no further difference (it had been previously pinched).

"Various observations were made on the larynx and pharynx after the pneumogastric nerves were divided; and subsequently ether was administered by a sponge applied to the opening in the windpipe. It gradually quickened the respirations from one in ten seconds to one in nine, eight, and ultimately seven seconds. Preparatory to trying to arrest the action of the heart with chloroform, some time after these observations with ether, chloroform was given on a sponge applied to the opening in the windpipe, in order to make the dog insensible, and thus keep him quiet during the final experiment. It was found that the chloroform in a very little time began to make the respirations quicker, they being first rendered apparently as natural as before the division of the pneumogastric nerves, and then becoming very deep and forcible, ninety in the minute.

"At one part of the experiment, and after the pneumogastrics were divided, Dr. Sibson introduced a stop-cock into the trachea, which, being of narrow calibre, increased the length and force of the inspirations and expirations, and the stop-cock being half turned, so as still further to lessen the aperture, the inspirations were rendered still longer; and I particularly remarked that the stop-cock being half turned at the end of an expiration, and before the commencement of the next inspiration, that inspiration immediately occurring was rendered of twice the length of the previous one, or, at all events, was much longer and more forcible.

"The dog having been made totally insensible by chloroform given on a sponge, the usual chloroform inhaler was adapted to the trachea by means of a piece of elastic tube, six or eight inches long, into which a smaller tube was put at the end next the trachea, wide enough to allow of easy respiration. The dog thus breathed to and fro through the inhaler, the water bath of which was at 120°. Two drachms of chloroform were immediately put into the hitherto empty inhaler, and after drawing five or six deep and sonorous inspirations, the breathing ceased; the sounds of the heart, however, continued for a little time (half a minute to a minute) afterwards, and after they could be no longer heard the dog drew one or two deep and final inspirations.

"On the body being opened, immediately afterwards, the right auricle was found to be contracting feebly, and the right ventricle just perceptibly. The muscles contracted strongly under electro-magnetism. On the following day the heart was opened, the cavities of both sides were found about half full of blood, which was coagulated, but not very firmly."

This experiment coincides with the experiments of

Legallois, Dr. John Reid, Longet, Volkmann, and of many other physiologists, demonstrating that while the par vagum exercises a very important influence on respiration, yet that the integrity of that important nerve is not necessary to respiration.

M. Volkmann removed the lungs from a new-born animal, yet the movements of respiration were performed rhythmically for the space of forty minutes. The fact is in keeping with the experiment in which Legallois removed the heart of a new-born rabbit, and yet the creature gasped repeatedly and rhythmically for the space of twenty minutes. It is evident that here the inspirations were not excited by the circulation through the pulmonary capillaries.

The experiment detailed at p. 239, and that in the Appendix, show, that although ether and chloroform remarkably accelerate respirations, yet the respirations are not materially quickened at first when the vapour enters the lungs and the blood circulating in the pulmonary capillaries; they are not indeed accelerated until the stimulus is conveyed by the circulation over the systemic capillaries. More than this, respiration is remarkably quickened by the administration of chloroform, and slightly by that of ether, even after the division of pneumogastrics; when, in short, the reflex influence could not be excited through the pulmonary incident nerves, their connection with the spinal marrow being cut across.

Although it is quite established that the division of the pneumogastrics causes a remarkable diminution in the number of respirations, yet it does not diminish their force. On the contrary, the power with which the inspirations are performed is greatly increased after the division of the par vagum. In the experiment just related, immediately before the division of those nerves, the animal breathed quietly, the mouth and nostrils being quiescent; immediately after their division, the mouth and fauces, and nostrils, were expanded to the utmost during each inspiration ; a great number of additional inspiratory muscles were called into play, and the causes exciting inspiration undoubtedly acted with greater force and effect.

In another experiment on a dog, detailed in the Appendix (Exp. A), I ascertained the amount of air respired before and after the division of the vagi, by means of an apparatus arranged for the purpose by Dr. Snow. Before the division of the vagi, when the breathing was somewhat hurried, the dog expired 900 cubic inches in seven and a half minutes, and in about 230 respirations ; the respirations varied from 22 to 44 in the minute ; and each expiration consisted, on an average, of four cubic inches. After the division of the vagi, the animal expired 900 cubic inches in eight and a half minutes, and in about 51 expirations ; the respirations were six in the minute, and each respiration consisted, on an average, of about twenty-two cubic inches. We thus see, that although, after the division of the vagi, the number of respirations were diminished to about one-fourth, yet the volume of each expiration was five times as great, and the total quantity expired was nearly as great as before the division ; notwithstanding that respiration was stimulated and accelerated while making the previous observation.

It is remarkable that certain mutilations of the nervous system, such as pithing, and the division of the vagi, while they arrest, or disturb, the ordinary respiratory movements, exalt or excite certain extreme movements of respiration, such as gasping and dilatation of the nostrils.

That the continuance of the respiratory movements after the division of the vagi is not due to volition, is evidenced by the experiments of M. Volkmann, M. Flourens, Dr. Reid, M. Longet, and Dr. Marshall Hall ; those physiologists divided the pneumogastrics, and also removed the brain, yet the respirations, though infrequent, were still performed.

It is evident, indeed, that the par vagum in some way controls and regulates the movements of respiration, just as we have seen that the brain controls the reflex movements.

Although the movements of respiration may continue, even with increased power, after the division of the pneumogastrics, yet it is quite certain that the respiratory movements may be excited through their agency. This is amply proved by the experiments of Dr. Hall and Mr. Broughton, and other physiologists.

Bichat observed that respiration was increased when he irritated the vagus; but this he attributed to the pain excited. Dr. Reid, however, found that even when an animal was under the influence of prussic acid, the respirations were increased by stimulating the vagi. In the first experiment in the Appendix, on laying hold of the vagus, the respiration rose from 9 in fifteen seconds to 20.

It is more particularly the expulsive or expiratory actions which are excited by stimulating the extremities of the vagus diffused in the pulmonary and other mucous membranes. This is in harmony with Müller's important generalization, that the stimulation of any part of the mucous membrane excites an expulsive effort, directed upon the neighbourhood of that part; thus sneezing is excited by stimulating the nostrils, vomiting by stimulating the fauces, the expulsion of the fœtus by stimulating the vagina. In like manner, in Mr. Erichsen's, Dr. Reid's, M. Brachet's, and my own experiments, coughing was excited by stimulating the bronchial mucous membrane. Indeed, as M. Valentin, according to Müller, states, irritation of the pulmonary branches of the par vagum excites expiration.

I consider, indeed, that as each ordinary inspiration is excited reflexly by the influence of the circulation in the cutaneous capillaries on the cutaneous and other incident nerves, so each ordinary expiration is excited by the influence of the blood circulating in the pulmonary capillaries on the pulmonary branches of the par vagum.

During expiration, while the systemic capillaries receive the greatest amount of blood, the pulmonic capillaries receive the smallest amount of blood. On the other hand, during inspiration, while the circulation is the least vigorous and copious in the systemic capillaries, it is most vigorous and copious in the pulmonic capillaries. When the external pressure is removed from the lungs, by the expansion of the chest, air forced inwards by atmospheric pressure is admitted more freely into the air-cells, and blood forced onwards by the ventricular contraction is admitted more freely into the pulmonic capillaries.

I consider that the incident pulmonary branches of the pneumogastric are stimulated during inspiration by the increased circulation in the pulmonary capillaries, and by the sudden exposure of the pulmonary mucous membrane to a purer and cooler atmospheric air, and that the reflex act of expiration is thus excited.

I consider, then, that the increased quantity and force with which the blood circulates during expiration in the systemic capillaries stimulates the incident and especially the cutaneous nerves so as to excite reflexly the next inspiration; and that the increased quantity with which the blood circulates during inspiration in the pulmonary capillaries, and the sudden impression of a cooler and purer air on the pulmonary mucous membrane, stimulate the incident pulmonary branches of the par vagum, so as to excite reflexly the next expiration. The inspiration has its usual source of excitement in the skin during the expiration; and the expiration has its usual source of excitement in the lungs during the inspiration.

I do not deny that the pulmonic branches of the par vagum may in some measure excite ordinary inspiration; but that they actually do so is certainly not proved. I know, indeed, that the pulmonic branches of the par vagum may be stimulated, like the other incident nerves of the mucous membranes, so as to excite a deep inspiration. Thus, on irritating the nostril a deep inspiration is excited, followed by violent sneezing. On stimulating the vagina during labour a deep inspiration is excited, followed by a violent expulsive expiration. So on stimulating the bronchial mucous membrane, an expulsive cough is excited, but that cough is preceded by a more or less deep inspiration.

In the experiments A and B, detailed in the Appendix, as well as in others, when I passed a probe through an opening in the trachea, downwards into the bronchia, I excited an expulsive effort, but such effort was invariably preceded by a deep inspiration. So long as I stimulated the bronchial mucous membrane by moving the probe freely about, I excited renewed deep inspirations, followed by expulsive efforts; the respirations being sometimes increased in number, sometimes diminished. If, however, I left the probe quiescent in the bronchia, the respirations were not perceptibly altered.

After the division of the vagi, the respirations were not in the slightest degree affected by moving the probe freely about in the bronchia.

If I passed the probe upwards into the larynx before dividing the vagi, I excited a cough or an expulsive effort, but such cough was in no instance preceded by an inspiration, even when the larynx was stimulated just at the end of an expiration. How beautifully special is the excitability of the incident nerves of the larynx. The stimulation of every other mucous membrane, as the vagina, the rectum, the neck of the bladder, the fauces, the nostrils, and the bronchial tubes, excites respectively, according to the part stimulated, the expulsion of the fœtus, the fæces, or the urine, vomiting, sneezing, or coughing; each expulsive effort being invariably preceded by a deep inspiration, so as to give additional purchase to the expiratory muscles, as well as, in sneezing and coughing, to flush the air-passages by the additional rush of air from behind, and in the acts of expulsion from the abdominal cavity, to compress the viscera by the descent of the diaphragm. Why is it that the stimulation of the larynx alone excites an expulsive effort that is not preceded by an inspiration? It is that the irritating gas or fluid which stimulates the larynx may be absolutely forbidden to enter the lungs, an event that in itself might prove fatal. (See p. 308.)

The blood in the pulmonary capillaries is more charged with carbonic acid during expiration than inspiration. It seems probable, therefore, at first sight, that the blood then circulating is more stimulating than the more arterial blood circulating during inspiration. If this were so, it would give support to Dr. Marshall Hall's view, that the inspiration is excited by the excess of carbonic acid which accumulates in the lungs and the pulmonary circulation during each expiration. The freshly oxygenated blood is, however, even more stimulating to the incident nerves than the carbonized blood. This is proved by an experiment of Legallois. He pithed a rabbit, and in three minutes and three quarters it ceased to gasp. In four minutes and a half, when the carotids were black, and the heart active, artificial respiration was performed. Within five seconds the carotids were full and red; and in fifteen seconds the gaspings were renewed. Here the oxygenated blood re-excited the gasping, which had ceased under the influence of carbonized blood.

If more blood, even although carbonized, circulated in the pulmonary capillaries during expiration than inspiration, then its increased quantity would more than make up for its less stimulating quality, and the pulmonary incident nerves would be more highly stimulated during expiration than inspiration; but, as we have already seen, the facts are directly opposed to this supposition, for there is less blood, as well as a less stimulating blood, in the pulmonary capillaries during expiration than inspiration. Besides this, the carbonic acid accumulates gradually in the air-cells and in the blood in the pulmonary capillaries during expiration. Now, reflex movements are not so readily excited by slowly increasing, as by sudden impressions. It is during inspiration, and not during expiration, that a sudden impression is made on the pulmonary incident nerves; since it is during inspiration that the cold air suddenly enters the lungs, and that the blood suddenly finds its way in an increased flow into the pulmonary capillaries. That blood, too, then becomes suddenly oxygenated, and so presents a rapid alternation from a state of torpor and carbonization in the pulmonary circulation during expiration to a state of energetic vitality and oxygenation during inspiration, the latter condition being greatly more stimulating to the pulmonary incident nerves than the former.

There is every reason, then, to infer, that while the inspirations are ordinarily excited by the increased flow of blood stimulating the systemic, especially the cutaneous incident nerves during expiration; the expirations are ordinarily excited by the increased flow of blood stimulating the pulmonary incident nerves during inspiration, as well as by the colder and purer air, then in the air-cells.

In the experiment B, detailed in the Appendix, perfectly rhythmical respiratory efforts were made for two minutes after the trachea was closed by the grasp of the finger and thumb. This experiment proves that the inspiratory movements do not depend on the alternate increase of carbonic acid in the lungs and pulmonary vessels during expiration, and diminution during inspiration; since tranquil respiratory efforts were made rhythmically, although the carbonic acid in the lungs went on progressively increasing; until at length, when its accumulation in the system as well as in the lungs was at the utmost, asphyxial convulsive respiratory movements were excited. It is to be observed, that these respiratory movements could not depend on the stimulation of the par vagum, since they were performed with equal regularity and force, after as well as before the division of the nerves.

Although the circulation is the ordinary excitor of respiration, yet in the cold-blooded, and the new-born imperfect warm-blooded animals, the respiratory movements may continue after the cessation of the circulation. This is instanced in Mr. Barlow's experiment, in which gaspings were renewed in the head of a decapitated eel, on its being immersed in warm water; and in the experiments of M. Legallois, on new-born rabbits, in which gaspings continued for twenty minutes after excision of the heart. When the adult warm-blooded animal is beheaded, gasping continues but for a very short period, the circulation being more necessary and efficient in exciting respirations in the adult than the young. In a series of experiments on adult linnets (see Appendix, p. 402), I found that gaspings were excited by decapitation, and that they lasted about ten seconds, while they continued for about fifty seconds when the cervical spinal column was severed, but the circulation in the carotids continued. I also found that if, in the latter case, I compressed the neck so as to arrest the supply of blood to the head, the gaspings ceased in about seven seconds. If, within two or three seconds of their cessation, I restored the circulation, the gaspings usually soon re-appeared. Here the carotids supplied the brain as well as the fifth pair in the face.

Dr. Reid's question, "Do the same excitations that occasion the muscular movements of inspiration operate in the production of the expiration which immediately follows, so that they are to be considered two stages of one and the same muscular action?" appears to be answered in the affirmative, in Mr. Barlow's experiment just referred to, and in Volkmann's experiment also, in which the respiratory movements continued forty minutes after the excision of the lung. Indeed, the respiratory movements are rhythmical, and like others of the rhythmical movements, it may be said that they are in a measure peristaltic. The heart's movements are rhythmical and peristaltic, beginning in the cava, ending in the ventricle; the respiratory movements may perhaps also be said to be peristaltic, beginning in the nostrils, passing thence to the glottis, and to the diaphragm and inspiratory costal muscles, and finally to the expiratory muscles. If the heart of the turtle be cut out, its movements, usually excited by the circulation, continue for hours; so with the movements of respiration, though usually excited by the circulation, they continue for a longer or shorter time after the circulation is cut off, especially in the cold-blooded animals.

On the Causes which Excite Respiration in Asphyxia.

If a stop-tap be tied into the trachea, and if the tap be turned so as to prevent the ingress or egress of air, a remarkable series of movements ensue. These movements consist in fruitless alternate repeated and rhythmical attempts at inspiration and expiration. These regular rhythmical movements were observed with minute exactness in the experiment A and B in the Appendix.

Dr. John Reid has very accurately observed the order of the phenomena. At first the animal is quiescent, and makes rhythmical efforts to breathe ; at the lapse of a minute and a half commence violent convulsive attempts at expiration. These struggling movements of expiration, alternating with movements of inspiration, last about a minute ; then succeed heaving inspirations, more and more feeble and distant, alternating with expirations.

Dr. Edwards and Dr. Marshall Hall have shown that the animal becomes unconscious as the convulsions commence. Dr. John Reid erroneously supposed that consciousness did not cease until the convulsions ceased.

If the stop-tap be opened, at an advanced period of the process of asphyxia, the respirations if renewed are diminished in frequency, slow and heaving.

In the adult animal the respiratory movements cease in about four minutes ; in a new-born animal they continue much longer. Legallois asphyxiated a new-born rabbit by submersion, and the respiratory movements continued for twenty-seven minutes.

The asphyxial respiratory movements are extreme ; their character is peculiar. Every respiratory muscle is called into powerful action ; the mouth and fauces being expanded to the fullest extent at each inspiration.

During the process, then, of asphyxia, the muscles are excited to action to a much greater extent and with much greater force than they are in ordinary respiration. It is therefore evident that the causes exciting the movements of asphyxial respiration are much more powerful than the causes exciting those of ordinary respiration.

We must here shortly consider what is the condition of the circulation during asphyxia. The successive labours of Bichat, Dr. John Reid, and Mr. Erichsen have shown that during asphyxia there is greatly increased resistance to the flow of blood through the systemic as well as the pulmonic capillaries. Those capillaries are swollen and distended with the increased quantity of slow moving, dark, carbonized blood. The force with which the blood is propelled along the arteries is at first greatly augmented, especially during the struggles of the animal, but also even after those struggles have ceased; gradually the circulatory force falls below even the normal standard.

We have already seen that Volkmann considers that the respiratory movements, reflex in their nature, are excited by carbonic acid circulating in the blood throughout the organism.

This view, which I have shown to be erroneous as regards ordinary respiration, is, I conceive, perfectly correct as regards asphyxial respiration.

During ordinary respiration the blood circulating in the capillaries is oxygenated, and is comparatively small in quantity; while during asphyxia the blood is excessive in quantity, and contains carbonic acid in excess.

The poisoned and augmented blood circulating in the capillaries during asphyxia is more stimulating to the peripheries of the systemic and pulmonic incident nerves than the healthy arterial blood present during ordinary respiration. Consequently, while the minor stimulus of arterial blood only excites the movements of ordinary respiration; the major stimulus of the augmented carbonized blood excites the increased and extraordinary movements of asphyxial respiration.

As I have already shown at p. 347 and seq., the increased movements of asphyxial respiration are not due alone to the increased excitation of the incident nerves, but are due also to the withdrawal of the control of the brain from the reflex and direct spinal functions. Indeed, the withdrawal of the control of the brain over the reflex and direct spinal functions, while those functions are themselves exalted, must be assigned as the cause of the violent convulsive movements which take place during rapid asphyxia. I say during rapid asphyxia, for if the asphyxia be very slowly brought about, no such convulsions are excited; the inspirations are however still characterized by the wide gasping of the mouth, palate, and fauces, and the extent of the muscular movements.

It is to be remarked that the inspiratory and expiratory movements are equally alternate and rhythmical, in asphyxial, as in ordinary respiration. It follows that the cause of the inspiration may then also be expected to alternate with the cause of the expiration.

In ordinary respiration, as I have more than once stated, I consider that during each expiration the augmented force and flow of arterial blood in the systemic capillaries stimulates the systemic incident nerves, and excites the reflex movements of inspiration; while, during inspiration, the increased amount of arterial blood in the pulmonary capillaries stimulates the pulmonic incident nerves, and excites the reflex movements of expiration.

It appears to me that a like chain of alternate increase and diminution, first in the systemic, and then in the pulmonic circulation, causes respectively by the very alternation, first the inspiration, and then the expiration.

In asphyxia, the greatest amount of blood is sent with the greatest force to the systemic capillaries during the expiratory effort; consequently, during expiration the incident systemic nerves are stimulated, and the reflex inspiratory movements are excited. On the other hand, during the effort at inspiration, owing to the enlarged space in the chest, caused by the expanding force of the inspiratory movements, the lungs contain a greater amount of carbonized blood, consequently the pulmonic incident nerves are stimulated, and the next expiration is excited.

Carbonic acid is not in itself, I conceive, more stimulating to the incident nerves than oxygen ; in fact, it is not, as I have already shown, so stimulating ; but one stimulus, as we have already seen, alternates with another. Oxygen first stimulates and then exhausts excitability ; carbonic acid re-stimulates the excitability, previously exhausted by the oxygen, and then again in its turn exhausts the excitability, which may be again aroused and again exhausted by oxygen.

Oxygen is, however, more stimulating, and more permanently stimulating, than carbonic acid ; but the one and the other will equally prove a stimulus in its turn.

The respiratory phenomena of chronic asphyxia differ, as I have already said, from those of rapid asphyxia, in the want of the violent convulsive expiratory movements. Those violent movements are wanting, I conceive, in chronic asphyxia, owing to the gradual deprival of consciousness and the gradual increase of the carbonic acid in the blood. The reflex and direct spinal functions are exhausted or lowered simultaneously with the removal of the cerebral control on the principle illustrated at page 357.

It is painfully interesting to notice asphyxial respiration creep slowly on in the dying, especially in those dying from bronchitis or pulmonary affections. The carbonized blood loiters in the cutaneous capillaries, and darkens the tumified skin. The inspiration becomes more heaving and slow ; more and more of the muscles of inspiration are put in action ; the nostrils dilate widely. At length the mouth gasps ; the tongue is protruded at the tip, and brought forwards and downwards at the base; the palate is raised ; and the glottis is expanded to the full by the wide inspiratory separation of the vocal chords.

Even when the air can only enter through an artificial opening in the trachea, the gasping movements of the mouth and nostrils take place.

Finally, after consciousness disappears, after the eye becomes fixed and glazed, after the muscles of the ribs cease to act, after the diaphragm itself ceases to move, and after even the nostrils have ceased to dilate, the mouth is still opened ; the upper jaw being raised during a few frightful gasps, while at the same time the tongue is lowered, the palate raised ; and these strange and ghastly movements are made sometimes at remote intervals for a minute, or even more, without any responsive expansion of the chest.

These last inspiratory movements, continuing perhaps after the circulation has ceased, are necessarily excited through the fifth pair ; death has stolen along the spinal system from below upwards ; the last nervous arc to die is the highest, that arc embracing the fifth pair, the reflex movements taking effect from the incident branches of the fifth, through the nervous centre, and back along the motor branches of the fifth, so as to retract the angles of the mouth by means of the buccal muscles, after the reflex movements of the nostrils have ceased to take effect along the seventh pair.

The mouth is expanded during asphyxial inspiration, whether the asphyxia be rapid or chronic, by the simultaneous elevation of the upper jaw and depression of the lower jaw ; the upper jaw is elevated by the muscles at the back of the neck, which pull down the occiput. I regard this asphyxial gasping as a most unfavourable and threatening sign. I have very rarely indeed seen persons recover who have exhibited this sign for some time; and I have watched, with a painful interest, such persons for days struggling in vain for recovery.

Whenever the organic processes are at work, circulation and respiration are active. The respirations are increased or diminished in proportion to the energy of the circulation and the activity of the organic functions. Whenever, wherever, and however the circulation is excited, whether by the activity of the organic functions, by exercise, by mental emotions, by the circulation of poisoned or stimulated blood, or by external stimulation, the respirations are proportionately increased. The circulation in the capillaries stimulates the peripheries of the incident nerves, and so excites the respirations in a reflex manner. Respirations are excited reflexly whenever the incident nerves are stimulated by the circulation, or by any other means, whether in the lungs or the system, the skin, the internal organs, or the general frame-work. The incident nerves are most abundant in the skin, and therefore the reflex respiratory movements are excited most frequently through the medium of the cutaneous incident nerves, stimulated by the cutaneous circulation. This is particularly manifested when respiration is quickened by the stimulation of the surface, as by the exposure of the surface of the cold-blooded animals to increased warmth, and of the warm-blooded animals, within certain limits, to increased cold; the incident nerves being stimulated, and the circulation and respiration roused, in one class by warmth, in the other by cold. But if torpor be induced in the warm-blooded animals by long-continued cold or inanition, then their nervous energies are lowered, and the respirations are diminished by increased cold.

The circulation of oxygenated blood is most abundant and energetic in the system during inspiration, in the lungs during expiration; and I conceive that the inspirations are usually excited reflexly by the stimulation of the systemic, especially the cutaneous incident nerves by means of the systemic circulation during expiration; and that the expirations are usually excited during inspiration by the stimulation of the pulmonary incident nerves by means of the pulmonary circulation, as well as by the sudden impression of the purer and cooler inspired air.

Deep inspirations are excited by excessive stimulation of the cutaneous nerves, and violent expirations, or expulsive efforts, by excessive stimulation of the pulmonary nerves, or indeed of the nerves distributed over any mucous membrane. Inspiration may, however, be excited as a precursor to the expulsive effort, and respiration may be increased by the stimulation of the bronchial as well as of any other mucous membrane, except that of the larynx; and expirations may be excited by the excessive stimulation of any of the incident nerves of the system.

Expiration may follow inspiration, and inspiration expiration, without a special excitation for each act; the respiratory movements being indeed rhythmical, and, I conceive, peristaltic.

Oxygen and oxygenated blood are in themselves more stimulating to the incident nerves than carbonic acid and carbonized blood; but blood when carbonized tends to accumulate in the capillaries, and when it does so it stimulates the incident nerves and the nervous centres to an inordinate degree; consequently during asphyxia violent convulsive respiratory movements are excited.

APPENDIX.

Experiment A.—In order to observe the effects of division of the vagi on respiration, I performed the following experiment on a dog, when I had the advantage of Dr. Snow's and Mr. Marshall's assistance.

After the animal was chloroformised, and the trachea was opened,

At 4 h. 15 min. the respirations were 12 in 15 seconds, 23 in 30 seconds.

4 h. 15 min. 16 secs. chloroform was administered through the opening in the trachea. The respirations were not quickened just at first; they were, however, speedily much accelerated.

At 4 h. 15 min. 45 secs. the respirations were 35 in 15 seconds.

4 h. 16 min. 30 secs. ,, ,, 44 in 15 seconds.

4 h. 17 min. the respirations were scarcely perceptible.
The chloroform was removed.

At 4 h. 19 min. 30 secs. a catheter was passed through the opening in the trachea down into the bronchia. The respirations were 25 in 15 seconds; the expirations became loud, forced, and noisy.

At 4 h. 20 min. the catheter was withdrawn; respirations, 15 in 15 seconds, the expirations being quiet.

At 4 h. 21 min. 30 secs. respirations, 15 in 30 seconds.

4 h. 22 min. a catheter was inserted into the bronchia, when loud coughing expirations were excited. Respirations, 22 in 30 seconds.

After this the respirations were successively 9 and 10 in 30 seconds. On re-administering chloroform the respirations gradually rose to 49 in 15 seconds.

At 4 h. 30 min. is under the influence of chloroform. Cutting excites no sensation. On putting a catheter down into the bronchia strong expirations are excited: a slight cough is excited on passing it upwards to the larynx. Putting the catheter downwards into the bronchia excites, first a deep inspiration, and then a forcible expiration, the respirations being 16 in 15 seconds. On passing it upwards to the larynx, a forcible expiration is excited, which is not preceded by an inspiration.

At 4 h. 46 min. respirations 10 in 30 seconds.

4 h. 46 min. 30 secs. a balloon was attached to the trachea, holding about 900 cubic inches, provided with valves, under the direction of Dr. Snow, and so arranged that all the expired air was sent into the balloon.

After the balloon was tied on, the respirations during successive periods of 30 seconds were 13, 14 somewhat blowing, 18 much deeper, 17 somewhat blowing, 19, 22, the animal then struggled a little, and was afterwards again quiet, the respirations falling to 11 in 30 seconds.

At 4 h. 54 min. the balloon being filled (in 7½ minutes) was withdrawn; after its removal the respirations were 17 in 15 seconds.

Soon after 5 o'clock the respirations were steady and regular, 9 in 15 seconds. On laying hold of the vagus, the respirations rose to 20 in 15 seconds.

A 5 h. 22 min. one vagus was divided; the animal ceased to breathe for a time, and then took a deep inspiration; the respirations were then 10 in 15 seconds. No palpable effect was excited on pinching either the upper or the lower end of the divided nerve.

When the respirations werē 7 in 15 seconds, the catheter was introduced into the trachea, with the effect of exciting cough, the respirations being 5 in 15 seconds.

On pinching the undivided vagus, coughing was excited.

At 5 h. 27 min. 50 secs. the opposite vagus was divided; the respirations fell to 4 in the minute. The creature gasped widely at each inspiration.

Putting the catheter down into the bronchia excited no movement of any kind. There were then from 5 to 6 respirations in a minute.

The balloon (holding 900 cubic inches) was re-applied to the trachea, and was filled in 9½ minutes, the respirations being regularly 6 in the minute during the whole period of inflation.

On a second occasion the balloon was filled in 8¾ minutes.

Subsequently, chloroform was applied over the opening in the trachea.

About 1 minute after the commencement of the inhalation of chloroform the respirations were 4 in 15 seconds; they were 9 in the next 15 seconds; and in the successive periods of 15 seconds they were 16, 18, 27, 36, 34; after this, the chloroform being removed, the respirations fell to 22, 19, 17. About this time the chloroform was renewed; the respirations rose from 20 in 15 seconds to 33. Finally, the chloroform was given in larger doses; the respirations fell progressively during each 15 seconds from 30 to 25, 21, 21, 19, 12, 18, 6 (20?), and finally to 3 in 15 seconds, that being the last record before the creature's death.

Experiment B.—The following experiment was performed on a cat; present, Dr. Snow and Mr. Marshall:—

When it was being chloroformised in a jar, it did not gasp; its nostrils were red; its breathing was slightly convulsive. It sank powerless to the bottom.

When under the influence of chloroform the trachea was opened; the respirations were 25 in 30 seconds. On putting a tube down into the bronchia, a deep inspiration was excited, and the expirations were more prolonged; the respirations were 7 in 15 seconds; after withdrawing the tube, during the second quarter of a minute, the respirations were 10 in 15 seconds. They were 18 in the next, and 14 in the next 30 seconds.

On passing the tube up to the larynx, a start and an expiration was excited, but this was not preceded by an inspiration even when the larynx was irritated at the end of an expiration, and when in the ordinary course an inspiration would take place.

Soon after the renewed administration of chloroform, the respirations were ... ... 14 during 15″.

The trachea was then closed by compressing it firmly between the finger & thumb.	the respirations	were	9	during the	1st 15″	after closing the trachea.
	,,	,,	7	,,	2nd 15″	,,
	,,	,,	8	,,	3rd 15″	,,
During the 6th, 7th, and 8th periods of 15 seconds the respiratory efforts were more powerful.	,,	,,	8	,,	4th 15″	,,
	,,	,,	8	,,	5th 15″	,,
	,,	,,	6	,,	6th 15″	,,
	,,	,,	6	,,	7th 15″	,,
	,,	,,	3	,,	8th 15″	,,
At the end of two minutes the air was re-admitted into the trachea.	,,	,,	0	,,	1st 15″	after re-opening the trachea.
	,,	,,	9	,,	2nd 15″	,,
	,,	,,	8	,,	3rd 15″	,,
	,,	,,	8	,,	4th 15″	,,
At the end of a minute the trachea was again closed.	,,	,,	25	,,	1st min.	after closing the trachea.

At the end of the first minute the animal gasped, and threw back its head, the respirations were 10 during the first half of the second minute.

At the end of 90 seconds the creature stretched itself, and the trachea was again opened.

After the trachea was again opened, the respirations were from 9 to 10 in 15″.

5 h. 7 m. One vagus was divided, the respns. were	7 in the 1st	15″		after the division of the vagus.
,, ,,	,,	6 ,,	2nd 15″	
,, ,,	,,	5 ,,	3rd 15″	
The trachea was then again closed,	,,	5 ,,	1st 15″	after closing the trachea.
,, ,, ,,	,,	5 ,,	2nd 15″	
During the 3rd 15 seconds the animal began to gasp,	,,	5 ,,	3rd 15″	,,
During the 4th 15 seconds the gasping increased,	,,	5 ,,	4th 15″	,,
During the 5th 15 seconds the gaspings were still wider,	,,	5 ,,	5th 15″	,,
At the end of 1 min. 15 secs. the trachea was opened, and the creature inspired very deeply,	,,	6 ,,	1st 15″	after opening the trachea.
	,,	5 ,,	2nd 15″	
	,,	4 ,,	3rd 15″	

The catheter was now passed into the bronchia without producing any effect.

Immediately before the division of the second vagus the respirations were 4 or 5 during 30″.

5 h. 13 m. The other vagus was divided. The respirations, not gasping, were 5 during the 1st 15″ after the division of the second vagus.

The creature then struggled, after which the respirations were 8 during the next 10″ after the division of the second vagus.

The respirations soon fell to 5 during 30″ after the division of the second vagus.

The trachea was then closed; the respiratory efforts were 7 during the 1st 30″ after closing the trachea.

At length the animal began to struggle, and gasped during each attempt at inspiration.

The trachea was again opened, when the lips separated slightly during each inspiration. The respirations were 7 during 30″ after opening the trachea.

The trachea was again closed.

The creature at first gasped slightly, respiratory efforts	4 during the	1st 15″		after closing the trachea.
The gasping increased, respiratory efforts...	4	,,	2nd 15″	
The gasping still increased, ,, ...	5	,,	3rd 15″	
The animal then began to struggle ,, ...	4	,,	4th 15″	
The trachea was then opened.				
The creature gasped exceedingly, the respiratory efforts were	8	,,	1st 15″	after re-opening the trachea.

Under the use of chloroform the gasping ceased and the animal soon died.

Experiment C (on a Pigeon).

I removed the brain from a chloroformised pigeon, and then decapitated it.

After the gasps had ceased, while Dr. Snow inserted one electro-magnetic wire into one nostril, I inserted the other wire into the opposite nostril, when the beak opened and closed in rapid quivering alternation. I immediately divided both fifth pairs, leaving the seventh intact; and we then re-applied the wires to the nostrils without producing any effect. I then applied one wire to the medulla, and so excited gasping movements of the beak.

I made several unsuccessful attempts to repeat this experiment.

Experiments D (*on Linnets*).—Present, Dr. W. T. Gairdner of Edinburgh, Dr. Snow, and Mr. Marshall.

I decapitated a linnet,	it afterwards gasped	8	times,	for the last time at the end of	10″.
,, another linnet	,,	9	,,	,,	5″.
,, ,,	,,	14	,,	,,	14″.[1]
,, ,,	,,	14	,,	,,	14″.

I cut across the spinal column high up in the neck in another, leaving the front part of the neck intact, so that circulation went on through the carotids.

The bird afterwards gasped	58	times,	the last time at end of	50″.
I repeated this expt. on another linnet, it gasped	40	,,	,,	25″.
,,	32	,,	,,	30″.
,,	21	,,	,,	15″.

There was more blood lost in the three latter of these four experiments than in the first.

I cut across the spinal column in a like manner in another linnet; it gasped seven times during the first 5 seconds. I then compressed the neck firmly between my finger and thumb, so as to stop the circulation in the carotids; at the end of eight additional seconds the gasps had ceased; I then removed the pressure so as to restore the carotid circulation, when the gasps returned, and were repeated nine times.

This experiment was repeated several times. The gaspings usually ceased about 7 or 8 seconds after the commencement of the pressure. In some instances the gaspings were renewed after restoring the circulation by removing the pressure, in others they were not.[1]

I have been favoured by Dr. W. T. Gairdner of Edinburgh with the notes of some experiments on rabbits, performed by him in 1845, with a view to ascertain the physiological effects of obstruction of the arteries leading to the head. The experiments were eight in number, and were supplementary to those of Sir A. Cooper, in *Guy's Hospital Reports*, vol. i., being, however, intended to show more particularly the effects of the obstruction of these arteries upon the respiration and general circulation.

Experiment 1 (*on a Rabbit*).—The pulse at the heart, at the commencement of the experiment, was about 32 on an average in the quarter of a minute,[2] and the respirations were 26 in the same space of time.

[1] It gasped for the last time after a pause of 4 seconds.

[2] The pulse and respirations were always counted by the quarter of a minute.

The carotid arteries were then tied, and after this the pulse was 38. Respiration, 17 to 18. The functions of the animal were not at all impaired.

The vertebrals were then compressed on both sides of the vertebral column, the trachea being carefully excluded. A few convulsive gasps followed, and in about 20 to 30 seconds there were violent convulsions of the whole body. On the ceasing of the convulsions, at one minute after compression, the pulse was 16 per quarter minute; the nostrils had ceased to move. The heart continued to beat for about 7 minutes.

Experiment 3 (*on a small Rabbit*).—Before commencing experiment, pulse 40 per quarter of a minute, respirations 24; after tying carotids, pulse 35, respirations 16; heart acting very strongly.

The vertebrals were now compressed.

In ½ a min. after compression, strong convulsions; pulse gone.
1 min. convulsions continue; pulse intermitting and slow, cannot be counted.
1½ min. pulse 44, weak; no respiration.
2¼ min. pulse 40 to 50, very weak; slight motion of whiskers; another convulsion.
3½ min. pulse scarcely perceptible.
4 min. pulse ceased; motion completely gone.
5 min. slight thrill at heart again.
6 min. pulse again quite imperceptible; surface cold; no motion.

The compression was now removed, and after about a minute more the thorax was laid open. As a comparative observation, the thorax of a rabbit asphyxiated by drowning was also opened. In this latter instance there was great congestion of the veins of the neck, and of the intestines; in the heart, the right ventricle and auricle were found gorged with venous blood; the left ventricle was empty and hard, being, in fact, spasmodically contracted, so that its cavity was obliterated. In the rabbit which was the subject of experiment, the heart was found replete with blood in all its cavities, both sides being about equally distended; the auricles were still inefficiently contracting, and the ventricles pulsated slightly on exposure. The venous system was notably less congested than in the asphyxiated rabbit, and the lungs were somewhat paler.

Experiment 5 (*on a moderate-sized Rabbit*).—At commencement, pulse 27 per quarter of a minute; respiration 16.

After tying the carotids and inserting a tube in the trachea, pulse 30, respiration not noted.

On the vertebrals being compressed, there were powerful convulsions of the trunk and extremities.

½ minute after compression of vertebrals the pulse was gone, and there were no respiratory movements.

Artificial respiration was now employed.

1 minute after compression, pulse returned, but intermitting.

1½ minute there was a barely perceptible thrill at the heart, and within a minute more it was gone.

Artificial respiration was kept up till the eighth minute, but without return of the pulse. The pressure was then removed, and the experiment discontinued.

On opening the thorax the auricles were found pulsating pretty strongly. The heart was distended in all its cavities with blood, which on the left side was very florid, much more so than in the preceding experiments; lungs pale, integuments exsanguine.

Dr. Gairdner writes: "It would be very desirable that similar experiments should be repeated on other animals, and with every precaution against fallacy. But the following conclusions appear to be deducible from them, without much risk of error.

"1. The tying of both carotids in the rabbit, all other parts being left intact, is followed by—

"*a.* A distinct and invariable lowering of the number of respirations, to the extent of from one-third to one-sixth of the previous number.[1]

"*b.* A lowering in some cases, but in others no change, in some even an elevation, of the number of pulsations of the heart.

"*c.* Little or no perceptible effect on the general condition of the animal in other respects."

"2. The ligature of both carotids and compression of both vertebrals is followed by—

"*a.* Absolute suspension of the respirations, after one or two convulsive gasps. In no instance, except the doubtful one in Experiment 2, did they return, when compression was maintained.

"*b.* Extreme diminution, both in force and frequency, of the heart's pulsations, amounting sometimes to absolute prostration, but followed in two or three minutes by partial recovery; the pulsations

	Before commencing experiment.			After tying carotids.		
[1] 1st experiment.	Pulse 32	Resp. 26	...	Pulse 38	Resp. 18	During fifteen seconds.
3rd ditto.	,, 40	,, 24	...	,, 35	,, 16	
4th ditto.	,, 33	,, 22	...	,, 29	,, 19	
5th ditto.	,, 27	,, 16	...	,, 30	,,	
6th ditto.	,, 29	,, 19	...	29·30	,, 16	
7th ditto.	,, 33	,, 17	...	,, 26	,, 14	
8th ditto.	,, 39	,, 25	...	36-40	,, 24	

In experiment 2 the vagus nerve was accidentally included, on one side, in the ligature; and there is some doubt as to whether the compression of the vertebrals was accurately effected. The results are therefore not here given.

returning sometimes to their original frequency, but never regaining an effective degree of force for carrying on the circulation.

"*c*. The passage of dark blood through the lungs into the left heart, or the commencement of the phenomena of a secondary asphyxia, which however is modified by the weak state of the left heart.

"*d*. General convulsions, lasting a few seconds, followed by complete insensibility and cessation of the reflex movements."

"3. The modification of these results by artificial respiration is very slight. In no instance did it succeed in restoring the heart's activity, nor in recalling any of the phenomena of nervous action, notwithstanding that the blood in the left heart was found florid on dissection. The prostration of the heart's action, upon which death evidently depends in these experiments, is therefore not due in any degree to *asphyxia*, but is of the nature of pure *syncope*. It is, moreover, a syncope in all probability absolutely dependent on the arrest of the circulation in the arteries leading to the head, as is proved by the recovery of the animals in Cooper's experiments, on removing the pressure within a limited period."

XI.

ON GASTRO-INTESTINAL DISTENSION, AND ENLARGEMENT OF THE LIVER.[1]

1. *In Gastro-Intestinal Distension, the Diaphragm is raised, the Lungs and Heart are compressed; respiration and circulation being impeded.*

THE effects of excessive flatulent distension of the stomach, colon, and small intestines, are well shown in the engraving from Clarke, a boy who had long suffered from diabetes, no doubt brought on and kept up by masturbation. In Clarke the abdominal distension was great for months before his death. In him the abdomen is enormously distended; the diaphragm is pushed upwards, so that the upper convex boundary of it is behind the third intercostal space on the right side, and the fourth intercostal space on the left side; and at the centre it is an inch higher than the lower end of the sternum. The thoracic cavity is materially lessened and the heart and lungs are necessarily compressed upwards, being packed into an unusually small space. The lower ribs, the diaphragmatic and intermediate sets, are pushed outwards by the distended stomach and displaced liver. Owing to the great distension of the stomach, the left diaphragmatic ribs are pushed outwards more than the right. This is very apparent to the eye, the left seventh cartilage, just below the sternum, being more raised than the right.

[1] From *London Medical Gazette*, vol. vii. 1848; p. 168.

Owing to the compression and diminution in size of the lungs and heart, respiration and circulation are both impeded by intestinal distension.

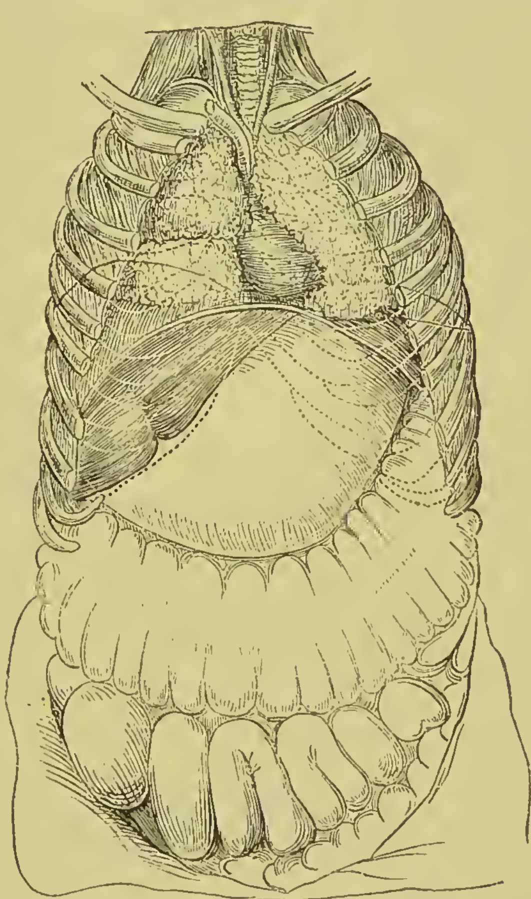

FIG. 1.—Thos. Clarke, æt. 15.—Gastro-intestinal Distension.

2. *Intestinal Distension is frequent in the dying.*

Intestinal distension is very frequent in the dying. From the examination of 122 diagrams of the position of the viscera, taken indiscriminately, I find that

Both the stomach and intestines were very much distended in .	28
They were considerably distended in	13
The stomach was much distended (the intestines not being so) in	11
The intestines were much distended (the stomach not being so) in	11
The liver was very much enlarged in	7
The distension was moderate in	20
And absent in	33

In these cases the abdomen was distended, the lower ribs pushed outwards, the diaphragm raised, and the heart and lungs pressed upwards, in proportion to the gastro-intestinal distension. In the first class of cases, in which the distension was very great, the upper convex boundary of the diaphragm was on the right side, usually behind the third intercostal space (as in Clarke), or the fourth rib; and in the cases in the last class, free from distension, it was usually behind the fourth intercostal space, or fifth rib.

3. *Intestinal Distension is invariable in Peritonitis.*

Intestinal distension is invariable in peritonitis, and is then probably due to the relaxation or paralysis in the muscular coat of the intestines induced by inflammation. It is remarked by Dr. Stokes, that all muscles are paralysed or rendered inactive by inflammation. The removal of the customary pressure, caused by the peristaltic action of the intestines, tends no doubt to the increase of their gaseous contents. Distension is also frequent in affections of the mucous membrane of the stomach and intestines, in dyspepsia, and in diseases attended by debility and relaxation of the muscular fibre.

4. *Use of O'Beirne's tube if the Colon be distended.*

Intestinal distension, when excessive, is in itself a serious malady; and when it accompanies acute diseases, such as peritonitis, it is a very formidable symptom, and is often, I believe, the immediate cause of death. The most successful plan of treatment usually pursued is to stimulate the mucous membrane, and the muscular coat of the stomach and intestines; but before this can be done to any good purpose, the great accumulation that, from its own distension, paralyses the muscular coat, must be removed.

If the distension be in the colon, the use of O'Beirne's tube will usually succeed. In inserting the tube it is important to remember, that the peristaltic action of the lower portion of the gut will often impede its introduction. This impediment may be always and easily overcome, by keeping up a continuous pressure, with gentle firmness, upon the seat of the contraction ; this at length yields of itself, and the tube glides on with ease, usually at once liberating some of the gaseous contents. In some cases the obstacle may be overcome by throwing up a few ounces of warm water; for this purpose it is well to have an enema syringe at hand, adapted to the tube. When the gas is escaping, it is often of service to press on the abdomen over the colon.

5. *Use of the Œsophageal tube if the Stomach be excessively distended.*

If the stomach be enormously distended, the distension may be immediately relieved by the introduction of the œsophageal tube. The fibrous coat of the stomach is paralysed by long-continued over-distension, in the same way that that of the bladder is. As the distended bladder, when there is retention of urine, must be emptied by the catheter before the muscular coat can recover its tone, so the distended stomach must be emptied by the œsophageal tube. In introducing the tube it is well not to do so rapidly, but to bear in mind, and as it were follow, the peristaltic action of the œsophagus.

6. *Discrimination between Gastric and Intestinal Distension.*

As the evacuation of the gaseous contents of the stomach and colon is required when they are over-distended, it is of practical importance to be able to distinguish whether the stomach alone be distended, or the colon. If the former, the left lower ribs, the intermediate and diaphragmatic sets, protrude more than the right; the gastric bulge, as in the case of Clarke, and contrary to custom, being greater than the hepatic bulge. The left thoracic ribs—the second, third, and fourth—are often flatter than the right. The rounded abdominal prominence of the stomach can be seen below the xiphoid cartilage, and between the opposite costal cartilages. By percussion the distinctive boundary between the stomach and colon can be readily recognised, and a groove along the boundary can be often seen. If the colon be distended, the expansion of the abdomen is diffused, the liver is pushed freely upwards, and the hepatic and gastric bulges are both increased, bearing their usual relative proportion. The diffused inequalities of the colon may often be felt through the abdomen. If both stomach and colon be distended, as in Clarke, the combined effects may usually be readily traced; if, after the use of O'Beirne's tube, the gastric distension be great, then the œsophageal tube may be used with advantage.

7. *Palpitation and Dyspnœa are often caused by Gastric Distension.*

In many persons suffering from dyspepsia, a hearty meal is followed by gastric distension; and this is frequently accompanied by, and the immediate cause of, dyspnœa and palpitation. This was painfully illustrated in the case of a poor girl who had, when in extreme poverty, lived for ten months on boiled potatoes mixed with barley. Her diet improved with her circumstances, but to this day the stomach has not recovered its tone. The action of the distended stomach on the heart and lungs is very apparent. The diaphragm is pushed directly upwards ; the heart, and to a less extent the lungs, are pressed upon, and their size diminished. At the same time the liver is pressed upwards, and compressed between the stomach and the diaphragm; and an additional amount of blood from the hepatic cava is directly thrown into the right cavities of the heart, at the very time that the heart's action is embarrassed by the upward pressure of the stomach. The majority of the patients of this hospital[1] who complain of palpitation, suffer from it most shortly after their dinner. In them the heart is usually sound, and the cause of the palpitation directly traceable to gastric distension.

8. *The Liver, when enlarged by interstitial abscesses, compresses the right Lung and the Heart, and pushes the Heart unusually to the left.*

Enlargement of the Liver.

In James Glann, affected with jaundice, the subject of the accompanying engraving, there were several large abscesses in the liver; he had peritonitis and excessive intestinal distension. The stomach was of normal size.

In Glann the abdomen is much distended ; the diaphragm is thrust upwards, in a manner very different from that in Clarke. The right convexity of the diaphragm is pushed upwards by the liver, greatly enlarged from abscesses, so that the upper boundary of its convexity is behind the lower edge of the second rib. The whole right lung is necessarily remarkably

[1] Nottingham.

lessened. But while the right side of the chest is so much encroached on, the left does not escape. The convexity of the liver is so great, that it partly occupies the left side of the

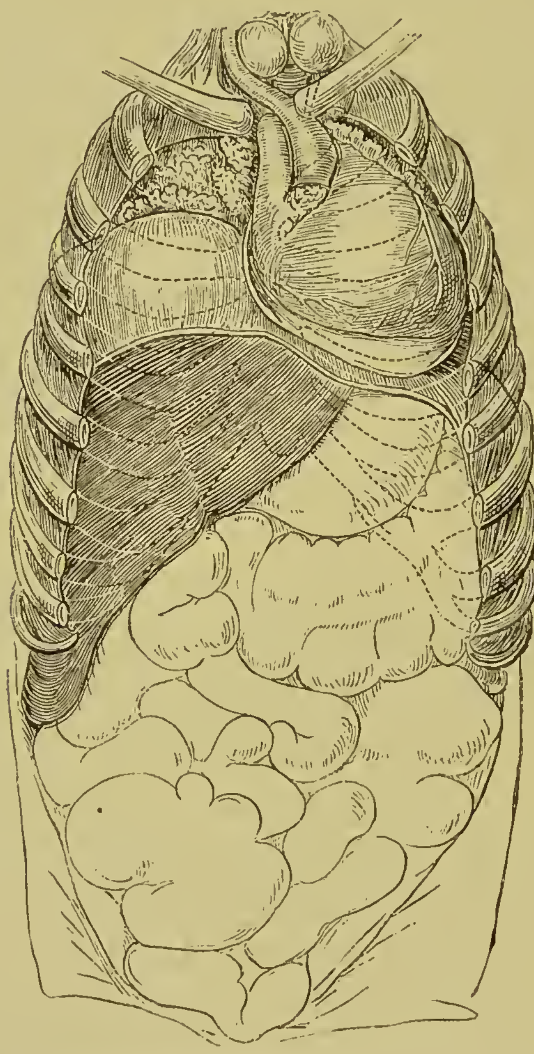

FIG. 2.—James Glann, æt. 24.—Extensive abscesses in the Liver.

chest, and carries the heart, resting upon it, completely over to the left side of the chest, so that no part of the heart is to the right of the sternum. The ventricles of the heart, and of course the apex, encroach unusually on the left lung; and as the left side of the diaphragm rises as high as the fourth rib, the whole left lung, as well as the right, is compressed upwards and backwards, and much diminished in size. Although the liver, enlarged from abscesses, extends over to the left side, yet by far the greater proportion of its increased bulk bears upon the right side; and in this respect, Glann, with irregularly enlarged liver, offers a well-marked contrast to Clarke with great gastric distension. In Glann the right lower ribs, from the fifth downwards, are pushed outwards much more than the left, the hepatic bulge being much greater and more extensive than the gastric; while in Clarke it is just the reverse, the gastric bulge being much greater than the hepatic. In both cases we find the abdomen distended, the lower ribs prominent, the diaphragm pushed upwards, and the heart and lungs pressed upwards, and diminished in size, being encroached upon by the abdominal organs.

In a patient that I saw some time since, the liver was manifestly, as in this case, much and irregularly enlarged; it encroached upwards on the right, and partially on the left side, carrying the heart over unusually to the left, so that the impulse was felt considerably to the left of the nipple. In this case the hepatic bulge was very large indeed, and the liver and the cysts connected with it (probably containing hydatids) encroached considerably on the abdominal viscera.

It is in such cases as Glann's, where the enlargement of the liver is caused by interstitial-deposits, such as collections of pus, malignant tumours, or hydatid cysts, that the liver encroaches so much on the lungs and heart. In such cases the liver is irregularly enlarged, its circumference and diameter being greatly increased, according to the size and position of the deposits.

9. *The Liver, when simply enlarged, displaces the other Abdominal Viscera downwards, but does not encroach on the Lungs and Heart, or interfere with their descent.*

When the liver is simply enlarged, without adventitious deposits, the liver scarcely rises higher than usual into the chest; it encroaches almost wholly downwards, and to the left, displacing the stomach, intestines, pancreas, and right kidney, and it interferes but little with the inspiratory descent of the diaphragm. If the liver be adherent, the encroachment on the right lung is considerable.

10. *Discrimination between Pneumonia of the Right Lower Lobe and enlargement of the Liver with adventitious deposits.*

There is no danger of mistaking enlargement of the liver, when free from adventitious deposits and without adhesions, for pneumonia or consolidation of the lower lobe of the right lung. It is, however, sometimes difficult to discriminate between those affections of the lung and enlargement of the liver with extensive adventitious deposits, or with adhesions. Among the best criterions, in addition to the other distinctive signs, are the great increase of the hepatic bulge, the unusual encroachment of the liver and its deposits on the abdomen, and the complete absence of vocal fremitus over the region devoid of sonoriety, if the disease be hepatic; and the non-existence of such signs if it be pulmonic.

XII.

ON THE INFLUENCE OF DISTENSION OF THE ABDOMEN ON THE FUNCTIONS OF THE HEART AND LUNGS.[1]

GENTLEMEN, I need not say to you, with whom I have so often worked with pleasure in these wards, what very great delight it is to me to come for one hour amongst you. My subject, as you will have seen from the announcement, is the influence of distension of the abdomen on the functions of the heart and lungs.

Since the chest is divided from the abdomen by the diaphragm, which forms the floor of one cavity and the roof of the other, the ascent or descent of that movable partition while it enlarges one cavity encroaches upon the other. When the chest enlarges, it enlarges in two directions; one outwards over its whole circumference by the expansion of the walls of the chest, the other downwards by the descent of the diaphragm. When the abdomen is enlarged, it is enlarged also in two directions; one outwards and downwards with the extension of the walls of the abdomen, the other upwards by the elevation of the diaphragm. When the abdomen is extremely distended, the whole cavity becomes oval in form, or shaped like a balloon, as you may see in this diagram; the outer part of it presses outwards, and the upper part of it presses upwards.[2] The cage of the chest

[1] Clinical lecture, delivered at St. Mary's Hospital, London. From *British Medical Journal*, Aug. 2, 1873, p. 105. The lecture was delivered after Dr. Sibson's resignation of his office of physician to the hospital.

[2] See vol. i. p. 82.

is raised by this upward movement. The whole of this wide cone formed by the upper part of the large oval abdomen, acting upon the lower ribs, forces them asunder to the right and to the left, and lifts up the whole front of the cage of the chest. The more important effect, however, of this distension is to lift up the heart at the centre of the chest, and the right and left lung on each side of it. When these organs are raised, as the cage of the chest in front of those organs is raised also, the apparent elevation of the heart is much less than the real elevation.

Distension of the abdomen may be caused by the distension of the stomach, the colon, and the small intestines, either singly or in conjunction; by the presence in the cavity of the abdomen of gas and of fluid; by the enlargement of the liver; and by tumours and cysts.

Swelling of the stomach and bowels with gas is caused not by the secretion of the gas from the living structures, but by its formation from the food taken into the stomach. This diagram, taken from a poor woman who literally died of starvation owing to cancer in the œsophagus, presents a perfect clinical proof of what I have said.[1] You will observe, that there is neither gas nor food in the whole digestive canal. The stomach is like an intestine. The great intestine is smaller than a small one. The food that is in the stomach, and the food that has passed from the stomach into the intestines, are the cause and source of the gas that they contain.

The heart, as you may see in these diagrams, rests upon the stomach. When the stomach is greatly swollen, the heart and the lungs, if healthy, suffer but slight inconvenience when rest is preserved; but moderate exertion, and especially quick walking, or the ascent of a hill, will often bring great distress in the region of the heart, and even actual anginal

[1] See vol. i. p. 34.

pain passing down the left arm. When, as is frequently the case, the stomach is swollen in patients affected with Bright's disease, or with affections of the aorta or of the heart, the patient has great distress of breathing even when raised in bed, but especially if he lie down or exert himself. In all these cases (diagrams) there was great distension of the stomach, and they show the serious and too often fatal contest that takes place between the enlarged organs of the chest, striving to get downwards, and the distended and enlarged organs of the abdomen, striving to get upwards. The functions of both the higher and lower sets of organs—the thoracic and the abdominal—are seriously interfered with; but those of the organs of the chest are more seriously and more often fatally deranged than those of the abdomen. The heart and lungs are both removed upwards from the more ample space of the middle region of the chest into the contracted area formed by the diminishing cone of the chest. The heart suffers from its inability to expand downwards, and yet, as it cannot send its blood through the compressed lungs, the right cavities of the heart become gorged with blood, as you may see in these drawings. Although, in all of them, the stomach and intestines are large and push the heart upwards, that organ is compelled to receive into it the blood that is sent from the whole system, which blood, once received into the organ, cannot be sent onwards through the lungs, the lungs having an additional obstacle to their expansion and to their reception of blood by being compressed upwards, owing to the elevation of the diaphragm.

In this case (diagram) we have, perhaps, as complete an illustration of the contest as any that I can give you—the contest between the organs of the chest and the organs of the abdomen. You will observe that the aorta, which is affected with atheroma, is very greatly dilated and greatly lengthened;

it has come down so low that the lower end of it is on a level with the lower end of the sternum. The consequence is, that the left ventricle and the right ventricle are pushed solidly downwards by the lengthened aorta, and the interior of the heart is itself compressed downwards by this very agency. Of course this displaces the stomach downwards. But here we have a fresh contest from below. The stomach is distended unduly with gas; so is the transverse colon; and so are the small intestines. The liver itself is gorged with blood, owing to the impossibility on its part of sending the blood forward to the right side of the heart; and, to crown all, in this case, we have effusion into the right side of the chest, displacing the heart to the side, and interfering with its work. Can we wonder that, under this accumulation of difficulties, this man died?

Here is another similar case. The man had aortic regurgitation. He was a labourer, aged 30, with a large athletic frame and an ample chest. He complained of shortness of breath, and of pain in the chest after a meal. This man would sometimes change rapidly from a state of comfort to one of extreme distress. Thus, on the 13th of July, when in these wards, he said that he never felt better in his life; and on the 14th, all was changed, and a frequent cough, increased beating of the heart, and difficulty of breathing, rendered it impossible for him to sleep or to remain in the recumbent posture. This attack was associated with, and apparently caused by, great fulness of the stomach from eating.

Here is the case of another patient, a carpenter, with aortic disease. He suffered, five years before admission, from pain in his chest, especially after eating, and, on exertion, he felt as if "something were scratching him at the back of the breastbone." When in the hospital he still suffered pain in the lower part of the chest after eating, if he walked about, but not if he sat still. Here are other drawings, in which you will see an enlarged heart—enlarged owing to mitral and other diseases—and enlarged lungs caused by the enlarged heart. In one instance, the enlargement of the lungs was supplemented by extensive pulmonary apoplexy; and, in another, the heart was adherent and the right lung was contracted owing to bygone pleurisy; while in this case, the lungs were enlarged to a very great extent by emphysema. In all these cases the stomach, and to a less degree the intestines, lifted the heart and the lungs upwards, compressed the whole of the organs of the chest within a narrow compass, and interfered with their functions. In truth, we may see that the final close to the existence of all these patients was hastened by the distension of the stomach.

Each organ holds within itself a reserved force many times greater than the amount of force that is brought into play in the ordinary and quiet demands of life; but, in proportion as those demands are increased, more and more of the reserved powers are brought into use. The lungs—I have ascertained this in my own person—possess sixteen times as much breathing power to be used during violent exertion as they employ when the body is at rest. Thus, the patient affected with aortic disease, to whom I referred, felt no discomfort in the heart after food if he sat still, for then the heart had sufficient force to do its work; but when he walked after food he felt pain in the heart, for that organ had no reserve force to resort to, and so, by making violent and undue exertion, like a wrenched muscle, it excited pain within itself—in short, angina pectoris.

In considering the treatment of this distension of the stomach that thus confines the action of the heart and lungs, I need not detain you with the well known medicines often so serviceable on such occasions. Some of these, such as the warm and cordial tinctures, camphor, and, perhaps, chloric ether, are agreeable ; some, if efficient, are repulsive, such as turpentine, assafœtida, and, perhaps, creasote ; while others are neutral, such as that valuable remedy guaiacum. I have, before me, the case of a gardener who had mitral disease ; he had, however, a complication of maladies—syphilis, subacute rheumatism, and ague. He complained of fluttering of the heart and great distension of the stomach. He was relieved by the use of turpentine and guaiacum.

Charcoal is of little or no use in these cases. Dried charcoal, owing to the immense distribution of its surface, absorbs a large amount of gas ; but wet charcoal loses its subdivision. Suspend a piece of dry charcoal in the stomach, and of course it will absorb the gas. The very act of swallowing causes it to become wet ; when it drops down into the stomach, it becomes more wet still, and it is clearly out of the laws of possibility for that charcoal there to absorb one cubic inch of the immense mass of gas that is in the stomach.

I wish, however, rather to bring before you the other, and non-medicinal, means that may be employed for the relief of the distension of the stomach with gas. This gas, as I have said, is secreted, not by the structure of the stomach, but by the food. If you cut off the supply of food, sooner or later, when that already in the stomach has passed away, relief will be obtained. But we cannot cut off the supply of food ; therefore we must select such kinds of food as give the greatest amount of nourishment, and tend to set free the least amount of gas ; for, although every kind of food will produce gas when the powers of digestion are weak, yet some kinds will do it much more freely than others. My rule is simply this : Take no bread, but eat biscuits instead. Take no solid vegetables, but use lemon-juice freely. Squeeze some of it over all your food. Shun soups, cucumbers, and fruit. Prefer meat, fish, fowl, or game tender, but perfectly fresh, lightly cooked and juicy—not hard and dry; or take it thoroughly soft and fragrant, as sent up by the hand of the artist. Take no rich sauces, or indeed, any other sauce, than wholesome fresh lemon-juice or mushroom ketchup; no twice-cooked, or salted, or seasoned, or dried meat. Let everything be fresh and savoury. Under this simple rule of substituting biscuit for bread and fresh lemon-juice for vegetables, relief will often be obtained from distressing symptoms indicating danger. Let the food be agreeable to the eye, fragrant to the nostril, and savoury to the palate; and, invited by those senses, the influences of the nervous system will bring those juices into the mouth and stomach that are required for the digestion of the food—juices that are attracted if the food is attractive, repelled if the food is repulsive.

The rules, however, that I have given are but a portion of the proper treatment. Each case stands upon its own grounds, and must be treated according to its own demands. In treating each case, the laws of nature must be strictly enforced. Departure from those laws has brought on the illness; and in a renewed obedience to those laws, we shall usually find the best road to restoration of health. The right treatment of disease is neither expectant nor heroic, but is a treatment founded on knowledge, a watchful interest in the patient, moderation, and good sense.

One patient had been quite well until the previous April, when, one night, after a late supper, he woke up fighting for breath and life. He raised a thin and frothy phlegm, which was stained the next day with blood. He had suffered from no such attack for a month; but he could not lie down; he was short of breath, and felt, as he said, inflated—blown out—sometimes almost ready to burst. His heart was very large, its action being powerful. There was a doubling of the first sound over the ventricles, and feeble first sound, and loud second sound over the aorta. Effusion was present in the right side of the chest. There was a mere trace of albumen in the urine, but I found in it one large waxy cast. The kidneys were the true seat of the disease. Under the influence of the restricted diet I have described, and the general treatment, he lost the distension of the stomach; he could lie down on one pillow; he had no return of the sense of suffocation; and the fluid in the right side of the chest disappeared. The condition of the heart and that of the kidneys were not materially altered.

Here is another case of a patient (represented in this little diagram) who complained of "trouble" over the region of the heart. His abdomen was swollen; the stomach displaced the lower boundary of the heart upwards, so that it was situated in the fourth space. Subsequently, under a restricted diet, the upper boundary of the stomach and the lower boundary of the heart fell almost to the extent of an inch. The heart having gained an increase of space, lost its "trouble;" and, though he was ill in other respects, the distension of the stomach disappeared.

Another diagram that I have here shows a more marked difference in the position of the heart during the second, as compared with the first observation made eleven days previously. This patient complained that he had pulsation through the body, and that the heart stopped for two or three beats. This state was worse after dinner, and was accompanied by fulness in the head. The irregular action of the heart disappeared with the descent of that organ that followed upon the diminution of the size of the stomach.

The last case to which I shall refer gave me at first some anxiety from its obscurity. This patient was a fine-looking man, with a large but not overgrown frame. He was of good colour and complexion. He complained of great shortness of breath, and he had a dropsical swelling of the right lower limb. The only unhealthy condition that I could discover in his internal organs was a distension of the stomach from gas. I will allow that I felt as if there must be some other cause, but I could find none. He took a dry diet; and although, a week later, the stomach was less distended, yet his right leg was still swollen, and his breathing short. He persevered, and gradually lost the shortness of breath and the swelling in the right leg, and he regained his usual good health.

Distension of the colon is illustrated in these diagrams. You will observe that, in these instances, the transverse colon is no longer transverse. In these they all form a loop from above downwards, the tip of the loop being midway between the navel and the pubes. You will also see that the ascending colon increases greatly in length, starting from its head in the crest of the ilium. You may remark, on looking at these two diagrams, that inasmuch as the top of the ascending colon immediately abuts upon the lower surface of the liver, the elongation of the ascending colon directly elevates the liver. So, also, with regard to this double flexure of the transverse colon. In one instance, you see the loop is single, and in another the loop is double. You will see that the descending colon is not in any of these cases, except perhaps in one, very greatly distended; yet there is in all of them great distension. In this diagram, representing a back view, the descending colon is distended quite as much as the ascending and transverse are in any of the others. In another instance, you see that the liver on the right side, and the stomach and spleen on the left, are both lifted up, as it were, upon the top of the lengthened colon.

You may remark in these cases that the liver rises very high; in one instance, quite into the lower end of the fourth space; and in another, as high as the third space. And you may observe how much higher the upper boundary of the right wing of the diaphragm, which is lifted up by the liver, is than the upper boundary of the left wing of the diaphragm, which is lifted up by the stomach. The result is that, in these cases we have the heart pushed over to the left side, owing to the elevation of the liver, which tends to displace the heart to the left; and while the right lung is compressed from below upwards, the left lung is encroached upon by the heart, which is pushed aside by the liver.

You will at once see, from the study of these diagrams, how seriously distension of the colon must affect the organs of the chest, not only the lungs, but also the heart, by displacing that organ to the left; whereas, in the case of the stomach, its displacement tended rather to the right.

The next set of cases that I shall bring before you are those in which the stomach, the colon, and the small intestines are all distended. In this diagram, distension of the stomach is not extreme, but there is extreme distension of the ascending, the transverse, and, I believe, the descending colon, and extreme distension of the whole of the small intestines owing to peritonitis. You will observe that this diagram shows, better than any other, the oval shape that the distended abdomen assumes. Contrast it with this one, which shows the shape of health, like a reversed sugar-loaf rounded at the top, while the other is a true type of complete abdominal distension, being a perfect oval. In this other case, where the abdomen is perfectly flaccid, you have neither the reversed sugar-cone shape of health, nor the oval of distension, but a double concavity. The centre of the abdomen is narrower than either the top or the lower part. We see here in another diagram, the effect of immense distension upon the walls of the chest. See how these cartilages are pushed aside to the left, and those to the right, so that there is an addition of nearly one-third to the width from side to side. Again, you may perceive that the cage of the chest is lifted up by this great oval mass below pressing upon it from below, and this will account for the remarkable fact that, although we have the heart and lungs so elevated by the diaphragm thus pushed up, yet the lower boundary of the heart is very little above the lower boundary of the sternum; the lower boundary of the lungs is very little above the position in which we often find it in a perfectly healthy body. If you look at the aorta you will see how completely that artery has been driven over to the right side. If you compare the breadth of the heart from side to side, with the length of the heart and the great vessels from below upwards, you will see that the whole organ is, in point of fact, compressed upwards. In health, as you may see in several of these instances, the apex of the heart is lower than the lower boundary of the heart behind the lower end of the sternum. In this instance, the apex of the heart has been lifted upwards and is a third of an inch higher than the lower boundary of the heart at the end of the sternum.

We find in these cases—that the heart and the lungs are put to an immense disadvantage—that the lungs are compressed and the reserved air driven out of them—that the heart is compressed and the blood driven out of it—that the ventricles are diminished in size and are incapable of receiving as much blood as they did before—that there is an obstacle to their action, and that they are incapable of sending out the blood that they have already received with the ease that they did before. Again, if you look at the walls of the chest and the diaphragm, you see what an obstacle is put to the very limbs, by which, as it were, the lungs expand and the heart is moved. The cartilages and ribs are pushed aside and lifted upwards. The cage of the chest has reached the limit of its powers by the elevation given to it, and permanently given to it by the distension of the abdomen. Again, look at the diaphragm, lifted up by this immense distension. How can it act downwards? If the diaphragm is affected with peritonitis, the inflammation paralyses the inflamed muscle. The whole contest is then narrowed to the smallest bounds; and the whole work of respiration must be done by the few ribs remaining unassailed at the top of the chest. In cases of peritonitis, respiration is what is very well called high. The whole of the breathing is performed by the laboured lifting up of the upper cartilages, the upper ribs and the clavicles. All the muscles that act—the sterno-cleido, the scaleni, the levators of the ribs and the scapulæ, are hard at work, and, in spite of that, you see visibly in the face that the patient is undergoing chronic asphyxia, and must soon die unless his breathing is relieved.

Here is another case:—a repetition of the other, but a little less extreme. It shows, in what I would call a rather beautiful and orderly manner, a series of tiers, one above another, the top one made by the distended stomach, the second by the circular curve of the transverse colon, and the third by the small intestines. Here is also another case, showing tier above tier in the same way, the intestines below, the transverse colon in the middle, the stomach above, and above that the heart. Here is also another, showing the intestines below, the transverse colon at the middle, and the stomach at the top, all pushing up the heart and lungs and interfering with their work. I could show to you other cases; but these are sufficient.

The tendency of this great distension of the stomach and intestines is to push the heart directly upwards, to flatten the heart from below, and to displace it somewhat to the right side. You see in this diagram that the aorta, instead of being shielded by the sternum, lies almost entirely to the right of that bone. The pulmonary artery, on the contrary, instead of lying entirely behind the spaces, is almost entirely behind the sternum. A similar condition obtains in this other case. You see that the apex has been raised. It is nearly half an inch higher than the lower boundary of the centre of the heart, although, naturally, it ought to be half an inch lower than that lower boundary. The position of the apex is the test of the extent to which the heart has been compressed upwards.

There are two means by which the treatment of great distension of the stomach may be met, independently of drugs; and I would say to you that when distension is extreme, drugs are worse than useless. They add, by their offensiveness, to the misery of the patient. These two modes are the insertion of the œsophageal tube into the stomach through the mouth, and the insertion into the stomach of the fine point for injecting morphia under the skin. I have the particulars of a case that occurred in this hospital—that of a man who had the most serious threatening of death in consequence of great distension of the stomach. The circumference of his chest was thirty-nine inches. We introduced the œsophageal tube, and a large quantity of gas escaped. The circumference of the chest was reduced from thirty-nine inches to thirty-seven, and for a time the man experienced perfect relief. Before this was done, he had great distress; after it, he was at ease. The relief lasted for some days. He had kidney-disease and various other serious affections; and after a time he died.

Another case, that I saw with the late Dr. Williams, of Swansea, was more fortunate. The patient had acute rheumatism of a low type. The stomach was extremely distended, and respiration was interfered with in consequence. Dr. Williams introduced the tube ; a large quantity of gas escaped ; the powers of respiration were restored, and gradually the patient recovered completely, lived for many years afterwards, and is, I believe, now alive. With regard to the other method—the insertion into the stomach of the fine point for injecting morphia under the skin—I have never had the opportunity of employing it ; but I have been always ready to use it if required ; and I believe, though I cannot put my hand on a case, that it has already been practised with advantage and success.

I now come to the question of the distension with gas owing to rupture of the intestine, one of the most formidable incidents that can occur. There are two classes of cases. In one class the distension takes place slowly, widening out the abdomen in an oval form ; while in the other class the distension takes place rapidly ; and inasmuch as the muscular walls of the abdomen are the sentinels of the cavity, they do not yield, and the abdomen does not assume the oval form that it does in cases of inflammation of the intestines and stomach, with distension of those parts. The result is that the whole of the distending force is expended upwards, and the liver and stomach are elevated to an extreme degree. You may see that the top of the liver and the top of the stomach are seated just below the third cartilage, and the lower boundary of the right lung immediately behind the fourth cartilage. All the organs are pushed up into the highest part of the chest ; and, as the chest is a cone narrowing from below upwards, they are pushed up into the narrowest part of the house that they inhabit. You will also see that, on the whole, the right side is more affected than the left ; and thus the liver, being a large and massive organ, is pushed upwards to a greater extent than the stomach. Thus in these two diagrams the right lung is much more highly raised than the left, and the apex of the heart is much less raised in proportion than the centre of the heart at its lower boundary.

I next come to distension of the abdomen from the effusion of fluid into the cavity. I am not rich in specimens of this kind of abdominal distension, but here is a very good example, admirably drawn by our old friend the artist, Mr. Fairland. You may see here that the whole of the interstices of the abdomen—especially the backward interstices—are filled up with fluid. You may mark the intestines and the stomach floating forwards, and the liver sinking backwards. You may see how the liver, instead of, when the stomach and intestines are distended, being pushed up so as almost to thrust itself and intrude upon the heart, drops away from the diaphragm, and leaves the fluid to make the elevation. You may mark how the whole abdomen assumes an oval form. The result is that the heart is pushed up, that the right lung is pushed up, and that the left lung is pushed up, all at about an equal pace, and you have, as the effect of all this, compression of those organs, and difficulty on their part to do their work. If those organs are at rest, and if there be neither heart disease nor lung disease, nor Bright's disease, then the patient may be able to lie down, and to go through his days and nights in bed, without shortness of breath. As a rule, however, patients who have a large amount of fluid in the abdomen are compelled to sit up. And this gives you a brief explanation of the inability to breathe in a recumbent posture in many of these cases. When the patient lies down, the fluid bears at once upon the diaphragm and presses it upwards. The right lung, the left lung, and the heart are compressed, and all the difficulties of respiration are most seriously increased ; but when the patient sits up, then the fluid drops downwards to the lower part of the abdomen ; the pressure is removed from the diaphragm and from the heart and lungs, and respiration can go freely on.

In cases, however, where you have disease of the heart, disease of the lungs, or disease of the kidneys, unfortunately the very cases in which fluid is often thrown out into the abdomen, and the very cases in which there is distension of the stomach and intestines, the mischief done is very great, and the relief to be afforded by any slight treatment is trivial.

I have one case in which the effect of the removal of a very little fluid lets in a flood of light upon the terrible influence of distension. It is the case of a man who was in the Albert Ward. He was a labourer, aged 23. He came in with aortic and mitral regurgitation, great enlargement of the heart, and distension of the abdomen. He complained of pain about the heart and great difficulty of breathing. The urine was scanty, amounting to only twenty ounces in the twenty-four hours ; and the quantity was not increased by the treatment adopted. The abdomen was greatly distended, its circumference measuring forty-one inches ; and this distension was chiefly due to swelling of the stomach and intestines with gas. The quantity of fluid was not great, but it was determined to remove as much as possible. An incision was made in the skin four inches below the navel ; and, to avoid the intestines, which were perilously near the surface of the abdomen, the point of the trocar was not pushed backwards, but obliquely downwards. At first, only a teaspoonful of serum flowed ; but we had been prepared for this ; and inserted a female catheter through the cannula, and so pressed gently backward the wall of intestine that was dropping upon the end of the cannula so as to stop it up. Seventy-five ounces flowed pretty quickly away through the female catheter. The measurement of the abdomen fell from forty-one to thirty-eight and a half inches. The man passed twenty-four ounces of urine that night. The next day he could breathe with perfect ease, and he felt in comfort. The quantity passed in the twenty-four hours increased from twenty ounces to seventy-four on the second day, eighty-six on the third, and ninety on the fourth. The treatment in all other respects was absolutely unaltered. The improvement continued for a time; but at the end of three weeks the urine lessened, and the fluid in the abdomen increased. One hundred and fifty ounces were withdrawn; but, although this produced relief and some increase of urine, the patient became gradually worse, and died about five weeks afterwards. In this case, the distension of the abdomen acted, as it were, as a ligature, and prevented the secretion of urine. As soon as this ligature was removed by the withdrawal of a moderate amount of fluid, the quanty of urine increased.

I find that my time has expired; and you know my old maxim about not transgressing the allotted period. The other subjects that I had intended to bring before you were, ascites associated with cirrhosis of the liver, when its effect on the functions of the heart and lungs is comparatively trivial; ascites associated with disease of the heart, when its effect is more serious; ascites associated with Bright's disease, when its effect is more serious still, and more difficult for the physician to combat; and the influence of enlargement of the liver upon the functions of the heart and the lungs. Pure enlargement of the liver produces very little mischief to the heart and lungs, and for this reason: if there be no distension of the intestines, the liver, owing to its bulk, drops downwards upon the intestines and compresses them ; it, therefore, does not push upwards and compress the heart and lungs. But, if there be enlarged intestines and a distended stomach, and fluid in the abdomen, pressing the liver upwards, then, if the liver be also large, you get, besides that accumulated series of causes of distension of the abdomen, this additional one. In these diagrams you have a fivefold series—the first made by the liver, the second by the stomach, the third by the transverse colon, the fourth by the small intestines, and the fifth by the fluid. But, if the right upper lobe of the liver be enlarged by an abscess, or a hydatid cyst, or a large cancerous mass, then the liver, ascending into the right side of the chest, forces the heart over into the left side, and compresses the right lung directly and the left lung laterally through the medium of the heart.

Gentlemen, I need not tell you that I have touched upon a subject, to illustrate which would require a series of practical lectures, but I shall be well rewarded if I have awakened in any of your ingenuous minds the desire to study, in the mortuary and in the wards, the various causes of distension of the abdomen, and the various and often serious and even fatal results that this distension may induce on the functions of the heart and lungs. The clinical study of disease is inexhaustible. It requires knowledge, patience, skill, an increasing interest in the welfare of the patient, an increasing interest in the study of his disease, as you watch it. Clinical study is ever living, ever fresh. It brings that true power that depends on true knowledge and wisdom, to him who has diligently pursued it, and who still pursues it to the end of his career.

END OF VOL. II.